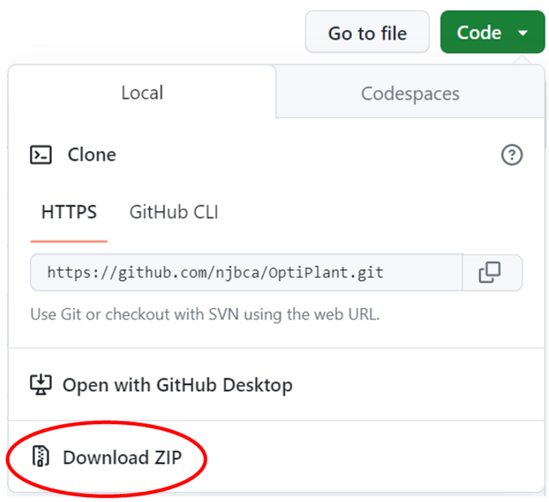
2) OptiPlant tool: User guide

DTU-Department of Technology, Management and Economics

The purpose of this document is to work as a guide of the **OptiPlant tool** for complete beginners. A copy of this document can also be found in the following link: https://github.com/njbca/OptiPlant.

To run the OptiPlant tool, one needs to have the following software installed: Microsoft Excel, Julia v1.8.5 (or later), Visual Studio Code v1.74 (or later), JuMP v1.6.0 (or later), Gurobi v10.0.0 (or later), and some JuliA packages such as CSV, ExcelReaders or Plots. An installation guide for all the mentioned software -except for Microsoft Excel- is also available in the link: https://github.com/njbca/OptiPlant, and goes under the name: ***'1) Installation guide: software needed to run OptiPlant tool'***.

Once the user has gone through all the steps of the *Installation guide*, he/she can download all the elements of the OptiPlant tool and start using it. To do so, go to the above-mentioned GitHub link and click on the green 'Code' button, and 'Download ZIP':



In the following pages of this document, one can find a detailed description of all the folders and files included in the downloaded ZIP file, and how to use them properly.

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Introduction

OptiPlant is a tool developed by Nicolas Campion from the DTU Department of Technology, Management and Economics that enables the user to model Power-to-X fuel production systems with a high variety of customizable input parameters and to optimize them according to different criteria. The model works under the 'dynamic power supply and system optimization' approach (DPS-Syst-Opt).

The fuel plant is modelled using a linear deterministic programming model which aims to minimize the fuel production cost of a PtX plant by managing the investments and operation of storage, power-supply and fuel production units under certain constraints. It assumes perfect foresight.

The system's optimization model has the following specifications:

- The model **input parameters** are: the techno-economic data of the different units, the hourly grid electricity prices, the hourly renewable power production profiles and the by-product market prices.
- The **goal** or **objective** of this model is to minimize the annualized system cost of the PtX power plant, using as variables the invested capacities and the hourly mass/energy flows. The system is constrained by a minimum fuel production quantity, the min/max load of the different units and the mass/energy balances between the different units.
- The **outcomes** or **results** of the model are the fuel production cost, the sizing of the different units of the system and the operation of the system (in terms of mass and energy flows).

The described optimization model characteristics are also presented in the *Fig.1* displayed in the next page.

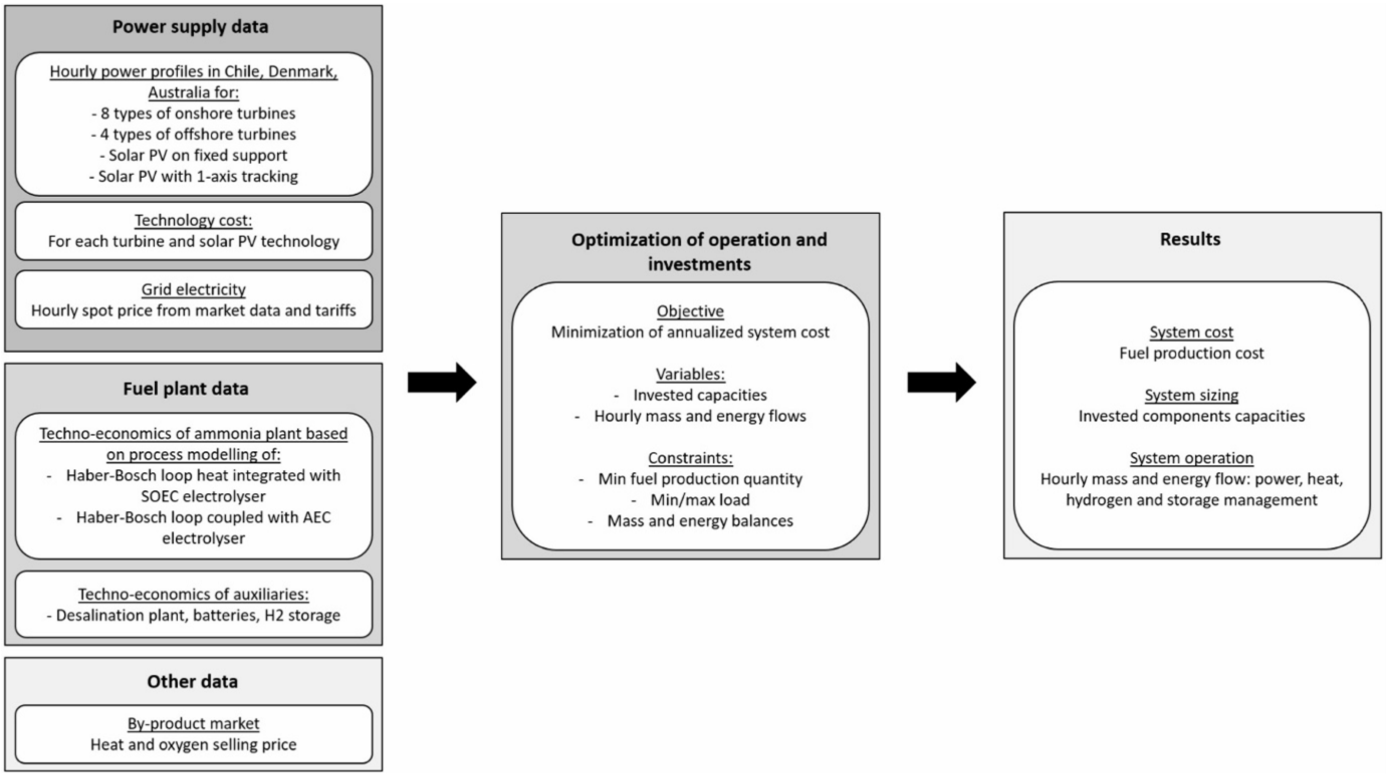


Fig. 1: Scheme of the OptiPlant-tool model including input data, optimization model and results [1]

The model is designed in such a way that the input parameters, the optimization objective, variables or constrains, and the outcoming results can be modified in a fairly easy way.

For a more detailed description of the OptiPlant model such as the components and structure of the simulated plant, the mathematical description of the optimization model, the sources of the data inputs or other considerations, one can check the following articles that used the OptiPlant tool (they can be found on DTU Orbit): [1], [2], [3].

OptiPlant tool: User guide

Inside the main folder of this tool, named as **'OptiPlant-World'**, one can find different folders and subfolders as shown and listed below:

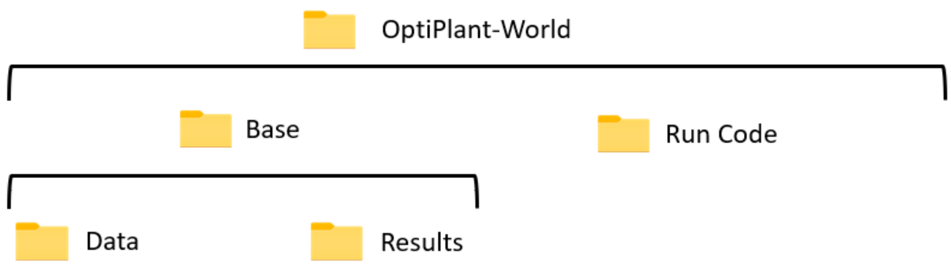


Fig. 2: Folder hierarchy and contents of the OptiPlant tool.

Note: The downloaded ZIP files may also include the files *License.md* and *README.md*, and the folder *envgit*. These three elements are not needed to run OptiPlant and can be ignored, that's why they are not included in *Fig.2* above.

BASE: It includes two subfolders named 'Data' and 'Results'. It includes all the elements that are not 'code-related'.

- **Data**: Includes two subfolders named 'Inputs' and 'Profiles'.

  Inputs: This folder contains different excel sheets where one can check and modify the input data for different study-case scenarios such as: units conforming for the PtX plant, their techno-economic information, the operation strategy of the plant,etc. More details on the 'Inputs excel sheets' in section *A.1*.

  Profiles: This folder contains the excel sheets where one can check and modify the wind/solar profiles and the electricity prices of different locations during different years (also including stochastic approach). More details on the 'Profiles excel sheets' in section *A.2*.

- **Results:** Has the results/outputs of the simulation. A new folder will be created any time a simulation is run, and its name would correspond to the one written in the 'Inputs excel sheet'. Includes different subfolders: Data used, Hourly results and Main results. More details on how to process the results and the 'Main results excel sheet' in section *B*.

RUN CODE: It includes four Julia scripts named ImportData.jl, ImportScenarios.jl, Main.jl, and Main_stochastic.jl

ImportData.jl: Imports into Julia the necessary input data to run the simulation such as: PtX plant units, their techno-economic characteristics, power profiles...

ImportScenarios.jl: Imports into Julia the necessary information regarding the scenario in which the plant operates in the study.

Main.jl: This is the optimization model per se. Uses the data imported from ImportData.jl, ImportScenarios.jl and extracts some results/outputs of the optimization model. More details on how to run the Main.jl script in section C.

Main_stocahstic.jl: It is the same as the Main.jl file, but instead of being a deterministic model, this one includes an stochastic (random but statistical-based) approach.

A. BASE folder > Data

One of the main folders of the OptiPlant tool is the **'Data'** folder. As it can be seen in [Fig.2], it is contained in the mother folder **'BASE'**. At the same time, it includes the subfolders *'Inputs'* and *'Profiles'* described below:

A.1 'Inputs' subfolder

As shown in [Fig.2], the *'Inputs'* folder of the OptiPlant tool can be found at **BASE** > **Data**. Inside the folder, it looks like something like this:

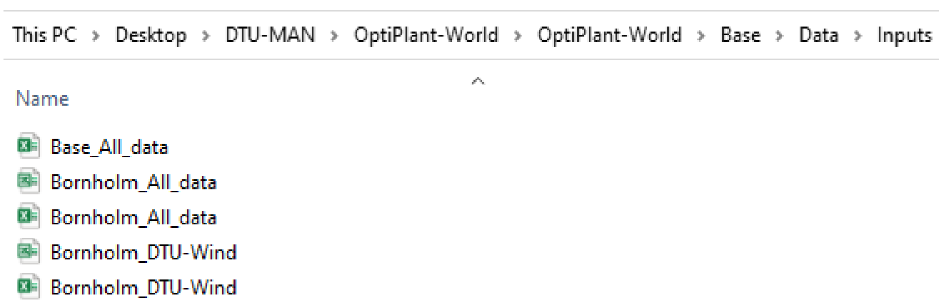


Fig. 3: Excel files found inside the *'Inputs'* folder.

Note: It is recommended to create a copy of one of these files and use one of them for each of the simulations or model analysis to perform. When saving it, do it in both '.xlsx' and '.xls' format.

If we enter one of these files, for instance, Bornholm_All_data, we find an excel document that has the following sheets:

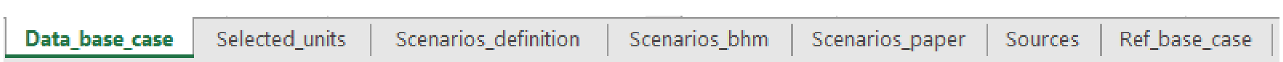


Fig. 4: Different excel sheets inside the excel files of the 'Input' folder

- **Data_base_case**: This sheet includes a list of the different units that can constitute the PtX plant and their characteristics: production rates, heat and electrical flows, load ranges, ramp up/down times, CapEx and OpEx, CO_2 emissions, etc.

					Electrical consumption (kWh/output)						Investment (EUR/Capacity installed)					
	bs	Su bs et	Type of units	net ear-	Electrical consumption 2020 worst	Electrical co 2020	Electrical 2020 best	Electrical 2030	Electrica 2040	Electric 2050	Investment (E 2020 worst	Investment 2020	Investmer 2020 best	Investme 2030	Investm 2040	Investn 2050
					40	41	42	43	44	45	46	47	48	49	50	51
Non-electrical	Pr	PWI	Electrolysers AEC	13	53.3	51.5	50	49.8	49.4	49	58440.82717	55000	52629.64	39840	32370	24900
	Pr	PWI	lectrolysers SOEC heat integrate	14	38	38	36.8	38	38	38	105260	105260	105260	39584	27392	15200
	Pr	PWI	Electrolysers SOEC alone	15	44	44	44	43.2	41.6	40	105260	105260	105260	39584	27392	15200
	Pr	PWI	Electrolysers 75AEC-25SOEC_HI	16	49.475	48.125	46.7	46.85	46.55	46.25	70145.62038	67565	65787.23	39776	31125.5	22475
	Pr	PWI	Electrolysers 75AEC-25SOEC_A	17	50.975	49.625	48.5	48.15	47.45	46.75	70145.62038	67565	65787.23	39776	31125.5	22475
	Re	Sub	H2 pipeline to MeOH CCU plant	18	0	0	0	0	0	0	0	0	0	0	0	0
	Re	Sub	H2 pipeline to BioMeOH plant	19	0	0	0	0	0	0	0	0	0	0	0	0
	Re	Sub	H2 pipeline to NH3 plant	20	0	0	0	0	0	0	0	0	0	0	0	0
	Re	Sub	H2 pipeline to client	21	0	0	0	0	0	0	0	0	0	0	0	0
	Heat_I		Heat from district heating	22	0	0	0	0	0	0	0	0	0	0	0	0
	Heat_:		Heat sent to district heating	23	0	0	0	0	0	0	0	0	0	0	0	0
	Pr2_s		Sale of oxygen	24	0	0	0	0	0	0	0	0	0	0	0	0
	St	Sub	H2 tank compressor	25	4	3.5	3.5	3.5	3.5	3.5	0	0	0	0	0	0
	St	Sub	H2 tank valve	26	0	0	0	0	0	0	0	0	0	0	0	0
	Ta	Sub	H2 tank	27	0	0	0	0	0	0	1000	900	900	800	650	500
	St	Sub	H2 pipes compressor	28	0.94	0.94	0.94	0.94	0.94	0.94	0	0	0	0	0	0
	St	Sub	H2 pipes valve	29	0	0	0	0	0	0	0	0	0	0	0	0
	Ta	Sub	H2 buried pipes	30	0	0	0	0	0	0	460.7554246	250	250	250	250	250
Electrical	RF	Sub	Solar fixed	31	0	0	0	0	0	0	552.6787	552.6787	552.6787	396.26	344.121	312.84
	RF	Sub	Solar tracking	32	0	0	0	0	0	0	761.2367	646.5298	583.9624	458.828	406.688	375.4
	RF	Sub	ON_SP198-HH100	33	0	0	0	0	0	0	1758.680753	1758.68075	1758.681	1633.06	1538.85	1507.4
	RF	Sub	ON_SP198-HH150	34	0	0	0	0	0	0	2188.79342	2188.79342	2188.793	2032.45	1915.19	1876.1
	RF	Sub	ON_SP237-HH100	35	0	0	0	0	0	0	1554.762792	1554.76279	1554.763	1443.71	1360.42	1332.7
	RF	Sub	ON_SP237-HH150	36	0	0	0	0	0	0	1947.473887	1947.47389	1947.474	1808.37	1704.04	1669.3
	RF	Sub	ON_SP277-HH100	37	0	0	0	0	0	0	1414.982856	1414.98286	1414.983	1313.91	1238.11	1212.8
	RF	Sub	ON_SP277-HH150	38	0	0	0	0	0	0	1807.693951	1807.69395	1807.694	1678.57	1581.73	1549.5
	RF	Sub	ON_SP321-HH100	39	0	0	0	0	0	0	1301.29478	1301.29478	1301.295	1208.35	1138.63	1115.4
	RF	Sub	ON_SP321-HH150	40	0	0	0	0	0	0	1694.006345	1694.00635	1694.006	1573.01	1482.26	1452
	RF	Sub	OFF_SP379-HH100	41	0	0	0	0	0	0	2205.190448	2205.19045	2205.19	1998.13	1873.89	1842.8
	RF	Sub	OFF_SP379-HH150	42	0	0	0	0	0	0	2534.607174	2534.60717	2534.607	2296.62	2153.82	2118.1
	RF	Sub	OFF_SP450-HH100	43	0	0	0	0	0	0	1988.123484	1988.12348	1988.123	1801.45	1689.44	1661.4
	RF	Sub	OFF_SP450-HH150	44	0	0	0	0	0	0	2265.527043	2265.52704	2265.527	2052.8	1925.17	1893.3

Fig. 5: Data_base_case excel sheet inside a standard file found in the *'Inputs'* folder.

Note: A lot of information is displayed in this excel sheet and can be overwhelming at first. However, it is quite simple to read once you start getting used to it, every unit parameter has their units and source stated. Furthermore, one would not usually change anything on this sheet. See that the different units are divided in 'non-electrical' and 'electrical'.

- **Selected_units:** This sheet contains a list of the different units (and electrolyzer technologies) that can constitute the PtX plant and the ones that are used for each fuel production process -i.e. NH_3, H_2, $MeOH$, etc.- For each case, a 1 implies that the unit is considered in the PtX plant and a 0 implies that it is not.

Water supply	Fuel produced	Bio-eMeOH	Bio-eMeOH	Bio-eMeOH	NH3	NH3	NH3
Waste water plant	Fuel energy content LHV (MJ/kg fuel)	19.9	19.9	19.9	18.6	18.6	18.6
H2 storage	Electrolyser	AEC	SOEC	Mix	AEC	SOEC	Mix
H2 buried pipes	Carbon capture	None	None	None	None	None	None
	Configuration	Bio-eMeOH_AEC_None	Bio-eMeOH_SOEC_None	Bio-eMeOH_Mix_None	NH3_AEC_None	NH3_SOEC_None	NH3_Mix_None
1	CO2 capture DAC	0	0	0	0	0	0
2	CO2 capture PS	0	0	0	0	0	0
3	MeOH plant CCU	0	0	0	0	0	0
4	Biomass	1	1	1	0	0	0
5	Bio-eMeOH plant - AEC	1	0	0	0	0	0
6	Bio-eMeOH plant - SOEC	0	1	1	0	0	0
7	NH3 plant + ASU - AEC	0	0	0	1	0	0
8	NH3 plant + ASU - SOEC	0	0	0	0	1	1
9	H2 client	0	0	0	0	0	0
10	Desalination plant	0	0	0	0	0	0
11	Waste water plant	1	1	1	1	1	1
12	Drinking water	0	0	0	0	0	0
13	Electrolysers AEC	1	0	0	1	0	0
14	Electrolysers SOEC heat integrated	0	1	0	0	1	0
15	Electrolysers SOEC alone	0	0	0	0	0	0
16	Electrolysers 75AEC-25SOEC_HI	0	0	1	0	0	1
17	Electrolysers 75AEC-25SOEC_A	0	0	0	0	0	0
18	H2 pipeline to MeOH CCU plant	0	0	0	0	0	0
19	H2 pipeline to BioMeOH plant	1	1	1	0	0	0
20	H2 pipeline to NH3 plant	0	0	0	1	1	1
21	H2 pipeline to client	0	0	0	0	0	0
22	Heat from district heating	1	1	1	1	1	1
23	Heat sent to district heating	1	1	1	1	1	1
24	Sale of oxygen	1	1	1	1	1	1
25	H2 tank compressor	0	0	0	0	0	0
26	H2 tank valve	0	0	0	0	0	0
27	H2 tank	0	0	0	0	0	0
28	H2 pipes compressor	1	1	1	1	1	1
29	H2 pipes valve	1	1	1	1	1	1
30	H2 buried pipes	1	1	1	1	1	1
31	Solar fixed	0	0	0	0	0	0
32	Solar tracking	0	0	0	0	0	0
33	ON_SP198-HH100	0	0	0	0	0	0
34	ON_SP198-HH150	0	0	0	0	0	0
35	ON_SP237-HH100	0	0	0	0	0	0

Fig. 6: Selected_units excel sheet inside a standard file found in the *'Inputs'* folder.

Note: One can change the 1/0 values according to their preferences. However, it is important to be aware that the default values are the 'standard case' ones. So note down which values you change or work on a copy file in order to be able to go back to the 'standard case' settings.

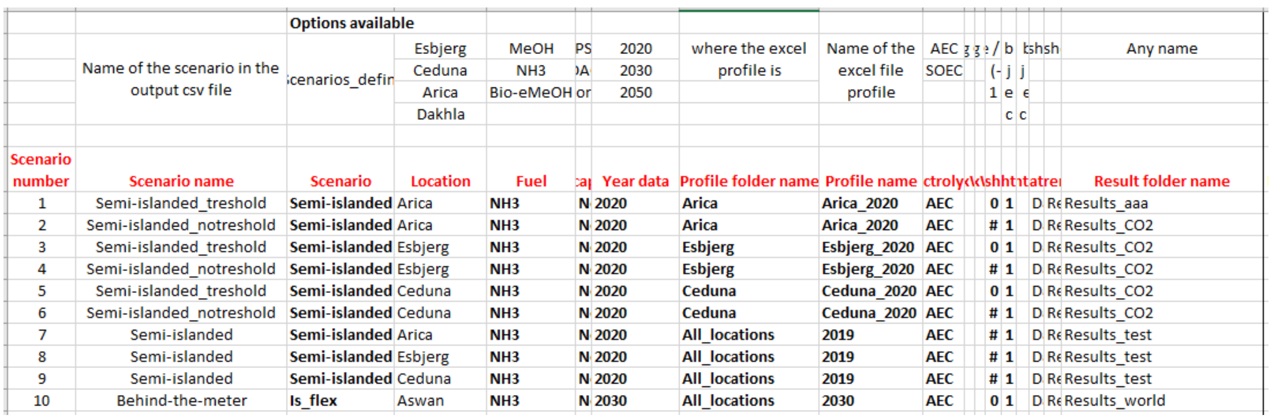
- **Scenarios_definition:** This sheet is used to define different scenarios considering factors such as the operation strategy of the plant, different operating constrains/conditions of the units,etc. It acts between a 'switch' between the Data_base_case + Selected_units and the output of the model.

Reference scenario	Scenario name definition	Type of units for change	Parameter changed	Year new value	New value	Year old value	Old value
	Semi-islanded	Electricity from the grid	Used (1 or 0)	All	1	All	1
Semi-islanded	Semi-islandedflex	MeOH plant CCU	Load min (% of max capacity)	All	0	2020	0.4
	Semi-islandedflex	NH3 plant + ASU - AEC	Load min (% of max capacity)	All	0	2020	0.4
	Semi-islandedflex	Bio-eMeOH plant - AEC	Load min (% of max capacity)	All	0	2020	0.4
	Islanded	Electricity from the grid	Used (1 or 0)	All	0	All	1
Islanded	Is_nonflex	MeOH plant CCU	Load min (% of max capacity)	All	1	2020	0.4
	Is_nonflex	NH3 plant + ASU - AEC	Load min (% of max capacity)	All	1	2020	0.4
	Is_nonflex	Bio-eMeOH plant - AEC	Load min (% of max capacity)	All	1	2020	0.4
	SI_nonflex	MeOH plant CCU	Load min (% of max capacity)	All	1	2020	0.4
	SI_nonflex	NH3 plant + ASU - AEC	Load min (% of max capacity)	All	1	2020	0.4
	SI_nonflex	Bio-eMeOH plant - AEC	Load min (% of max capacity)	All	1	2020	0.4
Islanded	Is_flex	MeOH plant CCU	Load min (% of max capacity)	All	0	2020	0.4
	Is_flex	NH3 plant + ASU - AEC	Load min (% of max capacity)	All	0	2020	0.4
	Is_flex	Bio-eMeOH plant - AEC	Load min (% of max capacity)	All	0	2020	0.4

Fig. 7: Scenarios_definition excel sheet inside a standard file found in the *'Inputs'* folder

Note: The logic of these cells is situated in between the inputs (1/0) made in the Selected_units sheet and the final output. So all the changes made in this sheet are made compared to the input data sheet (i.e Data_base_case and Selected_units). This sheet is specially useful when one wants to do sensitivity analysis.

- **Scenarios_(***):** One would find different excel sheets called Scenarios_*** (where *** can be any given name) inside the excel file. These sheets are used to list the different scenarios to be run through the optimization model. The conditions and characteristics of each of the listed scenarios make reference to the other sheets in the same excel document. One can set the scenario parameters such as: operating strategy, location wind/solar data, year data, produced fuel, electrolyzer technology, etc. The output results of the model are going to be stored as CSV files in **Results > Results_folder_name** (the folder is automatically created) -see image below-:



		Options available														
	Name of the scenario in the output csv file	;cenarios_defin	Esbjerg	MeOH	PS	2020	where the excel profile is	Name of the excel file profile	AEC	ʒ	ʒ	e /	b		tshsh	Any name
			Ceduna	NH3	)A	2030			SOEC			(-	j	j		
			Arica	Bio-eMeOH	or	2050						1	e	ϵ		
			Dakhla										c	c		
Scenario number	Scenario name	Scenario	Location	Fuel	ca	Year data	Profile folder name	Profile name	ctroly	‹k	\sh	ht	ıt	ta	reı	Result folder name
1	Semi-islanded_treshold	**Semi-islanded**	Arica	**NH3**	**N**	**2020**	**Arica**	**Arica_2020**	**AEC**		**0**	**1**		D	Re	Results_aaa
2	Semi-islanded_notreshold	**Semi-islanded**	Arica	**NH3**	**N**	**2020**	**Arica**	**Arica_2020**	**AEC**		**#**	**1**		D	Re	Results_CO2
3	Semi-islanded_treshold	**Semi-islanded**	Esbjerg	**NH3**	**N**	**2020**	**Esbjerg**	**Esbjerg_2020**	**AEC**		**0**	**1**		D	Re	Results_CO2
4	Semi-islanded_notreshold	**Semi-islanded**	Esbjerg	**NH3**	**N**	**2020**	**Esbjerg**	**Esbjerg_2020**	**AEC**		**#**	**1**		D	Re	Results_CO2
5	Semi-islanded_treshold	**Semi-islanded**	Ceduna	**NH3**	**N**	**2020**	**Ceduna**	**Ceduna_2020**	**AEC**		**0**	**1**		D	Re	Results_CO2
6	Semi-islanded_notreshold	**Semi-islanded**	Ceduna	**NH3**	**N**	**2020**	**Ceduna**	**Ceduna_2020**	**AEC**		**#**	**1**		D	Re	Results_CO2
7	Semi-islanded	**Semi-islanded**	Arica	**NH3**	**N**	**2020**	**All_locations**	**2019**	**AEC**		**#**	**1**		D	Re	Results_test
8	Semi-islanded	**Semi-islanded**	Esbjerg	**NH3**	**N**	**2020**	**All_locations**	**2019**	**AEC**		**#**	**1**		D	Re	Results_test
9	Semi-islanded	**Semi-islanded**	Ceduna	**NH3**	**N**	**2020**	**All_locations**	**2019**	**AEC**		**#**	**1**		D	Re	Results_test
10	Behind-the-meter	**Is_flex**	Aswan	**NH3**	**N**	**2030**	**All_locations**	**2030**	**AEC**		**0**	**1**		D	Re	Results_world

Fig. 8: Any of the Scenarios_(***) excel sheet one can find inside a standard file found in the *'Inputs'* folder

Note: Be especially cautious on writing the name for the different cell's inputs correctly in this sheet, as these 'names' need to 'call' the other sheets in the same excel document. It is also recommended to create a new sheet for each study case where you define the scenarios to run through the model. If you do that, though, be aware that the name of this excel sheet will be called in the code ***Main.jl (line 17)***, so be sure it is correctly called/changed in this code line too.

- **Ref_base_case Sources:** These sheets include the references and sources of the data used in the sheet Data_base_case. One would not need to edit the content of these sheets when running optimization of scenarios.

A.2 'Profiles' subfolder

As shown in [Fig.2], the *'Profiles'* folder of the OptiPlant tool can be found at **BASE** > **Data**. Inside the folder, it would look like this:

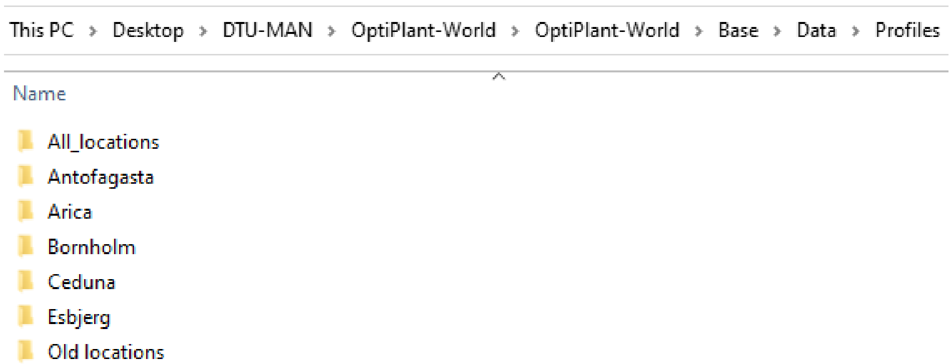


Fig. 9: Subfolders found inside the *'Profiles'* folder

Each of these subfolders corresponds to one of the locations studied/considered so far. For instance, if we go inside the *'All_locations'* folder, we find this:

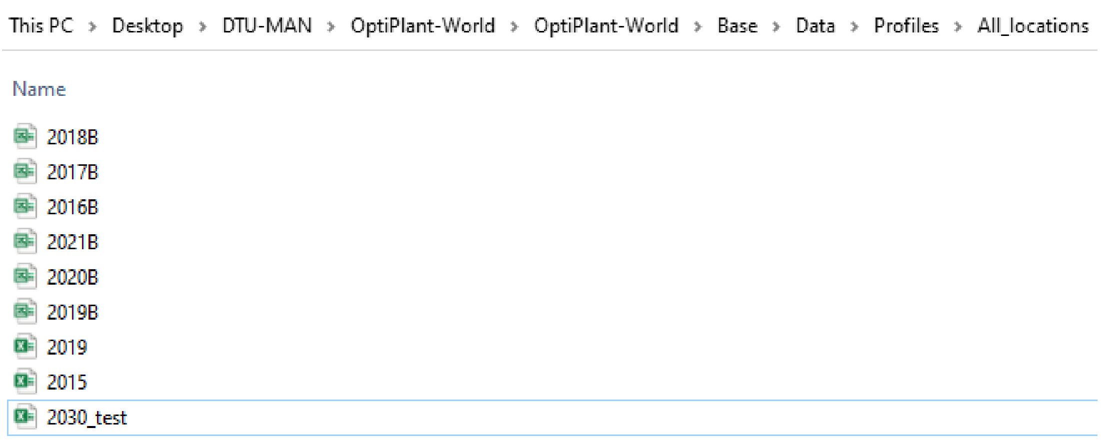


Fig. 10: Subfolders found inside the *'Profiles'* folder

Each of these files contains the 'solar' and 'wind' profiles for different years (corresponding to the name of the file), among other information. When opening one of these files, it is important that it includes the following sheets -otherwise, the model's code won't read the file correctly-:

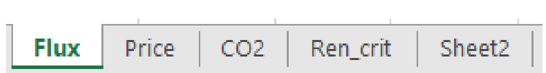


Fig. 11: Different excel sheets that should be included inside the excel files found in the *'Profiles'* folder.

Note: A good approach to have an 'exactly' build excel file for each case, is to copy one of the existing files and change its name and contained the data for the updated/necessary one. This way, one would avoid problems that may arise in the model's code when reading these files.

The content of each of the sheets is slightly described below:

- **Flux:** This sheet contains the hourly solar and wind profiles for the year '20**' using different solar and wind technologies. The Price sheet contains the hourly grid electricity price for the year '20**'. Finally, the CO2 contains the carbon dioxide emissions attributed to the grid electricity produced for each hour of the year '20**'.
- **Price:** It contains the hourly grid electricity price for the year '20**'.
- **CO2:** This sheet contains the carbon dioxide emissions attributed to the grid electricity produced for each hour of the year '20**'.
- **Ren_crit:** It contains the necessary information to assess if some renewable criteria are considered or not.

Note: The solar/wind power profiles included in the ***Flux*** excel sheet are extracted from the CorRES tool (for wind profiles), and from renewable.ninja (for solar profiles).

B. BASE folder > Results

As one can see in [Fig.2], the **'Results'** folder of the OptiPlant tool can be found inside the **BASE** main folder, and it looks similar to this:

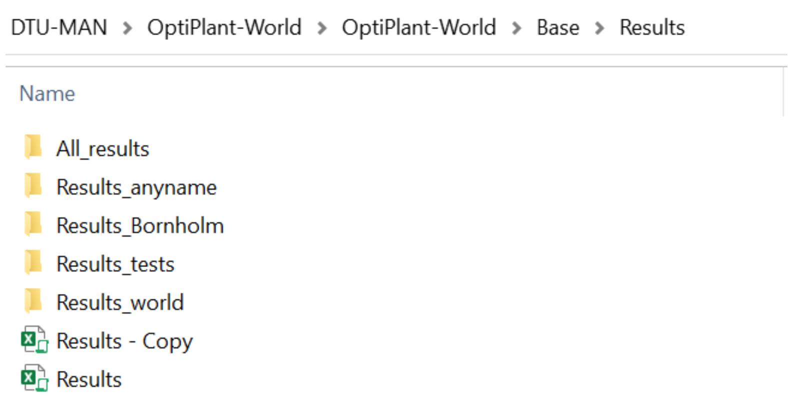


Fig. 12: Files and subfolders found inside the **'Results'** folder.

Each of the folders corresponds to one simulation run, and as stated before, its name is settled inside the Scenario_*** excel sheet from the 'Inputs' file. Each of these folders -e.g. *'Results_test'*- includes three subfolders named *'Data used'*, *'Hourly results'*, and *'Main results'*, that include the inputs and results of the simulation in CSV files, respectively:

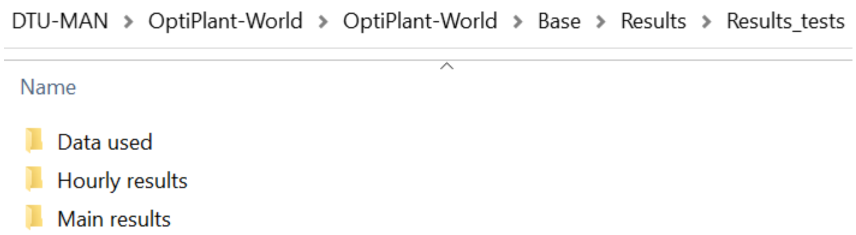


Fig. 13: Elements found inside any of the *'Results_***'* subfolders.

To process and read the CSV results included in the folders shown above, it is recommended to create a copy of the <u>'Results'</u> excel file that can be found in the main **'Results'** folder -see [Fig.11]- and save it in the corresponding *'Results_***'* subfolder, like shown below:

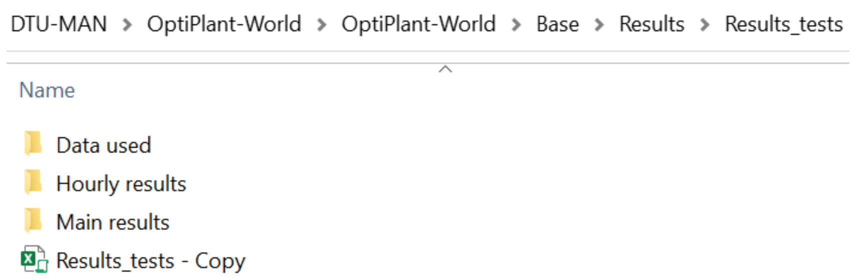


Fig. 14: Elements found inside any of the *'Results_***'* subfolders.

When opening any of the <u>'Results'</u> excel file (or one of its copies) one would find a document with the following sheets:

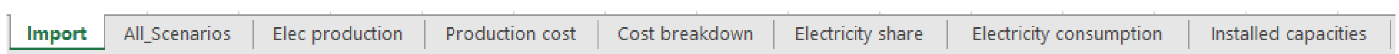


Fig. 15: Some of the excel sheets inside any of the <u>'Results'</u> excel file

First off, to check the results of the corresponding simulations, open the <u>'Results_***'</u> excel file and import the corresponding data by going to the 'Import' excel sheet, writing the right CSV files directory and clicking on the macros:

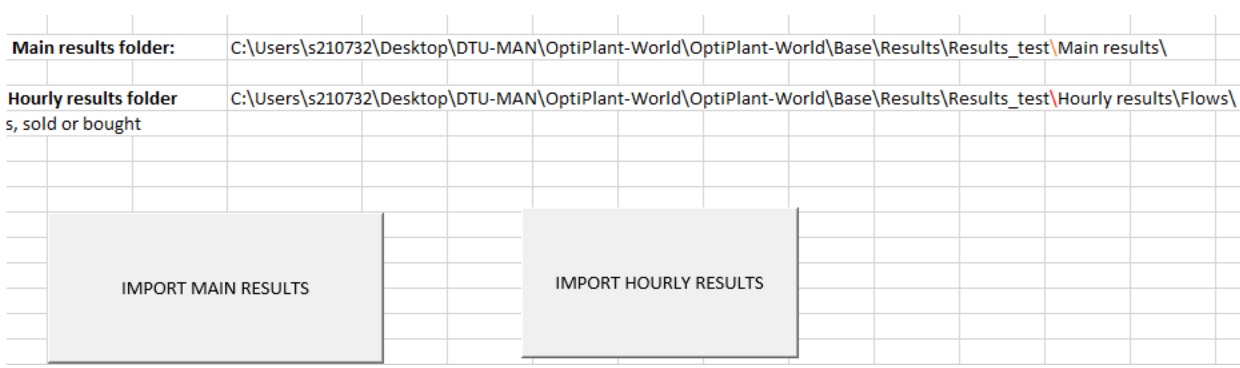


Fig. 16: 'Import' excel sheet inside any of the <u>'Results'</u> excel file

Once this is done, one would be able to see the outcomes and results for the different studied scenarios individually in the 'All scenarios' sheet. Each scenario will be named herein as it was in the 'Inputs' excel file:

Scenario	Type of unit	Year	Location	Profile	Fuel	Electrolyser	CC	C	C	We	M	Re	C	Installed capacity(MW	Total investment(MEuros)	Annualised invest
Hydrogen-AEC-2016	H2 client	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	16.94072541	0	0
Hydrogen-AEC-2016	Waste water plant	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	190.5831608	23.05925887	2.694002721
Hydrogen-AEC-2016	Electrolysers AEC	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	16.94072541	674.9185002	59.72730091
Hydrogen-AEC-2016	H2 pipeline to client	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	16.94072541	0	0
Hydrogen-AEC-2016	Heat from district heating	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0
Hydrogen-AEC-2016	Heat sent to district heating	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	96.15555741	0	0
Hydrogen-AEC-2016	OFF_SP379-HH100	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0
Hydrogen-AEC-2016	OFF_SP379-HH150	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	892.8755904	2050.592269	182.1488482
Hydrogen-AEC-2016	OFF_SP450-HH100	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0
Hydrogen-AEC-2016	OFF_SP450-HH150	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0
Hydrogen-AEC-2016	Curtailment	2030	Bornholm	2016B	H2	AEC	Nc			C1.	#	Nc	0	4.107227716	0	0
Hydrogen-AEC-2017	H2 client	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	14.80584507	0	0
Hydrogen-AEC-2017	Waste water plant	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	166.5657571	20.1533173	2.354502889
Hydrogen-AEC-2017	Electrolysers AEC	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	14.80584507	589.8648677	52.20043077
Hydrogen-AEC-2017	H2 pipeline to client	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	14.80584507	0	0
Hydrogen-AEC-2017	Heat from district heating	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0
Hydrogen-AEC-2017	Heat sent to district heating	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	84.03797664	0	0
Hydrogen-AEC-2017	OFF_SP379-HH100	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0
Hydrogen-AEC-2017	OFF_SP379-HH150	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	776.5763148	1783.497505	158.4235058
Hydrogen-AEC-2017	OFF_SP450-HH100	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0
Hydrogen-AEC-2017	OFF_SP450-HH150	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0
Hydrogen-AEC-2017	Curtailment	2030	Bornholm	2017B	H2	AEC	Nc			C1.	#	Nc	0	0	0	0

Fig. 17: 'All_scenarios' excel sheet inside any of the 'Results' excel file

The obtained outcomes and results from the simulation and optimization of the different scenarios is broken down in the rest of the excel sheets of the document, focusing on a single parameter only (installed capacities, electricity consumption, cost breakdown...).

It is important to mention that the **UNITS for the outcomes and results** (if not specified) are in tons per hour (t/h) for the 'non-electrical' units and in megawatts (MW) for the 'electrical' ones. The units corresponding to the results shown in the *hourly flows* are :1000 (i.e. kg per hour and kilowatt, respectively).

Note: When in any of the particular results sheet of the document, -i.e. installed capacities-, remember always to refresh the PivotTable (right click + refresh) to load the new results.

C. RUN CODE folder

The **'RUN CODE'** folder is one of the two main folders in OptiPlant tool -together with the **'BASE'** folder-. This folder is simpler than the 'BASE' one as it only includes 4 Julia code files inside:

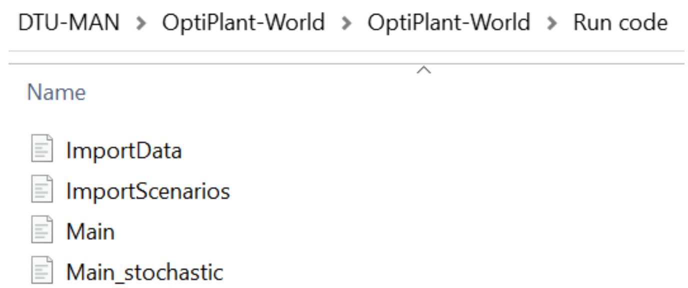


Fig. 18: Julia code files included inside the **'Run code'** folder

The main purpose of each of the Julia scripts has been previously described. In most cases, one will only need to modify and run the ***'Main.jl'*** file, as the other files act just as a bridge to import the date form the 'Input' excel files. Inside the ***'Main.jl'*** code, one should only change/edit the parameters shown in the red box of the image below to match with the correct directories on their PC:

```julia
#Project name
Project = "Base"
# Folder name for all csv file
all_csv_files = "All_results"
# Folder paths for data acquisition and writing
Main_folder = "C:/Users/s210732/Desktop/DTU-MAN/OptiPlant-World" ;
Profiles_folder = joinpath(Main_folder,Project,"Data","Profiles") ;
Inputs_folder = joinpath(Main_folder,Project,"Data","Inputs") ;
Inputs_file = "Bornholm_All_data"
```

Comment from the author:

I hope this tutorial was clear and useful for the reader. In the next section of this document called **'troubleshooting'** -see next pages-, one can find some of the most common errors when running the scripts in the **'RUN CODE'** folder (among others), and how to solve them. If encountered with errors not treated in the troubleshooting section, I would suggest to use internet forums or other tools to tackle them.

Have fun using the Optiplant tool! :)

Troubleshooting: Common errors that may appear when running OptiPlant (and how to solve them)

The purpose of this section is to list and offer a solution for some of the most typical errors one can encounter when running the OptiPlant tool for the first time. This part of the document is though to be edited and upgraded by the different users using the tool.

1) ERROR: Package X not found

```
ERROR: ArgumentError: Package JuMP not found in current path.
- Run `import Pkg; Pkg.add("JuMP")` to install the JuMP package.
```

If this message appears, you probably haven't activate the environment before running a code. The environment includes all the packages installed necessary to run the code successfully. **To solve it, activate the environment**.

To activate the environment: Enter the 'package manager' press ']' (you will see that the colored text 'julia>' text changes to '(@v1.8) pkg>'. Activate the environment by writing 'activate env' on the package manager.

If the error still appears, check that the package you need to use is correctly installed by writing 'status' on the package manager (after activating the environment). If it does NOT appear there, it means the package is not installed. You can install it by writing: 'add ***' (***= name of the package) in the 'env' option.

Another reason this ERROR may appear is that you are not calling the package X at the beginning of the code. To solve it, call the necessary packages. It is done like this:

```
using JuMP, Gurobi, CSV, DataFrames, XLSX, ExcelReaders
```

2) ERROR: File not found 'not such file or directory'

```
ERROR: LoadError: PyError ($(Expr(:escape, :(ccall(#= C:\Users\s210732\.julia\packages\PyCall\twYvK\src\pyfncall.jl:43 =# @pysym(:PyObject_Call),
FileNotFoundError(2, 'No such file or directory')
  File "C:\Users\s210732\.julia\conda\3\x86_64\lib\site-packages\xlrd\__init__.py", line 166, in open_workbook
    file_format = inspect_format(filename, file_contents)
  File "C:\Users\s210732\.julia\conda\3\x86_64\lib\site-packages\xlrd\__init__.py", line 60, in inspect_format
    with open(path, "rb") as f:
```

If this message appears, you probably haven't routed the different Julia scripts and excel sheets correctly to the optimization code 'Main'. **To solve it, make sure that you are routing all the files correctly**. For instance:

```
#Project name
Project = "Base"
# Folder name for all csv file
all_csv_files = "All_results"
# Folder paths for data acquisition and writing
Main_folder = "C:/Users/s210732/Desktop/DTU-MAN/OptiPlant-World" ;
Profiles_folder = joinpath(Main_folder,Project,"Data","Profiles") ;
Inputs_folder = joinpath(Main_folder,Project,"Data","Inputs") ;
Inputs_file = "Bornholm_All_data"
```

Note: Pay extra attention to the routes when having numerous folders and subfolders!

3) ERROR: XLRDError, File format NOT supported

```
ERROR: LoadError: PyError ($(Expr(:escape, :(ccall(#= C:\Users\s210732\.julia\packages\PyCall\twYvK\src\pyfncall.jl:43
XLRDError('Excel xlsx file; not supported')
  File "C:\Users\s210732\.julia\conda\3\x86_64\lib\site-packages\xlrd\__init__.py", line 170, in open_workbook
    raise XLRDError(FILE_FORMAT_DESCRIPTIONS[file_format]+'; not supported')
```

If this message appears, the excel sheets you are trying to read are not in the right format (which is .xls). Most probably, the files you have are saved as .xlsx, the new excel version.

To solve this, the .xlsx has to be changed to .xls in several places:

a) Make sure the excel sheets (data inputs and profiles) are saved as .xls, and if not, make a copy of the original sheet in the .xls format.

b) Change a line in the code in the file 'ImportScenarios.jl', and define the data inputs as .xls files, and not .xlsx (line 3):

```
using ExcelReaders

Datafile_inputs = joinpath(Inputs_folder,Inputs_file*".xls")
Data_scenarios = readxlsheet(Datafile_inputs,Scenarios_set)
```

Do the same in the file 'ImportData.jl' (lines 61 and 63):

```
#------------------2 - Folder path for profiles and techno_eco data ---------------
#Techno-economics data
Datafile_techno_economics = joinpath(Inputs_folder,Inputs_file*".xls")
#Profile data
Datafile_profile = joinpath(Profiles_folder,Profile_folder_name,Profile_name*".xls")
```

4) ERROR: Format error when displaying the simulation results in excel

Once the model has run successfully and some results have been generated, one can encounter some problems when reading the CSV results file.

For instance, when importing the 'main results' CSV, one can get 'weird/unrealistic' results if the importing method is not defined correctly. For instance:

Scenario	Type of unit	Criterion applicati	Installed capacity(MW or t/h)	Total investment(MEuros)
Ammonia-AEC	NH3 plant + ASU - AEC	0	8.484.093.126.040.480	5.652.238.586.058.180
Ammonia-AEC	Waste water plant	0	19.530.929.787.645.200	23.631.089.127.453.200
Ammonia-AEC	Electrolysers AEC	0	17.360.826.477.906.800	6.916.553.268.798.090
Ammonia-AEC	H2 pipeline to NH3 plant	0	15.271.367.626.872.800	0
Ammonia-AEC	Heat from district heating	0	0	0
Ammonia-AEC	Heat sent to district heating	0	985.400.510.885.994	0
Ammonia-AEC	Sale of oxygen	0	13.472.001.346.855.700	0
Ammonia-AEC	H2 pipes compressor	0	9.476.005.393.052.820	0

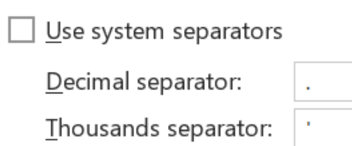
It can be clearly seen that the obtained results are too large. There must be an error on the CSV reading process. To check that the error is in the file lecture and not actually in the results, we open any of the CSV files on 'Main results' with the notebook. One should see the following:

```
Scenario,Type of unit,Year data,Location,Profile,Fuel,Electrolyser,CO2 capture,CO2 tax level upstream (Eur/kgCO2)
Ammonia-AEC,NH3 plant + ASU - AEC,2030,Bornholm,2019,NH3,AEC,None,0.0,0.0,C1.0_E0.0,-1.0,None,0.0,84.840931260404
Ammonia-AEC,Waste water plant,2030,Bornholm,2019,NH3,AEC,None,0.0,0.0,C1.0_E0.0,-1.0,None,0.0,195.30929787645232,
```

The numbers here are realistic and *a priori* seem correct. Observe that the CSV file separates cells with commas and decimals with dots.

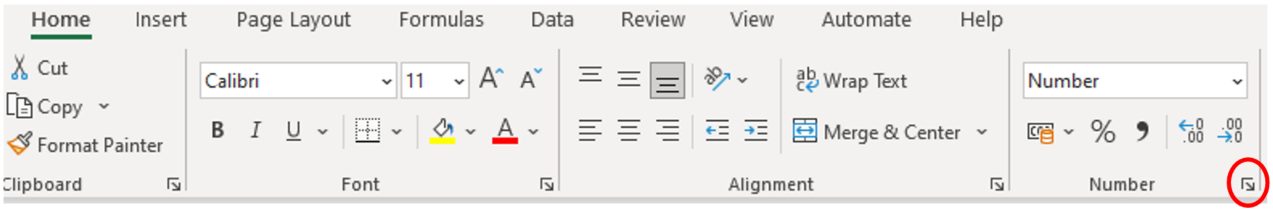
To make our excel file read the file and use the separators correctly we do the following:

1. Inside excel, go to File > Options > Advanced and look for this lines here:

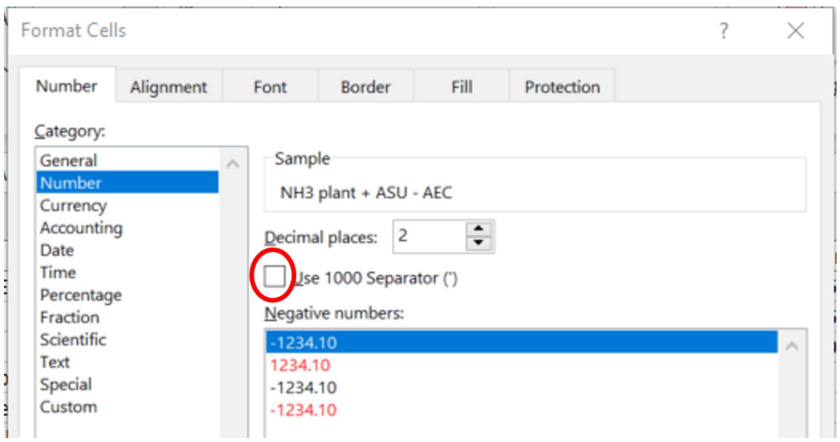
   

   The decimal separator should be a dot (.). If possible, set the thousands separator to 'none' or just add any symbol which is not a dot (.), for instance an apostrophe (').

2. Go to HOME and click in the 'Number' tab -bottom corner right of the image-:



3. Untick the 'Use 1000 separator' box:



After these two steps have been done, reset Excel and import the data again. It should look like this now:

Scenario	Type of unit	Criterion applicati	Installed capacity(MW	Total investment(MEuros)
Ammonia-AEC	NH3 plant + ASU - AEC	0	84.84093126	565.2238586
Ammonia-AEC	Waste water plant	0	195.3092979	23.63108913
Ammonia-AEC	Electrolysers AEC	0	17.36082648	691.6553269
Ammonia-AEC	H2 pipeline to NH3 plant	0	15.27136763	0
Ammonia-AEC	Heat from district heating	0	0	0
Ammonia-AEC	Heat sent to district heating	0	98.54005109	0
Ammonia-AEC	Sale of oxygen	0	134.7200135	0
Ammonia-AEC	H2 pipes compressor	0	947.6005393	0

Issue solved!

References

[1] Nicolas Campion et al. "Techno-economic assessment of green ammonia production with different wind and solar potentials". English. In: *Renewable Sustainable Energy Reviews* 173 (2023). ISSN: 1364-0321. DOI: `10.1016/j.rser.2022.113057`.

[2] Nicolas Jean Bernard Campion, Philip Robert Swisher, and Marie Münster. "Optimal energy system configuration for electro-fuels production in different locations". English. In: (2022). 7th World Maritime Technology Conference 2022, WMTC 22 ; Conference date: 26-04-2022 Through 28-04-2022.

[3] Nicolas Jean Bernard Campion et al. *MarE-fuel: LCOE and optimal electricity supply strategies for P2X plants*. English. Technical University of Denmark, 2021.