CLIMATE INTERACTIVE

Fossil Fuel Extraction in Biomass-Rich Areas Calculator (FEBAC)

USER GUIDE

2025

Table of contents

List of tables

List of figures

1. Introduction

The Fossil fuel Extraction in Biomass-rich Areas Calculator (FEBAC) tool is designed to help analysts estimate carbon emissions from fossil fuel (Oil, gas, and coal) extraction in **forest areas** around the world.

It utilizes land carbon data (biomass and soil) from the Global Forest Watch public database (Harris et al., 2021; Sanderman et al., 2018), and fossil fuel data from the Statistical Review of World energy data (SRWED) (Energy Institute, 2025).

The tool supports country, project, and block-level analyses. Depending on the available data, a user is directed to fill in only the relevant tabs of this tool, guided by the instructions panel on the landing page.

The tool calculates both a lower-end (likely) and a higher-end (potential) **emissions estimate from forest disturbance due to fossil fuel extraction**, **as well as from the combustion of the extracted fuels**, by the desired scenario analysis year. The two estimates reflect the uncertainty in fossil fuel project lifetimes—proved reserves represent only part of total reserves, and more of the resource may become recoverable over time. Longer project lifetimes can lead to extended forest disturbance, which is reflected in the higher-end estimate.

The **"Summary results"** tab collates the key inputs provided by the analyst, and the final estimates for emissions from forest land use change and from the combustion of extracted fossil fuel resources.

We advise the analyst to work with the tool using MS Excel, as some of the tool's features may be lost when using other spreadsheet-based software. Please do not attempt to use this tool in Numbers or Google Sheets.

2. Landing Page

The tool's landing page includes an instructions panel that guides the analyst to effectively navigate and use the calculator.

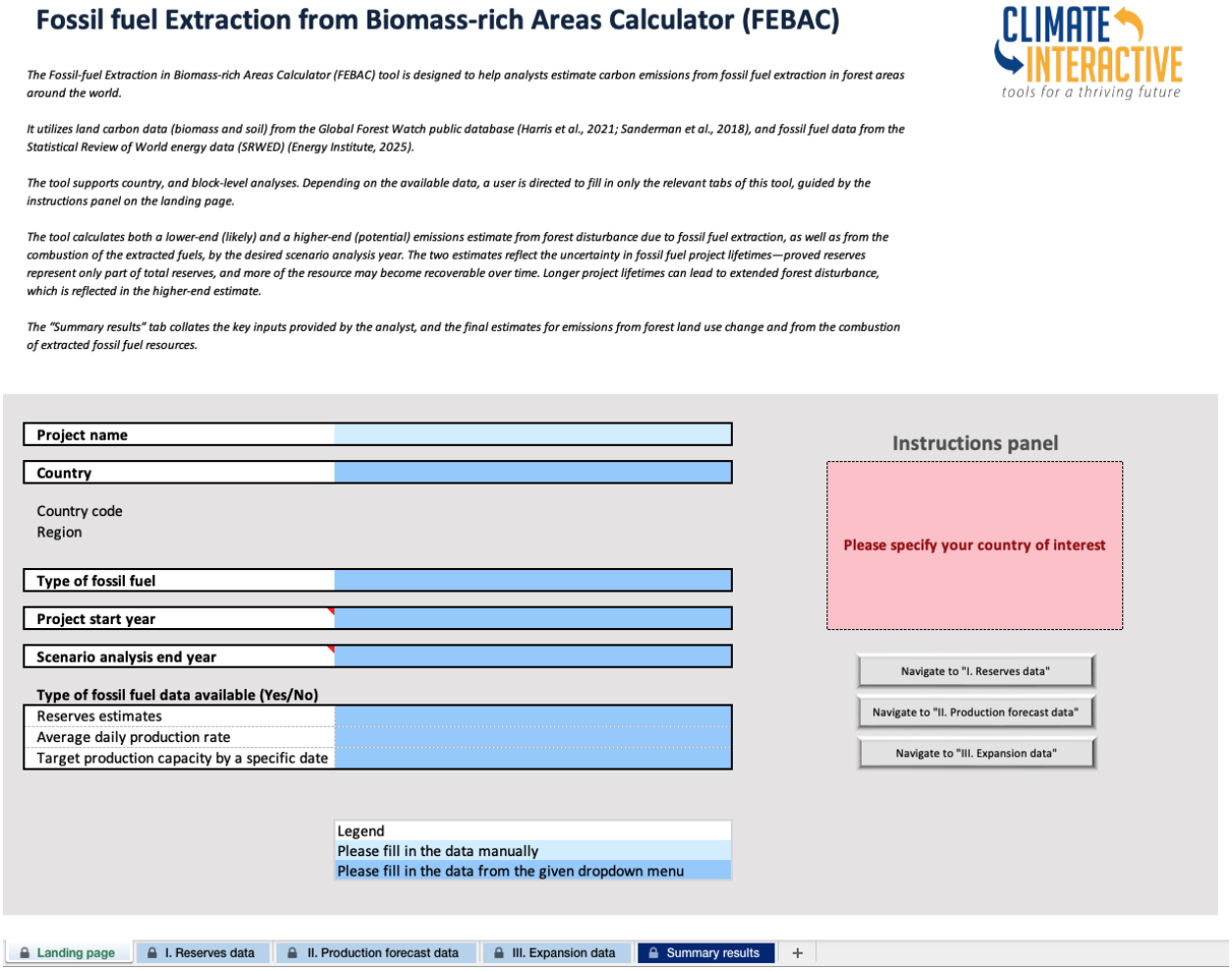


Figure 1: FEBAC landing page

Before starting a new scenario, save a copy of the spreadsheet in your analysis folder using a consistent naming convention (e.g., **"FEBAC-PROJECT_NAME-YYYYMMDD.xlsx"**). This preserves traceability of the inputs, calculator version, and results generated for each scenario run.

The purpose of the landing page is to take some general inputs from you, then direct you to the next tab, where more data can be input, enabling the tool to perform the emissions calculations. Having filled in the project information and some general inputs, you are asked about the **"Type of fossil fuel data (yes/ no)"** available to you. Accordingly, you will be directed to the relevant tab(s) to provide more input data. The tool is designed to utilize all available data when estimating fossil fuel emissions for a given project.

3. Input Tabs

The table below compares the three types of fossil fuel data corresponding to the three tabs in the tool. For more details on fossil fuel reserve classifications and definitions, please refer to the Petroleum Resources Management System (PRMS) (SPE, 2018).

Fossil fuel data type	Description
Reserves estimates	The tab **"I. Reserves data"** enables the analyst to input data on fossil fuel reserves (whichever is available to the analyst). The tool generates an emissions estimate even if only one type of reserves was specified, the **1P, 2P, or 3P (low, best, high estimates)**. Proved reserves are those that are expected to be recovered (extracted) with a level of reasonable certainty under current economic, technical, and regulatory conditions. Some notations used to refer to the proved reserves are **P90, 1P, or P1. It is considered to be the "low estimate,"** where the recoverable quantities of fossil fuel in the reserve are expected to be equal to, or exceed, the estimate with a 90% probability. Probable reserves, or P2, are resources that are less likely to be recovered based on technical data but are still more likely to be extracted than possible reserves. Adding the P2 and P1 reserves gives the **"best estimate" which is sometimes referred to as the P50, or 2P reserves**, with actual recovery estimated to be equal to or larger than the best estimate with a probability of 50%. Possible reserves, or P3, are the reserves that engineering and geoscience analysis suggests are less likely to be recovered compared to probable reserves. Adding P1, P2, and P3 gives the **"high estimate" for reserves, denoted by 3P** with actual recovery estimated to be equal to or larger than the high estimate with a probability of 10%. The tool generates a likely emission estimate based on the lower reserves estimate specified by the analyst. If the analyst has an estimate for non-proved reserves, the tool generates a potential emissions estimate based on the upper estimate for reserves provided by the analyst. If the analyst does not have an estimate for non-proved reserves, the tool calculates a daily production rate based on proved reserves and **R/P ratio** *(the ratio between proved reserves and current production rates which is a commonly used industry metric to indicate the proportion of a fossil resource that is extracted annually. For more details see section **3.1 R/P ratio and the rate of fossil fuel depletion** in the **Technical Reference**)*, and assumes fossil fuel extraction continues steadily, unabated, until the scenario analysis end-year.

Fossil fuel data type	Description
	If the analyst does not have an estimate for proved reserves, but has a best estimate (2P), the tool first generates a 1P estimate using a heuristic relationship between 2P and 1P. The tool then uses the R/P ratio to calculate a production rate that can be, as a next step, extended up to the scenario analysis end year to calculate potential emissions.
Average daily production rate	The tab **"II. Production forecast data"** enables the analyst to input data on daily production or extraction rates when the data is available. The tool generates a likely emissions estimate by calculating a **"low estimate"** of reserves using the production rate and R/P ratios. The tool also generates a potential emissions estimate by assuming fossil fuel extraction continues steadily at the rate input by the analyst, unabated, until the scenario analysis end-year.
Target capacity by a specific date	The tab **"III. Expansion data"** enables the analyst to input data on a country's expansion plan, expressed in **"target production rate"** vs. **"current production rate"**. The tool asks the analyst if they are conducting a country-level analysis or a project/ block-level analysis. If the analyst opts for a block-level analysis they are asked to specify the number of blocks. If they are conducting a country-level analysis the tool defaults to 1 block to capture the total emissions from the expansion project in a single unit (i.e., the country). The tool generates a likely emissions estimate by generating a "low estimate" of reserves using the production rate and R/P ratios. The tool also generates a potential emissions estimate by assuming fossil fuel extraction continues unabated until the scenario analysis end-year.

Table 1: The three types of fossil fuel data the tool is able to generate emissions estimates for

4. Building a scenario

4.1. Building a Scenario: Introduction

Below is an example scenario to demonstrate how to use the tool step-by-step. The table below shows the test case with sample data. The task is to estimate the land and fossil fuel emissions from the **"Sample Project X"** in Ecuador.

	Variable	Details
Project name	Sample project X	
Country	Ecuador	
Project start	2025	
Land	Area	138,881 hectares of forest land
	Level of disturbance	High
Fossil fuel	Type of fossil fuel	Oil
	Fossil fuel data	Forecasted daily production: 10,400 barrels/ day Recoverable reserves: 35.5 million barrels

Table 2: Case details for a sample project

First, add the prospective project's name and select the country where the project is taking place. Specifying the country is important to estimate both the land carbon density and the fossil fuel reserves to production ratio (R/P ratio).

Next, specify the type of fossil fuel, the project start year, and the scenario analysis end-year.

The carbon content of gas differs from coal and oil. Also, emissions will vastly differ if the analysis year is 2030 compared to, say, 2100. For this example, the year 2100 is selected as the scenario analysis end year. Finally, specify the type of fossil fuel data to be input, which is discussed in detail in the following sections.

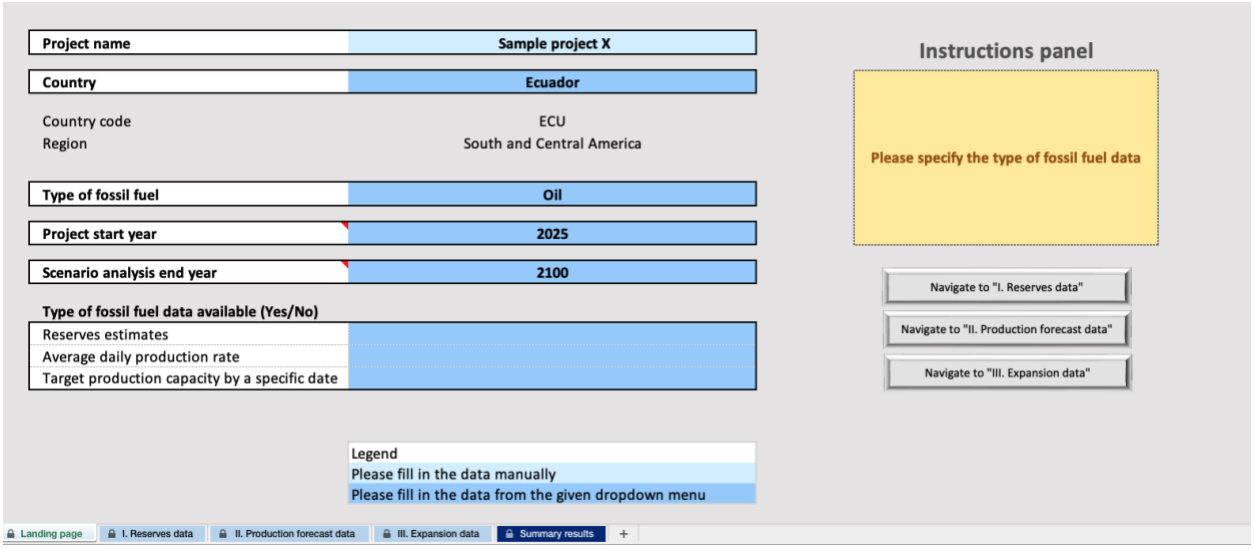


Figure 2: The FEBAC landing page giving instructions to specify the type of fossil fuel data

4.2. Building a Scenario: Single data parameter for fossil fuel

If a single data type is available related to the fossil fuel (reserves, production rate, expansion plan) the analyst should fill a single tab. Each tab is structured slightly differently to capture the data inputs available to the analyst. By inputting "yes" to **"Reserves estimate,"** the instructions panel directs the analyst to the corresponding tab with the message, '***Please fill in data in the tab "I. Reserves data,"'*** as shown below.

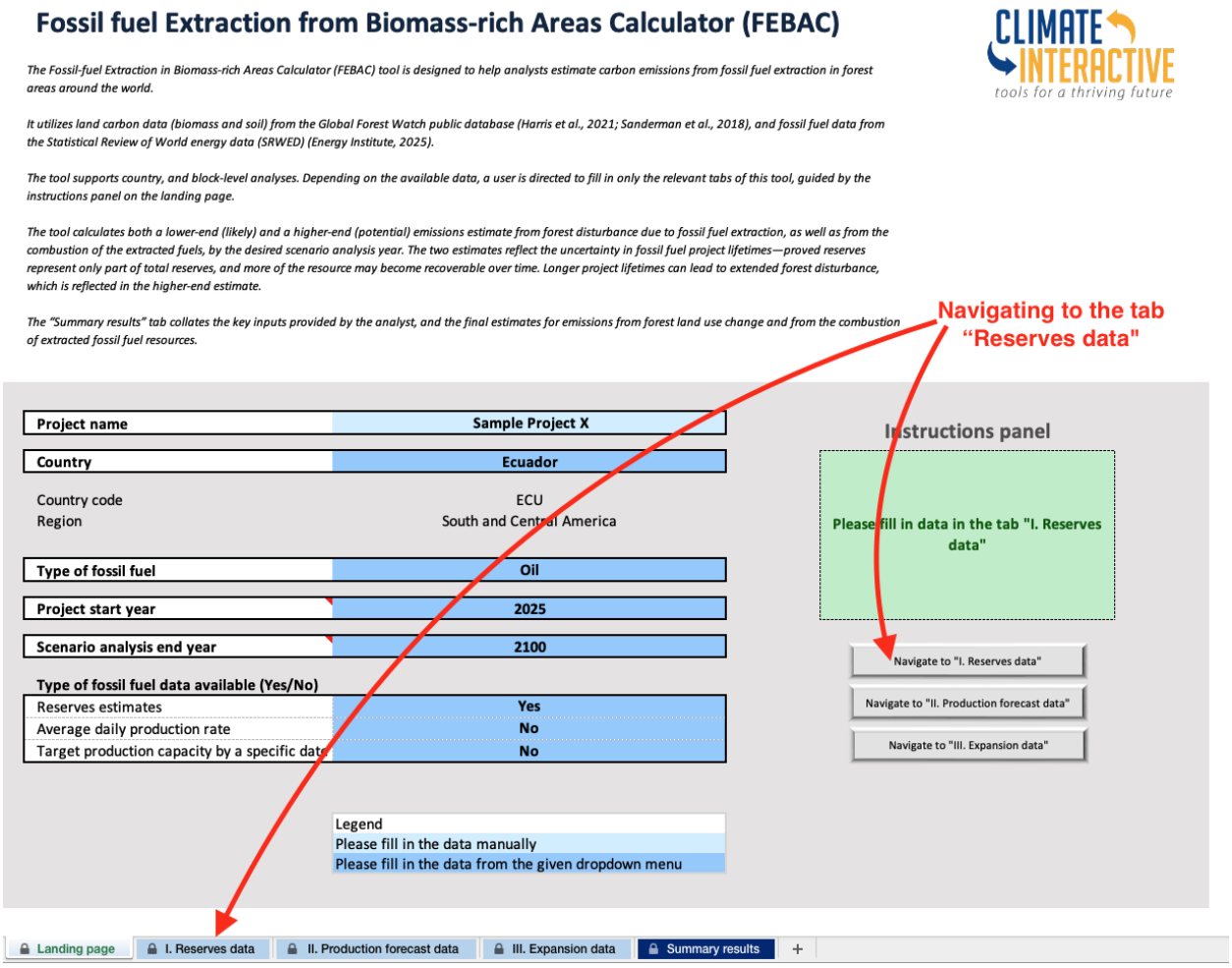


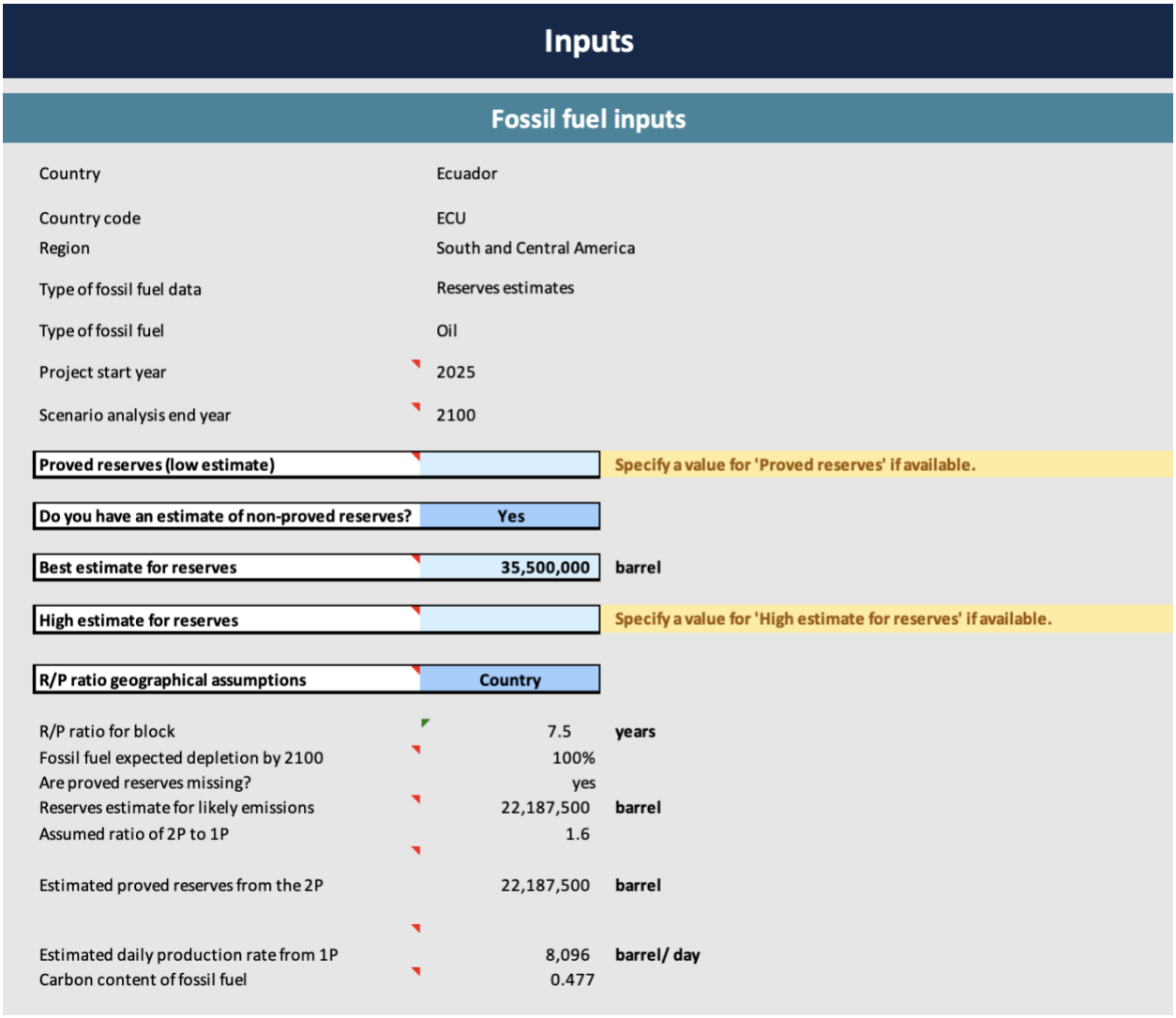
Figure 3: The FEBAC landing page giving instructions to navigate to the "Reserves data" input tab

Navigate to the tab **"I. Reserves data"** by clicking the relevant button below the instructions panel, or selecting the tab from the bottom.

You are asked if data on non-proved reserves is available. In this example, the answer is "**yes**," since the case details stated **"recoverable reserves."** Usually, proved reserves are labelled as **"proved"** or **"proven,"** while other estimates are labelled differently.

Enter the figure from the case details—**35.5 million barrels**—in the box **"Best estimate for reserves."** That is the only estimate for reserves in the case details.

Next, you are asked to specify your assumption for the R/P ratio, the typical ratio between proved reserves and production rate that may be calculated on a country, regional, or global level. The general rule is to start with a **"Country"** assumption. In case there is no data for the country of interest, you should opt for a **"Regional"** R/P ratio assumption. You are also encouraged to explore the **"World"** R/P ratio assumption and compare your results with the regional figure.



Inputs

Fossil fuel inputs

Country	Ecuador	
Country code	ECU	
Region	South and Central America	
Type of fossil fuel data	Reserves estimates	
Type of fossil fuel	Oil	
Project start year	2025	
Scenario analysis end year	2100	
Proved reserves (low estimate)		Specify a value for 'Proved reserves' if available.
Do you have an estimate of non-proved reserves?	**Yes**	
Best estimate for reserves	**35,500,000**	**barrel**
High estimate for reserves		Specify a value for 'High estimate for reserves' if available.
R/P ratio geographical assumptions	**Country**	
R/P ratio for block	7.5	**years**
Fossil fuel expected depletion by 2100	100%	
Are proved reserves missing?	yes	
Reserves estimate for likely emissions	22,187,500	**barrel**
Assumed ratio of 2P to 1P	1.6	
Estimated proved reserves from the 2P	22,187,500	**barrel**
Estimated daily production rate from 1P	8,096	**barrel/ day**
Carbon content of fossil fuel	0.477	

Figure 4: The inputs tab "Reserves data" displaying fossil fuel inputs for the sample case

If the **"low estimate"** for proved reserves was available, in addition to a **"best estimate,"** the tool would calculate both lower-end and upper-end values for oil reserves. Given no data was available on proved reserves, the tool estimates a value for proved reserves

based on the **"best estimate,"** assuming that 2P reserves are **~1.6x** the proved reserves. For details see section **3.2 Estimating proved reserves from the "best estimate"** in the **Technical Reference**.

Furthermore, the tool calculates an estimated daily production rate based on the proved reserves value and the R/P ratio. The carbon density of the fossil fuel is also displayed. For more details on the assumptions underlying such estimates, see section **3.1 R/P ratio and the rate of fossil fuel depletion** in the **Technical Reference**.

Next, you are required to fill in the land assumptions. From the case details, the forest area of the project is **138,881 hectares** and the level of disturbance is expected to be **"High"**. High disturbance translates to 7% of the block area deforested by 2100 in the likely emissions scenario, and 30% of the block area deforested by 2100 in the potential emissions scenario. We take into account both direct (e.g., clearing land for wells, roads, and pipelines) and indirect disturbances (colonization by migrant workers) of forest area resulting from the fossil fuel extraction project. For details see section **3.6 Forest disturbance** in the **Technical Reference**.

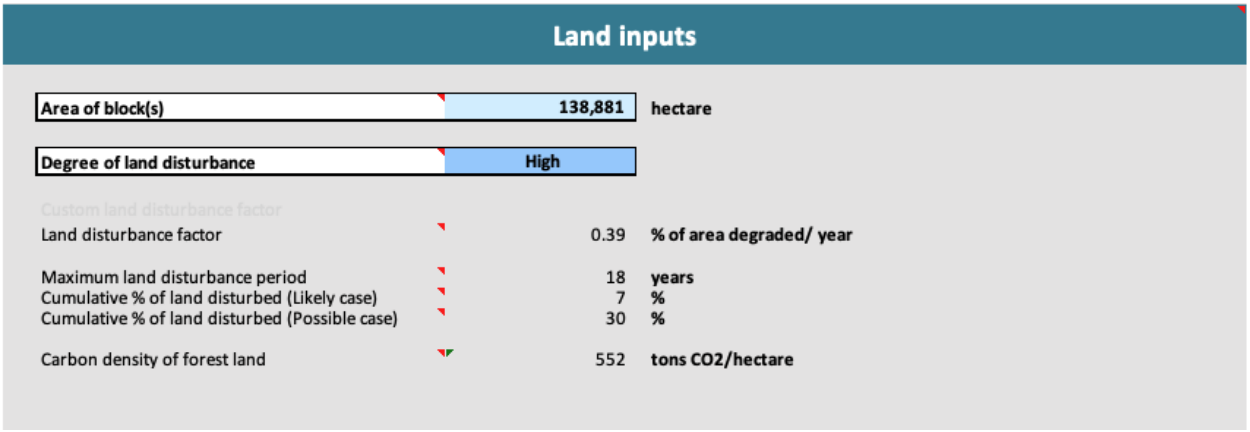


Figure 5: The inputs tab "Reserves data" displaying land inputs for the sample case

Having filled all the required entries, the tool displays a lower-end (likely), and an upper-end (potential) estimate of carbon dioxide emissions from forest disturbance due to fossil fuel extraction, as well as from the combustion of the extracted fuels.

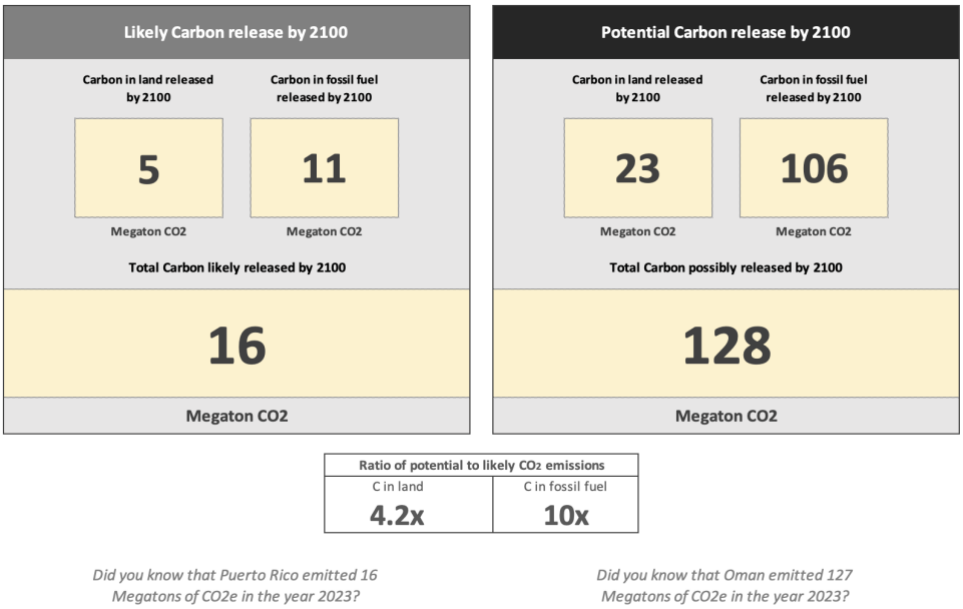


Figure 6: The "Reserves data" tab displaying emissions estimates for the sample case

The tool also contextualizes the emission estimates by displaying annual country emissions that are comparable in magnitude to the total emissions from the given project over its lifetime. For details on how the likely and potential emissions are calculated, see section **1. Fossil Fuels Emissions** section in the **Technical Reference**.

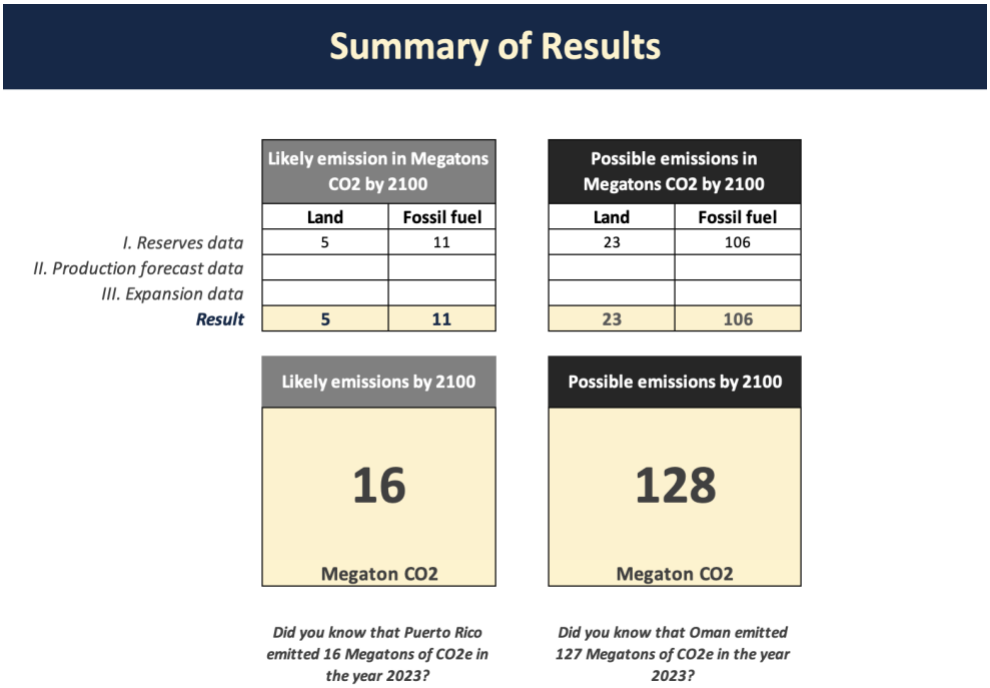


Figure 7: The "Summary results" tab displaying emissions estimates for the sample case

The lower-end estimate is **16 Mton CO_2** by the year 2100 from forest disturbance and combustion of the oil extracted, which is equivalent to the annual emissions of Puerto Rico in the year 2023. The upper-end estimate is **128 Mton CO_2** by the year 2100, corresponding to the annual emissions of Oman. The **"Summary results"** page displays the case details and results for a final check by the analyst.

It is clear in the **"Summary of inputs"** below that the **35,000,000 barrels** of **"Recoverable reserves"** provided in the case were not *directly* used to estimate fossil fuel emissions, rather they were used to estimate Proved reserves, **~22,200,000 barrels** (around 1.6x less than the **'Best estimate'**), which *then* were used to calculate emissions from the extracted oil.

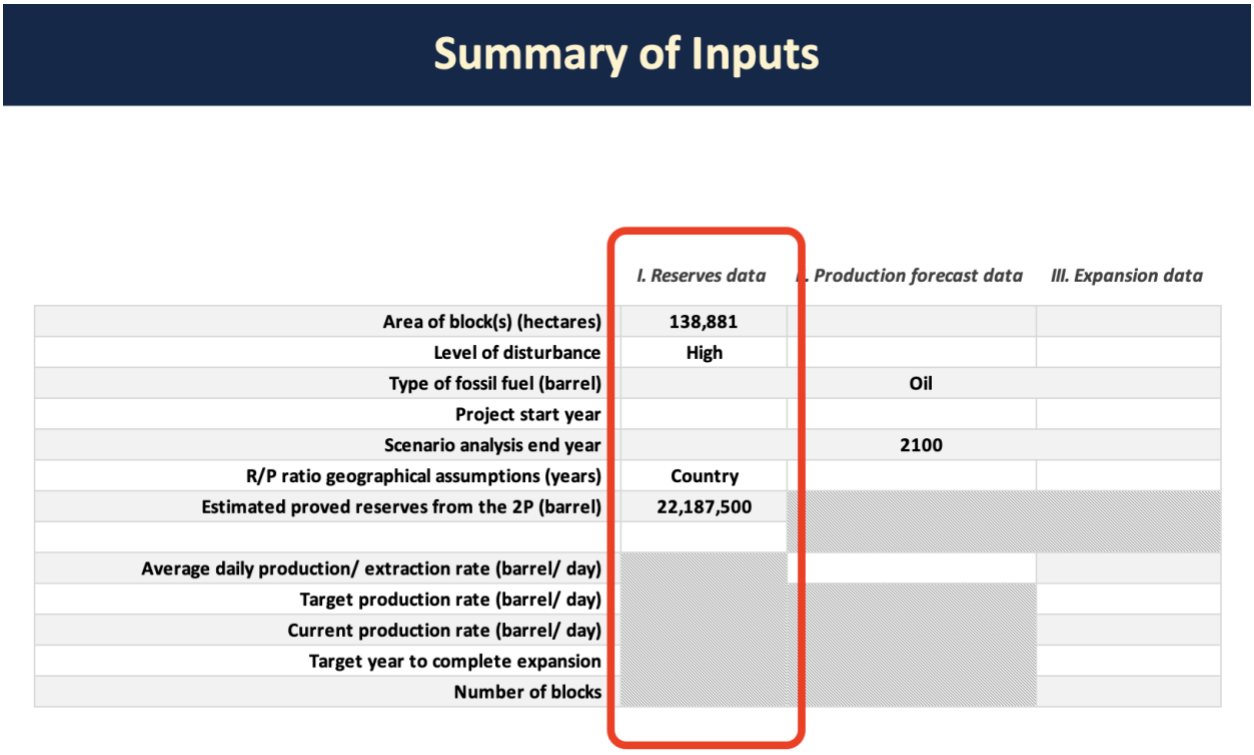


Figure 8: The "Summary results" tab displaying the summary of inputs for the sample case

4.3. Building a Scenario: Multiple data parameters for fossil fuel

For the test case, two types of data relating to the fossil fuel are available: an estimate for reserves and a forecasted daily production rate. Thus by adding **"yes"** next to the **"Average daily production rate"** in the landing page, the instructions panel updates to the message shown below, guiding the analyst to fill in two tabs instead of one.

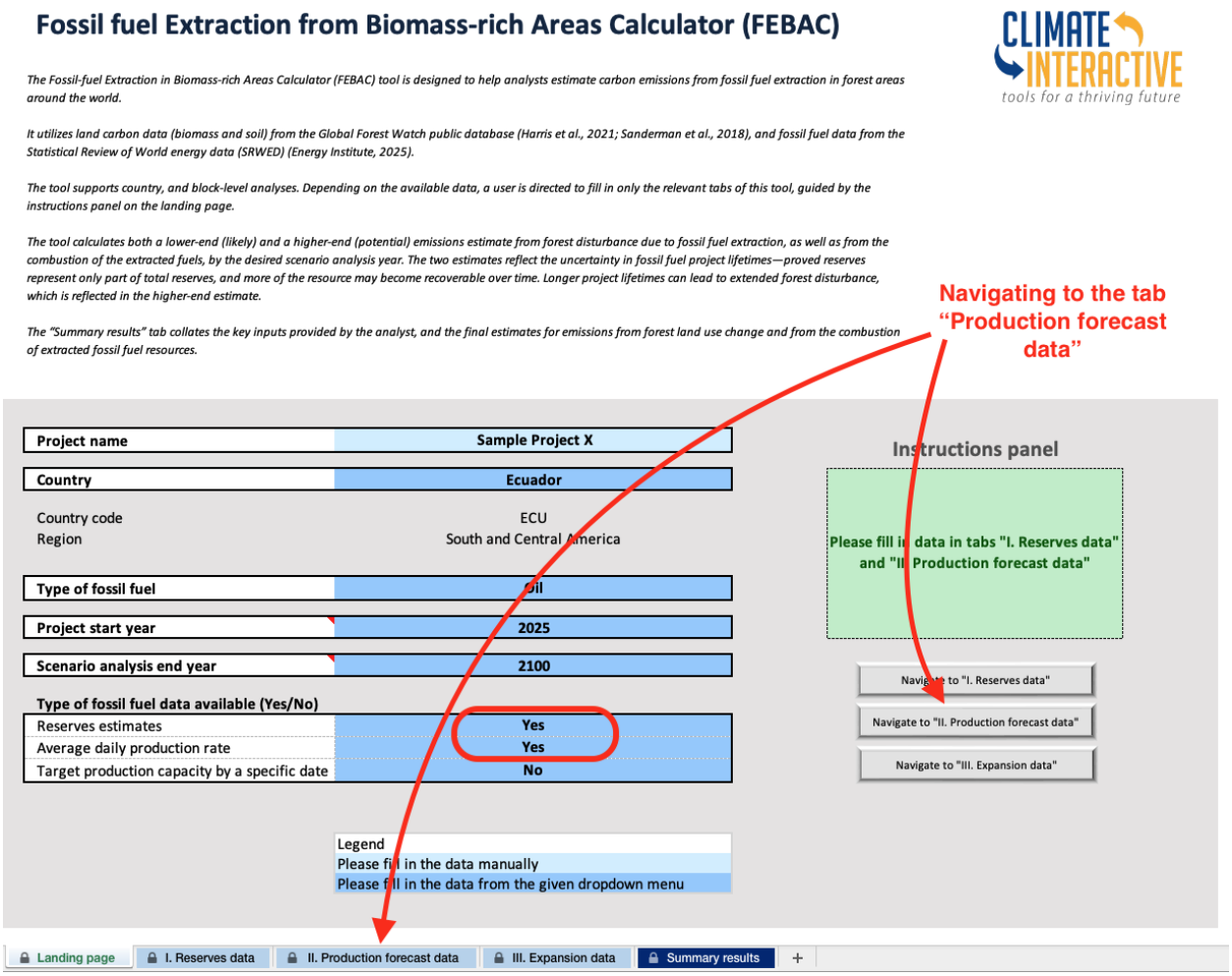
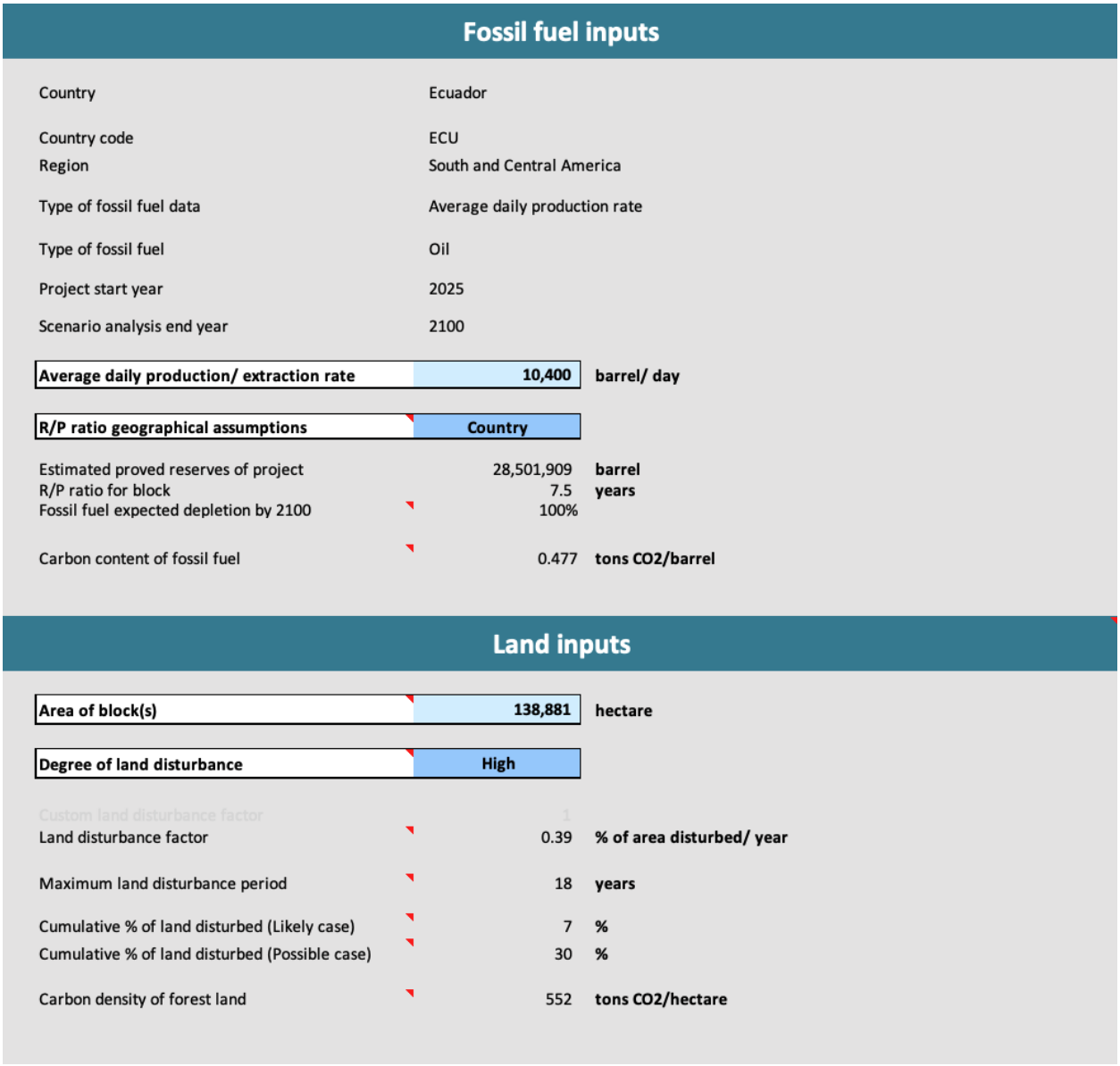


Figure 9: The FEBAC landing page giving instructions to navigate to the "Production forecast data" input tab

Only the average daily production rate and the R/P ratio assumption (country) are required. The land assumptions have already been input in the **"I. Reserves data"** tab. However, to avoid confusion, we advise to fill in the same land assumptions in all tabs used.



Fossil fuel inputs

Country	Ecuador	
Country code	ECU	
Region	South and Central America	
Type of fossil fuel data	Average daily production rate	
Type of fossil fuel	Oil	
Project start year	2025	
Scenario analysis end year	2100	
Average daily production/ extraction rate	**10,400**	**barrel/ day**
R/P ratio geographical assumptions	**Country**	
Estimated proved reserves of project	28,501,909	**barrel**
R/P ratio for block	7.5	**years**
Fossil fuel expected depletion by 2100	100%	
Carbon content of fossil fuel	0.477	**tons CO2/barrel**

Land inputs

Area of block(s)	**138,881**	**hectare**
Degree of land disturbance	**High**	
Custom land disturbance factor	1	
Land disturbance factor	0.39	**% of area disturbed/ year**
Maximum land disturbance period	18	**years**
Cumulative % of land disturbed (Likely case)	7	**%**
Cumulative % of land disturbed (Possible case)	30	**%**
Carbon density of forest land	552	**tons CO2/hectare**

Figure 10: The inputs tab "Production forecast data" displaying fossil fuel inputs for the sample case

The tool generates emissions estimates that are different to those generated by tab **"I. Reserves data,"** as shown below.

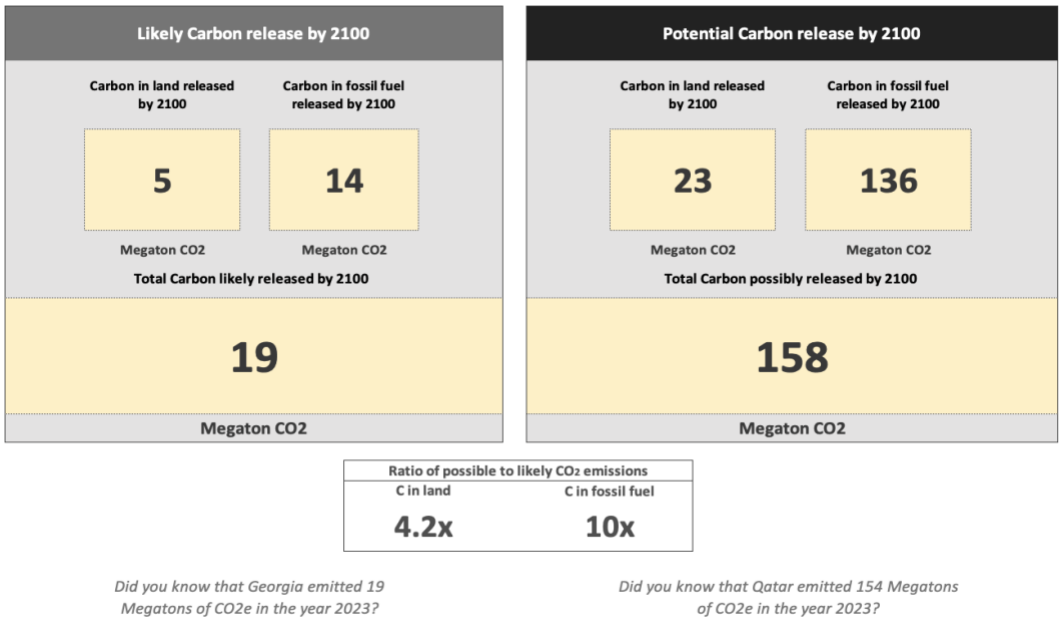


Figure 11: The "Production forecast data" tab displaying emissions estimates for the sample case

Finally, navigate to the **"Summary results"** tab to compare the results from the two types of fossil fuel data and view the final emissions estimates, as shown below.

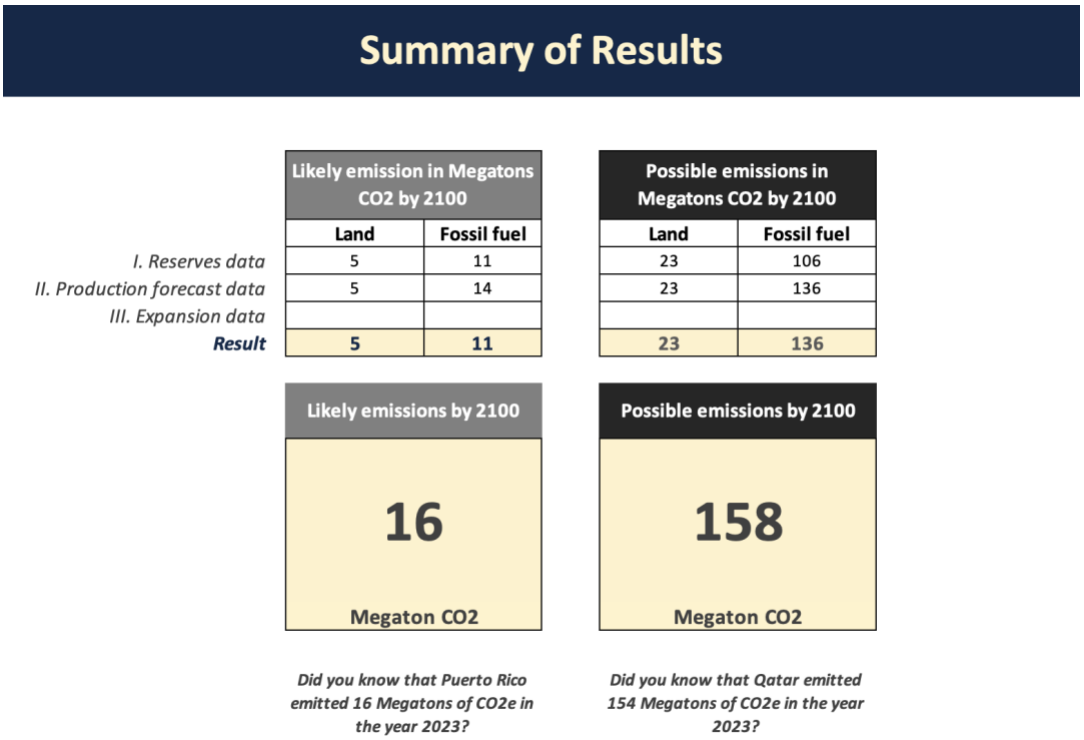


Figure 12: The "Summary results" tab displaying emissions estimates for the sample case from the two tabs (reserves, and production forecast)

It is important to note that the likely emissions results take the **MINIMUM** of the fossil fuel emissions, which is why after inputting the data in tab **"II. Production forecast data"** the likely total emissions stayed the same at **16 Mton CO_2**. This is because the emissions calculated from the production forecast data resulted in a higher estimate for likely fossil fuel emissions. Land emissions were unchanged.

On the other hand, the potential emissions results take the **MAXIMUM** of the emissions estimates from the two fossil fuel scenarios. The estimate for potential emissions was **106 Mton CO_2** based on the reserves estimate, and **136 Mton CO_2** based on the forecasted production rate by the year 2100. Thus, there is an increase in the potential emissions estimate from **128 Mton CO_2** to **158 Mton CO_2**. This example shows how different information is utilized by the tool to provide robust estimates.

The tool contextualizes the emissions estimate by displaying annual country emissions that are close to the total emissions from the given project over its lifetime.

Finally, we advise you to take a quick glance at the "Summary of inputs" to make sure all the case data was correctly input into the tool.

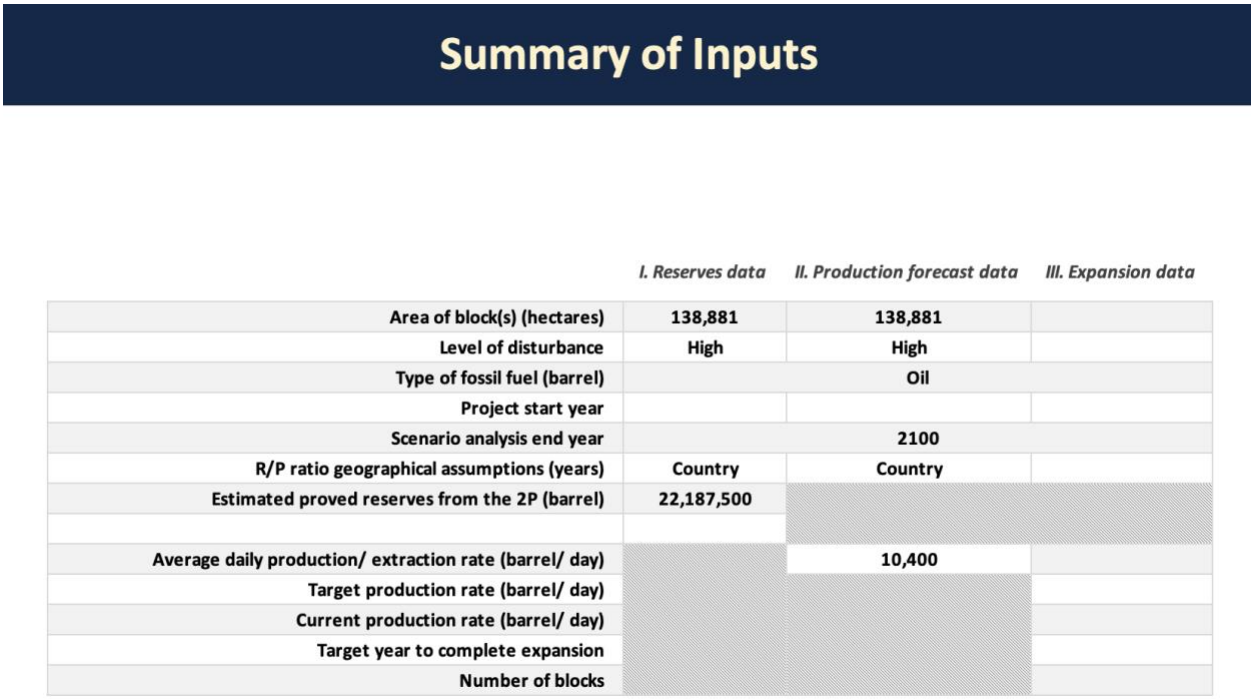


Figure 13: The "Summary results" tab displaying the summary of inputs for the sample case from the two tabs

4.4. Building a Scenario: Running Multiple Land Scenarios

There was only one estimate for the land area in the test case. However, it is possible to calculate emissions for a given project when the land area affected, or its level of disturbance, is uncertain. The analyst can simply add the two figures for land area in two separate tabs of the tool.

Building on the sample test case, let's assume the land estimate was uncertain, between **138,881** and **200,000 hectares**. Below the tab **"II. Production forecast data"** was used to input the second estimate of **200,000 hectares**, keeping land disturbance level **"high."** as shown in the **"Summary results"** tab below.

Summary of Inputs

	I. Reserves data	*II. Production forecast data*	*III. Expansion data*
Area of block(s) (hectares)	138,881	200,000	
Level of disturbance	High	High	
Type of fossil fuel (barrel)		Oil	
Project start year			
Scenario analysis end year		2100	
R/P ratio geographical assumptions (years)	Country	Country	
Estimated proved reserves from the 2P (barrel)	22,187,500		
Average daily production/ extraction rate (barrel/ day)		10,400	
Target production rate (barrel/ day)			
Current production rate (barrel/ day)			
Target year to complete expansion			
Number of blocks			

Figure 14: The "Summary results" tab displaying the land inputs from the two tabs

The likely emissions results remained unchanged since it takes the **MINIMUM** of forest disturbance (land) emissions from the two scenarios (calculated from **138,881** and **200,000 hectares**), and separately the **MINIMUM** of the fossil fuel emissions.

On the other hand, the potential emissions scenario takes the **MAXIMUM** of the emissions estimates (separately for land, and fossil fuel). The estimate for potential emissions was **~23 Mton CO_2** based on the low-end land area estimate, and **33 Mton CO_2** by the year 2100 based on the higher land area estimate. Thus an increase in the potential emissions estimate by **~10 Mton CO_2** is observed. For more information on how the tool generates the emissions estimates, see section **2. Land Emissions** in the **Technical Reference**.

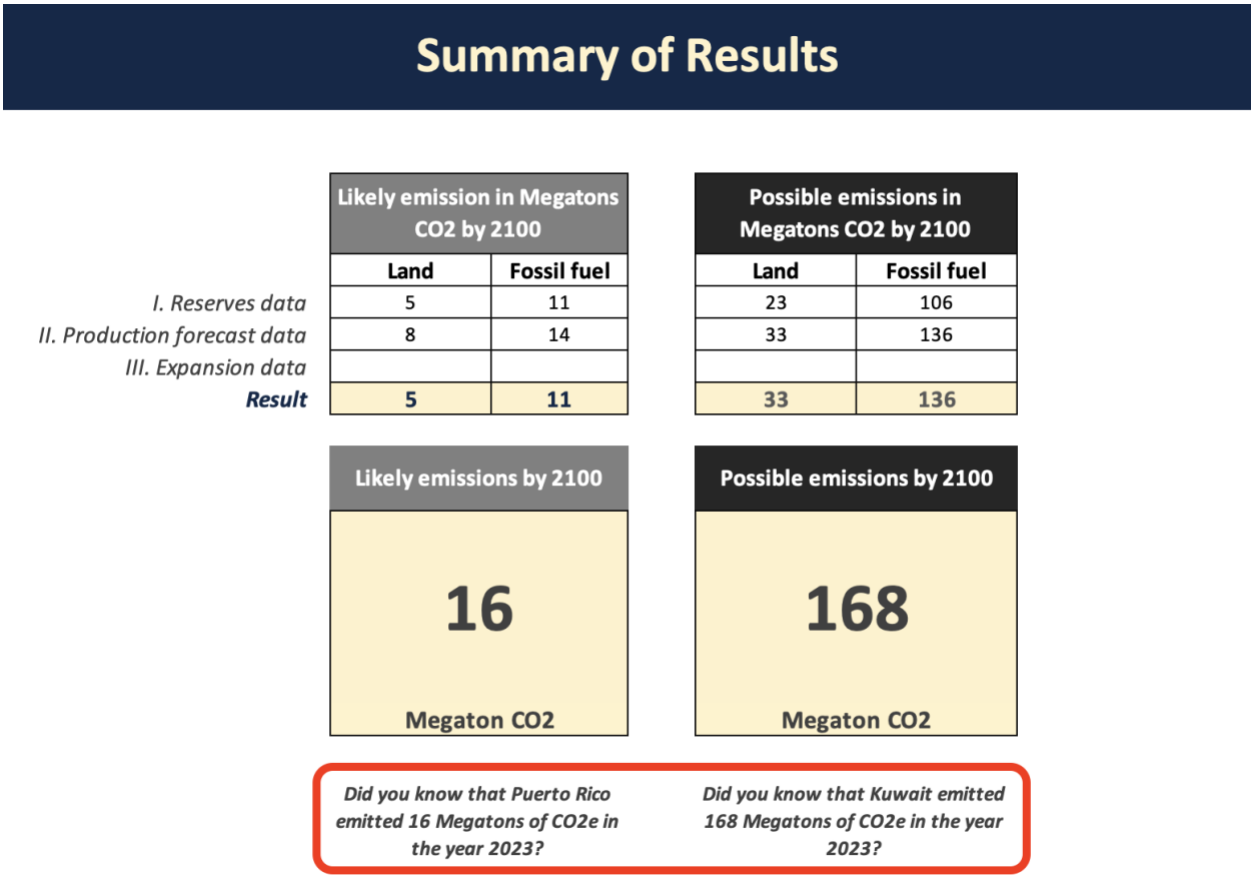


Figure 15: The "Summary results" tab displaying the contextualized emissions results from the two tabs

Finally, given the explanation above, the likely emissions still correspond to the emissions from Puerto Rico in 2023 while the potential emissions changed from Qatar (**158 Mton CO_2**) to Kuwait (**168 Mton CO_2**).

We discuss some caveats and tips for analysts using the tool below.

5. Other Tips for Using the Tool

Below are some considerations when using the tool

- The tool is designed to estimate land emissions for **fossil fuel extraction projects in global forest areas only**. Thus, for other biomes the tool's land emissions will be inaccurate (overestimate).
- For offshore projects, only the fossil fuel emissions calculations generated by the tool are valid. Land emissions should not be calculated using the tool for offshore projects.
- If a country-level analysis includes both onshore and offshore blocks, the land area input should only be the onshore forest area associated with the country-level project(s).
- For blocks that could include both oil and gas, the analyst is required to re-run the tool for each fuel type. However, the land inputs can be added to either one of the two analyses as we do not use fuel-specific land disturbance factors. Thus land emissions for a given constant forest area will be identical irrespective of the type of fossil fuel being analyzed.
- The **"low estimate"** for reserves refers to the proved reserves. Fossil fuel data and literature are almost always explicit about proved reserves. Thus if a reserve estimate is labelled anything other than **"proved"** or **"proven,"** it is most likely referring to the **2P** or **3P** estimates, the **"best estimate (P50)"** and **"high estimate (P10)"** respectively.
- The reserves data should increase progressively, such that the **"low estimate"** is the smallest number, followed by the **"best estimate,"** which is the sum of proven and probable reserves estimates, and the **"high estimate,"** which is the sum of proven, probable, and possible reserves estimates.
- If only an estimate for **"proved reserves"** is available, the analyst must specify the answer to **"Do you have an estimate for non-proved reserves?"** as **"no."** This ensures that the tool calculates potential emissions (the high-end estimate) correctly, using the daily production rate estimated from proved reserves, the R/P ratio, and the difference between **"project start year"** and **"scenario analysis end year."**
- If only one reserves estimate is available, and it is not explicitly labelled as **"proved,"** the analyst should add it as the **"best estimate for reserves."**
- The default of the tool is analysis on a block level; however, it can also be used on a national level to estimate emissions from the total production/ reserves of fossil fuels.

- For fossil fuel data type **“Target capacity by a specific date,"** if the analyst is conducting a country-level analysis, the tool defaults to a number of blocks equal to 1, so as not to divide the production rates by the number of blocks.
- For fossil fuel data, type **“Target capacity by a specific date." “Target year to complete expansion"** is the year by which the extraction capacity scale-up will be completed. Scaling up capacity, and thus reaching **“Target production rate”** takes time thus it is important to calculate an **“average production rate during scale-up”** for estimating likely emissions. This is not to be confused with **“Scenario analysis end year,”** which is the time horizon for calculating emissions.
- Generally, the analyst is advised to input all the data at their disposal related to a specific project. The tool is designed to take all data into account when calculating the likely and potential emission results. The **“summary results”** tab enables the analyst to determine the specific tab that corresponds to the low and high emissions estimates.
- If a required data entry is not at the analyst’s disposal, we advise the analyst to leave the cell blank rather than place a ZERO in it. This is to prevent them from misinterpreting the emissions results generated by the tool.

6. References

Energy Institute. (2025). *Statistical Review of World Energy.: Vol. 74th ed.* https://www.energyinst.org/statistical-review/resources-and-data-downloads

Harris, N. L., Gibbs, D. A., Baccini, A., Birdsey, R. A., De Bruin, S., Farina, M., Fatoyinbo, L., Hansen, M. C., Herold, M., Houghton, R. A., Potapov, P. V., Suarez, D. R., Roman-Cuesta, R. M., Saatchi, S. S., Slay, C. M., Turubanova, S. A., & Tyukavina, A. (2021). Global maps of twenty-first century forest carbon fluxes. *Nature Climate Change*, *11*(3), 234–240. https://doi.org/10.1038/s41558-020-00976-6

Sanderman, J., Hengl, T., Fiske, G., Solvik, K., Adame, M. F., Benson, L., Bukoski, J. J., Carnell, P., Cifuentes-Jara, M., Donato, D., Duncan, C., Eid, E. M., Ermgassen, P. Z., Lewis, C. J. E., Macreadie, P. I., Glass, L., Gress, S., Jardine, S. L., Jones, T. G., … Landis, E. (2018). A global map of mangrove forest soil carbon at 30 m spatial resolution. *Environmental Research Letters*, *13*(5), 055002. https://doi.org/10.1088/1748-9326/aabe1c

SPE. (2018). *Petroleum Resources Management System (PRMS)*. Society of Petroleum Engineers.