9. Annexes

9.1. Annexe A

This Annexe includes a collection of users' stories, which were the starting point for the creation of the Demo-Mock up (also here introduced), and finally the Comment-Response Matrix. The latter included the comments received on the Demo Mock-up and was the reference to develop CCG-SAND Interface.

9.1.1. User Stories

Table 21 includes the OSeMOSYS User Stories: the functionalities that a user would like to have when using an Interface based on OSeMOSYS which were provided by United Nations Department of Economic and Social Affairs (UNDESA).

Table 21: User Stories Collection from UNDESA

Tasks	**Description**	**Acceptance criteria**	**Value**
	Write what you want to see	**Requirements**	**1 Low – 5 High**
Create a new model	As a user, I want to be presented with a series of forms that takes me through the necessary steps to specify the essentials of an Osemosys model	The user should be able to: 1) name the model and provide a description 2) Specify model horizon 3) Specify intra-year time resolution 4) Edit any entries made	5
Create/edit/copy/delete commodities	As a user, I want to see a form to provide the necessary information needed to specify a new member of the "commodity" set	User can: 1) Create a new member of the set "Commodity." 2) Provide a name and description of that commodity 3) Specify any group membership 4) Specify units from a list 5) Specify parameters for which you want to provide data from a list of all eligible parameters (i.e. parameters that have the commodity dimension) 6) Copy, edit or delete any commodity	5

Create/edit/copy/delete technologies	As a user, I want to see a form to provide the necessary information needed to specify a new member of the "technology" set	User can: 1) Create a new member of the set "Technologies." 2) provide a name and description of that technology 3) Specify any group membership 4) Specify units of capacity and activity from a list 5) Specify multiple input and output commodities from a list 6) Specify multiple emissions from a list 7) Specify parameters for which you want to provide data from a list of all eligible parameters (i.e. parameters that have the technology dimension) 8) Specify group memberships 9) Set RET tag 10) Specify modes of operation from a list 11) Copy, edit or delete any technology	5
Create/edit/copy/delete emissions	As a user, I want to see a form to provide the necessary information needed to specify a new member of the "Emission" set	User can: 1) Create a new member of the set "emissions", 2) provide a name and description of that emission 3) Specify any group membership 4) Specify units 5) Specify parameters for which you want to provide data from a list of all eligible parameters (i.e. parameters that have the emission dimension) 6) Copy, edit or delete any emission	5
Create/edit/copy/delete storages	As a user, I want to see a form to provide the necessary information needed to specify a new member of the "Storage" setting	User can 1) Create a new member of the set "Storage", 2) Provide a name and description of that storage 3) Specify any group membership 4) Specify units 5) Specify parameters for which you want to provide data from a list of all eligible parameters (i.e. parameters that have the storage dimension)	4
Create/edit/copy/d	As a user, I want to be able	User can	3

elete groups	to create, edit, copy and delete groups for all relevant sets (Commodities, Technologies, Emissions Storages) and select the members of this group.	1) Create a new group (Commodities, Technologies, Emissions Storages) 2) Provide a name and description for that group 3) Add and remove members for that group 4) Copy or delete that group	
Create/edit/delete units	As a user, I want to be able to create, edit and delete monetary units, units of capacity for technologies and units for commodities (the latter can be used for commodities, emissions, technology activity and capacity of storages). A default list should come with the UI distribution.	User can 1) Create a new unit (in either of the three categories) 2) Edit or delete these units	5
View/Enter/edit parameter data	As a user I want (as per the mockup) to be able to view and edit, in a tabular format, all parameter inputs with options for sorting (by scenario, commodity, technology, emission, parameter) and filtering (by scenario, commodity, technology, emission, parameter)	User can 1) View data as a table 2) Enter data directly or copy from other application (e.g. Excel) 3) Sort data by set (Column) 4) Filter data by set (through checking/unchecking in "set boxes" as per mockup) 5) For each parameter entry the units should be displayed (a function of the parameter, technology, commodity, emission, storage)	5
Create/edit/copy/delete a scenario	As a user, I want to be able to create and configure new scenarios	User can: 1) Create a new scenario 2) Provide a name and description for that scenario 3) Copy and delete scenarios 4) Enter data, create new technologies, commodities, storages and emissions in that scenario (could be a switch to set which scenario one is editing at any given time) 5) A scenario should only contain data that has been added or changed relative to the reference case.	5

Create/edit/copy/delete a case	As a user, I want to be able to create and configure new cases	User can: 1) Create a new case 2) Select multiple scenarios to comprise that case (from a list) 3) Order scenarios in a case to set sequence/preference 4) Edit/copy and delete a case	5
Run a case	As a user, I need to be able to run/execute a model run (case)	User can: 1) Run his/her specified case and upload results (acceptable if parts of this process are done outside the UI itself)	5
View results	As a user I want (as per the mockup) to be able to view in a tabular format, all variable outputs with options for sorting (by scenario, commodity, technology, emission, parameter) and filtering (by scenario, commodity, technology, emission, parameter)	User can 1) View results as a table 2) Copy data directly to other applications (e.g. excel) 3) Sort data by set (Column) 4) Filter data by set (through checking/unchecking in "set boxes" as per mockup) 5) If possible: pivot table style results viewing 6) For each result variable the correct units should be displayed (a function of the parameter, technology, commodity, emission, storage)	5
Export results	As a user, I need to be able to run/execute a model run (case)	User can: 1) Export a table to excel at the press of a button	5
Model management	As a user, I need to be able to open/close and delete existing models. I should also be able to transfer models from one user to another (i.e. export/import facilities or similar)	User can: 1) Open an existing model and work on it 2) Create a copy of a model and work on it 3) Delete a model 4) Export a full model 5) Import a full model	5

9.1.2. Demo Mock-up

Based on the User Stories above described, as a first step, an online Mock-up Widget was developed, which aimed at visualizing which functionalities the new Interface need to have and gather feedback from expert users of the Optimus Community of Practice [44]. A screenshot of the online interactive Mock-Up is shown in Figure 32, and it is available online [89]. On the left side, there is a sidebar to move through the different sections (i.e. Time representation, Commodities, Technologies, Emissions). For example, in the demo, the user has the option to "Edit an existing commodity" or "Add a new commodity". By selecting one of the two, the user is brought to a new page where it can define the activity and capacity units, select the commodity of interest, save and go to the next step.

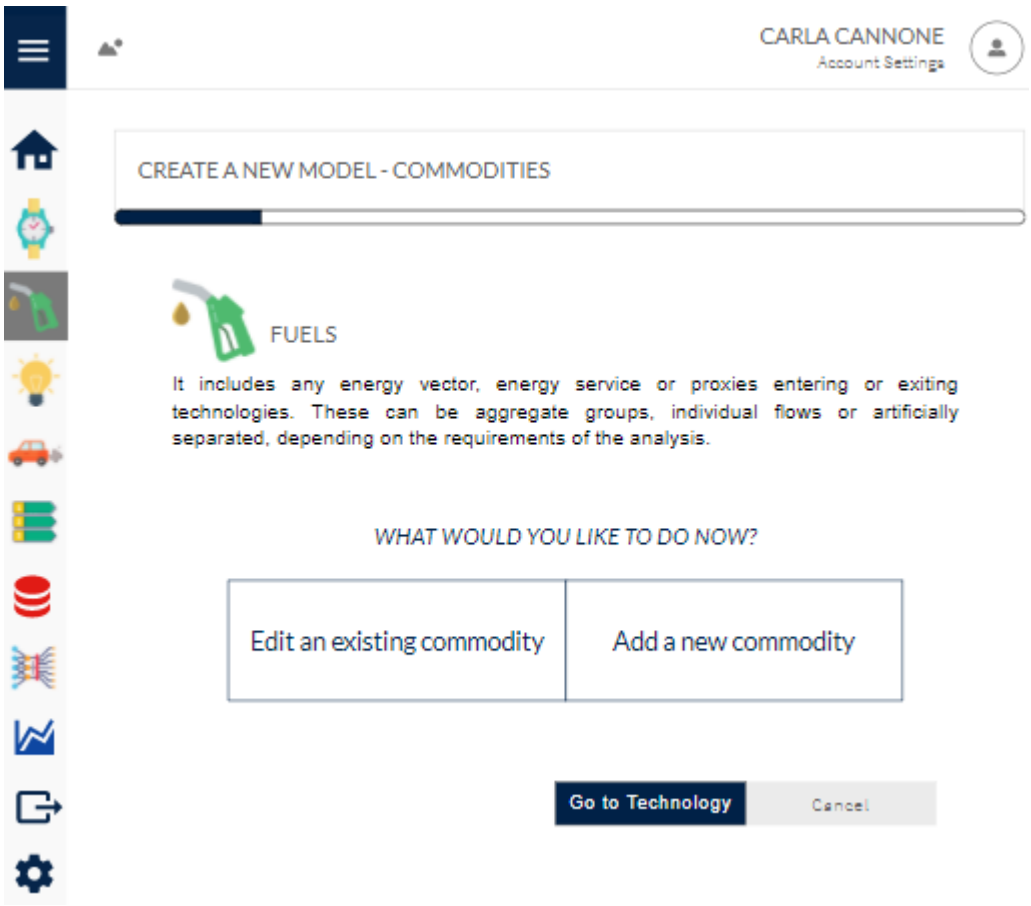


Figure 32: Preview Demo Mock-up Tool elaborated from the identified gaps of the OSeMOSYS interfaces [89].

9.1.3. Comment-response matrix

The Demo Mock-Up tool was shared with expert users of the Optimus Community of Practices, which includes OSeMOSYS users from international organization to academia. The feedback received were collected in a Comment-Response Matrix to include in CCG-SAND all these functionalities. In the right column of Table 22, it was assigned a colour proportional to the level of achievement in the newly created CCG-SAND Interface of a specific goal: achieved (green), partially (orange) and not achieved (red). This method was used for the transferability of the work, therefore allowing for future improvements of the Interface. The Comment-Response Matrix was the starting point for the development of CCG-SAND Interface, which tried to include as many features as possible of the one listed in Table 22.

Table 22: Comment-Response Matrix including the feedback to the Demo Mock-up tool and the respective response in CCG-SAND Interface

Comments on the development of a functional mock-up interface for long-term energy modelling				
Section	Feedback on the Demo Mock-up	Submitted by (Name/Organization)	Level of achievement in CCG-SAND Interface	Description of the Response in CCG- SAND Interface
Export the model	In the model page, does the 'open existing model' option also allow the user to import an existing model? I think it would be great to have the option, if possible.	Francesco Gardumi / KTH	YES	SAND Interface is based on Excel. It is possible to share the Excel workbook and work on the same model.
Naming	I would use consistently, everywhere (also on the sidebar on the left), the word 'Commodity' rather than the fuel.	Francesco Gardumi / KTH	YES	In SAND, it was consistently used the term 'Commodity' instead of

				'Fuel.'
Naming	In the 'open existing model' page, I think the 'edit model' and 'edit set data' names are not very straightforward for newcomers and students. In my experience, the students get quite confused with that naming in MoManI. I wonder whether we could change the tags to something more intuitive. E.g. 'Choose equations' and 'Edit system structure'?	Francesco Gardumi / KTH	YES	In SAND, it was created a separate sheet called 'SETS' that serves as the only place where the user can change the name of the technologies, commodities and emissions.

Inputs data	In the sheet/page where the user gives the actual inputs, I'd allow the user to give the value of a parameter for the base year and then decide whether it is going to stay constant, to increase at a specific % rate, or to give the whole time series.	Francesco Gardumi / KTH	YES	In SAND, the user can decide the data for each year and modify them.
Results visualization	Could the user change the units on the right? Also, could the user choose which scenario he/she wants to view the results for?	Francesco Gardumi / KTH	YES	SAND Interface is a blank shell, so no unit is set before. By using the "Data preparation template," the user can keep all the data in one place and adjust them according to the unit chosen.
Residual Capacity	For calculating the residual capacity, it would be neat to ask the user to insert the 'historical capacity', by giving 1) capacity and 2) year of installation in the past.	Francesco Gardumi / KTH	YES	In the 'Data preparation template' there is a section for

				the residual capacity calculation which includes the historical capacity: 1) the capacity and 2) the year of installation in the past
Time Representation	For the set 'Year', I wonder whether we could allow the user also to enter the 'Timestep', i.e. to have a model representing only every five years. It requires some modification of the OSeMOSYS code, but it is feasible.	Francesco Gardumi / KTH	NO	SAND has a fixed amount of years and a fixed time: from 2020 to 2070
Add/modify technology, fuel, emission	I wonder if “Add new” should be “Create new …” which then allows you to enter all the parameters for that technology, emission, fuel.	Will Usher / KTH	YES	In SAND, it was created a separate sheet called 'SETS' that serves as the only place where the user can change the name of the technologies, commodities and emissions. This entry point is linked to the other sheets
Export models	It might be neater to hold a list or table of all the set elements, with three buttons next to each - row - clone, edit, delete; and then have a ‘create new’ button	Will Usher / KTH	YES	In SAND, it was created a separate sheet called 'SETS' that serves as the only place where the user can change the name of the technologies, commodities and emissions. This entry point is linked to the other sheets

Data input	I do not see the point of directing users to enter data into a giant spreadsheet - I thought the whole point of the GUI was to enable an alternative way of entering data. With this in mind, is it possible to come up with a generic view on the data which works for each set element? For example: - technology: a table with one technology per row, and critical summary parameters (e.g. cost, efficiency); then a technology detail form which pops up when you click on a technology. This form contains, e.g. a sub-table for all parameters with a year index, e.g. residual capacity. Ideally, all parameters relating to that technology should be displayed with the possibility to add, edit or delete data for each of those parameters.	Will Usher / KTH	YES	In SAND, there is a giant spreadsheet called 'Parameters' where the user can add data by using filters in a very intuitive way.
Add/modify technology, fuel, emission	Standard functionality required for each set element (technology, fuel, emission) should be to - create new from scratch, copy (clone) existing (with a new name) but rest of the data identical, edit existing, delete existing)	Will Usher / KTH	PARTIALLY	In SAND, it is not possible to clone. It is instead possible to create new technology and copy past the data from the first to the second.
General	Do we need user/authentication? Will this run on a server or in the cloud? If local to users laptop/desktop, then this just adds unnecessary bulk	Will Usher / KTH	YES	SAND Interface does not require any authentications. The file will be freely available for download in GitHub as well as the 'Data preparation File.'
Timeslices	How do you edit timeslices?	Will Usher / KTH	PARTIALLY	Time slices in SAND are fixed to 96. Future work might include linking

				the names of the Time slices with the SETS sheet
Results visualization	Show headline results (primary energy, final energy, capacity, activity - electricity only, activity - all energy, objective function, capacity costs, variable and fixed costs; emissions etc.)	Will Usher / KTH	YES	In the 'ToDataFile' sheet it was added the parameter 'ResultsPath' which allows the user to add the path of his/her folder where he/she will visualize a folder of CSV results.
Results visualization	Enable comparison of these headline results between scenarios in two ways - tables or charts shown side-by-side; table or chart showing the difference between policy scenario and reference scenario	Will Usher / KTH	PARTIALLY	The comparison between different graphs is still not automatic. The user should run the model in the interface for each scenario and then manually compare the results in the form of graphs.
Results Visualization	Detailed results by technology or result parameter	Will Usher / KTH	YES	In the 'ToDataFile' sheet it was added the parameter 'ResultsPath' which allows the user to add the path of his/her folder where he/she will visualize a

				folder of CSV results.
Input Data	https://app.moqups.com/l62U1FNXad/view at the moment, I have just pasted all the input parameters onto the screens, but for me, this is the real challenge. Working out how a user can efficiently move around a model, entering data and editing different components.	Will Usher / KTH	YES	In SAND, there is a giant spreadsheet called 'Parameters' where the user can add data by using filters in a very intuitive way.
Input Data	My main question/concern after having looked at this is that I do not quite know/understand how the user enters/interacts with the data.	Thomas Alfstad / UNDESA	YES	In SAND, there is a giant spreadsheet called 'Parameters' where the user can add data by using filters in a very intuitive way.
Input Data	to have a wizard is good, but there needs to be a convenient, useful and ideally intuitive way to work with the inputs and results.	Thomas Alfstad / UNDESA	YES	In SAND, there is a giant spreadsheet called 'Parameters' where the user can add data by using filters in a very intuitive way.
Naming	in this case, the user selects from a predefined list of commodities, technologies, emissions. That limits it to users/uses at a very introductory level. I think we can have something functional for teaching beginners, without losing the flexibility/customizability needed by more advanced users.	Thomas Alfstad / UNDESA	YES	In SAND, it was created a separate sheet called 'SETS' that serves as the only place where the user can change the name of the

				technologies, commodities and emissions. This entry point is linked to the other sheets
General	Also, the process of building a model is not linear, so it cannot be presented as a sequence of steps.	Thomas Alfstad / UNDESA	YES	In CCG-SAND, the process of build up the model is not linear anymore. The user can choose his/her way of working.

9.2. Annexe B

In this section, it is presented a detailed description of CCG-SAND Interface, the functionalities available, the actions that the user need to take and instructions on each step. A description of the additional materials developed is also included. Detailed limitations and potential future work are provided at the end of this Annexe.

9.2.1. Instructions

In the first Sheet, shown in Figure 33, the user finds general instruction on how to use the Interface, which folder he/she should create, which files should be created and how to proceed with the exercise.

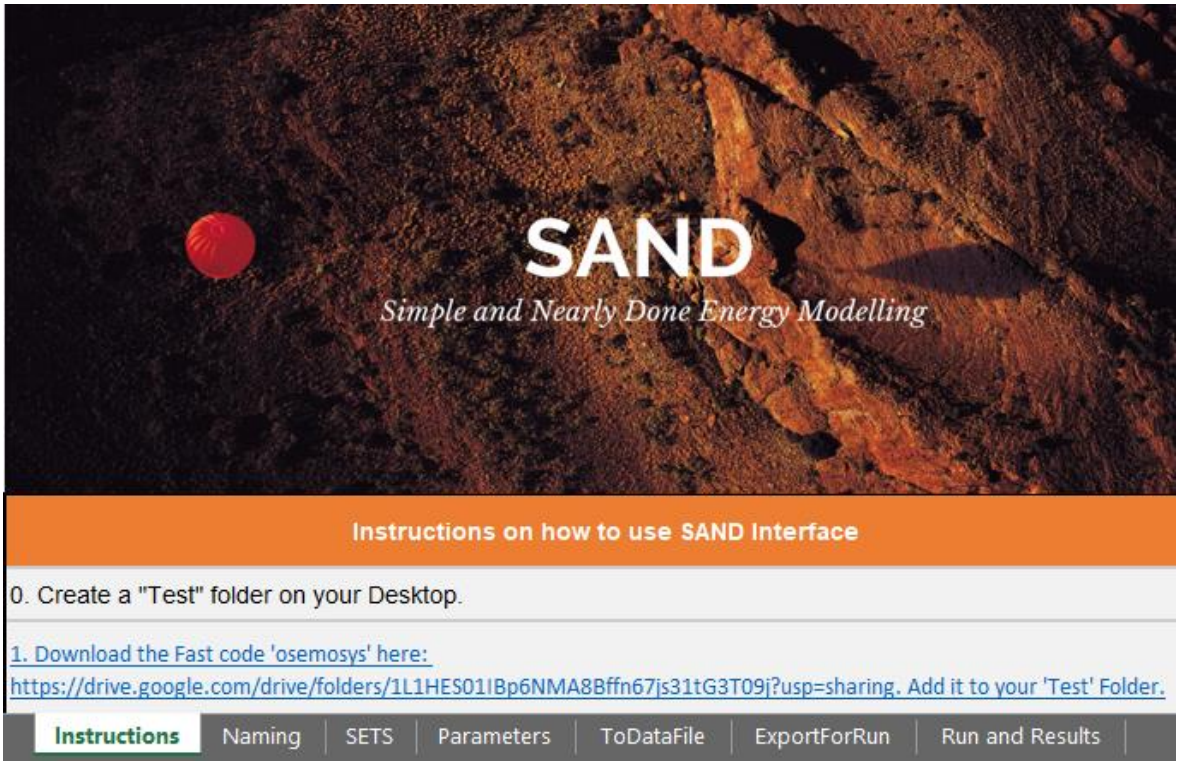


Figure 33: Instruction Page CCG-SAND Interface [46].

9.2.2. Naming

Figure 34 shows the Naming Sheet, which includes a description of all the Sets, Parameters and Variables used in OSeMOSYS. The majority of those are used in the CCG-SAND, whereas others, being, for example, intermediate variables or parameters not needed in the equations of the fast code, were neglected. This Sheet aims at helping the beginner user in creating the model, and to dive in the multitudes of definitions that might be overwhelming to learn by the earth in the first approach to this kind of exercise.

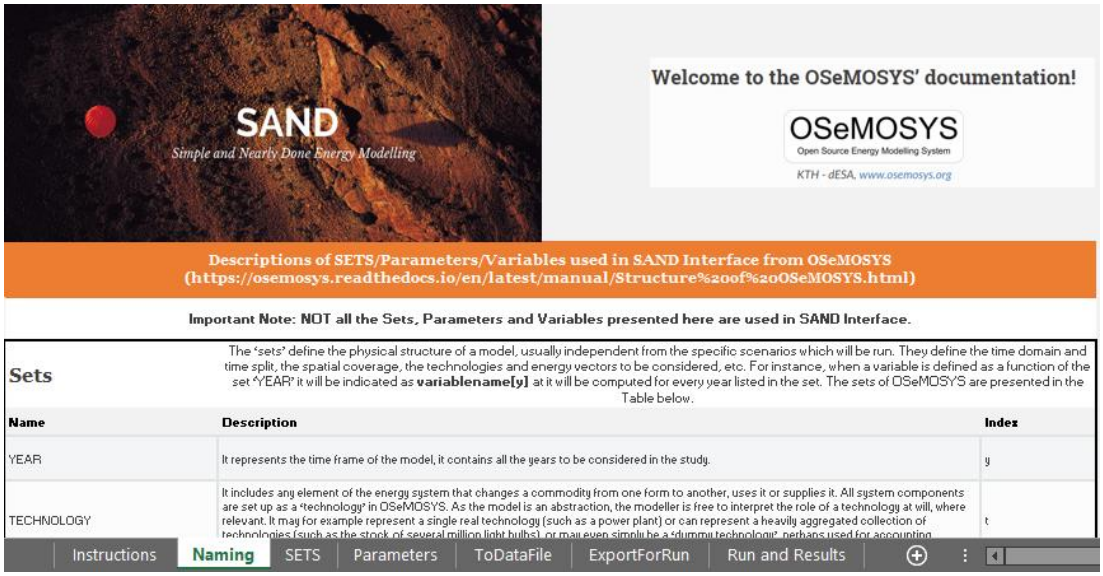


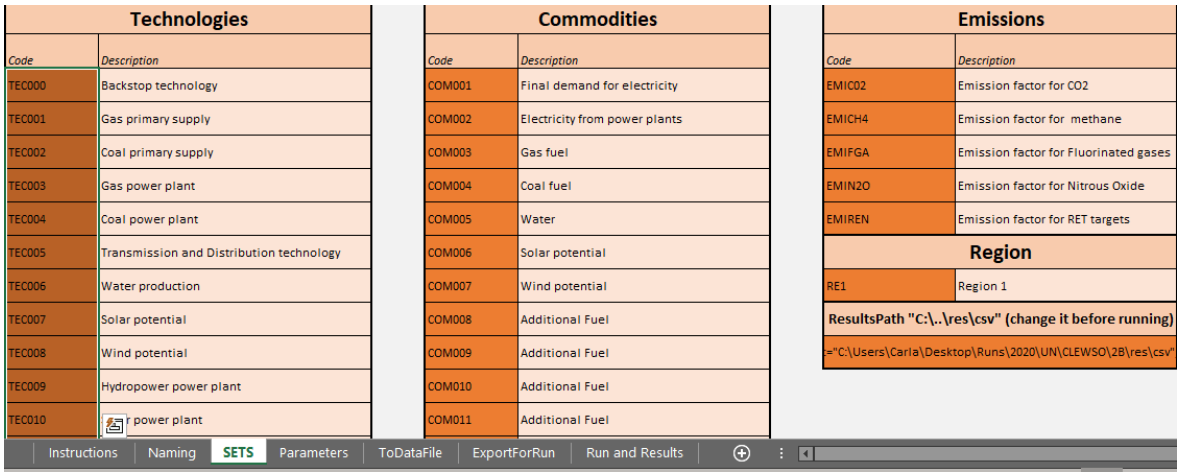
Figure 34: Naming Page CCG-SAND Interface [46].

9.2.3. Sets

SETS, Parameters and ToDataFile Sheets represents the core of the Interface, and they are entirely interconnected to each other. SETS Page, shown in Figure 35, is the space where the user can define the name of its Technologies (column B), Commodities (column E) and Emissions (column H). These three columns are linked to the "ToDataFile" Sheet that has the format needed by the solver to find the optimal solution. Therefore, whenever the user specifies the name of a Technology, Commodity or Emission in these columns, it is automatically reported in the respective cell in the ToDataFile Sheet. The user has the freedom to change names as many time as necessary without losing the data previously added for that specific entry. This represents a significant improvement in the user experience compared to MoManI, where the user had to lose data when changing the name of an entry.

Column C, F, I allow the user to add a description of each entry. The naming convention of reference is available on the Google Drive folder [88], together with the conventional description to be used. For the moment, it is useful to mention that the "Description" is the

name printed later in the Graphs. Detailed information about the result visualization phase are given in 9.2.7 and 9.2.10.



Technologies	
Code	Description
TEC000	Backstop technology
TEC001	Gas primary supply
TEC002	Coal primary supply
TEC003	Gas power plant
TEC004	Coal power plant
TEC005	Transmission and Distribution technology
TEC006	Water production
TEC007	Solar potential
TEC008	Wind potential
TEC009	Hydropower power plant
TEC010	r power plant

Commodities	
Code	Description
COM001	Final demand for electricity
COM002	Electricity from power plants
COM003	Gas fuel
COM004	Coal fuel
COM005	Water
COM006	Solar potential
COM007	Wind potential
COM008	Additional Fuel
COM009	Additional Fuel
COM010	Additional Fuel
COM011	Additional Fuel

Emissions	
Code	Description
EMIC02	Emission factor for CO2
EMICH4	Emission factor for methane
EMIFGA	Emission factor for Fluorinated gases
EMIN2O	Emission factor for Nitrous Oxide
EMIREN	Emission factor for RET targets
Region	
RE1	Region 1
ResultsPath "C:\..\res\csv" (change it before running)	
="C:\Users\Carla\Desktop\Runs\2020\UN\CLEWSO\2B\res\csv"	

Figure 35: Sets Page CCG-SAND Interface [46].

9.2.4. Parameters

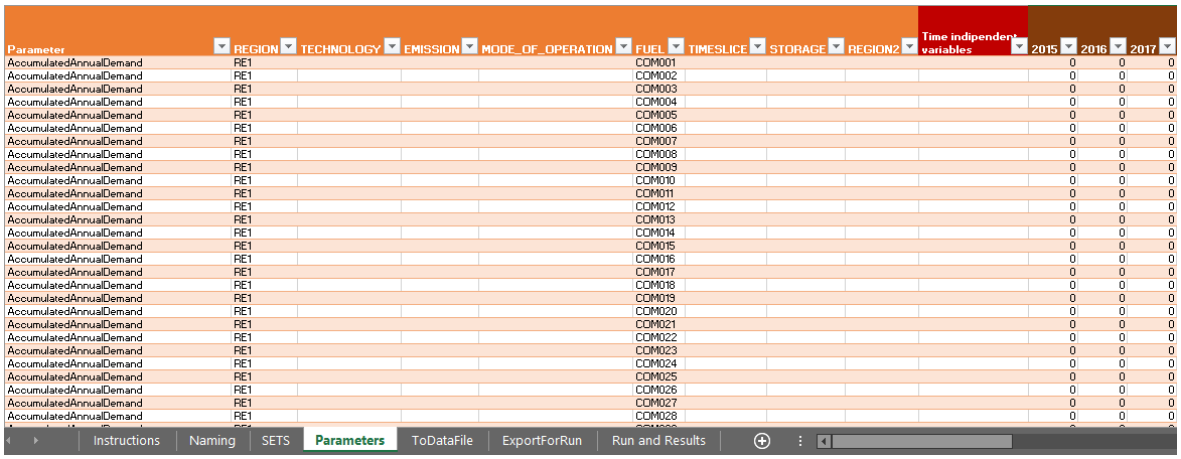
SETS and Parameters are the Sheets were the user can input data. Indeed, after downloading the OSeMOSYS fast code and CCG-SAND Interface, the user is asked to input the data in the Interface, by mean of the "Parameters" Sheet. To do so, a "Data Manipulation Template" was developed, which simplifies and standardize the data collection process. More information on this additional material is provided in 9.2.9. It is worth mentioning that this template constitutes a complementary material, not needful for CCG-SAND Interface to operate, but helpful for a beginner user to keep track of the data.

The "Parameters" page is a giant sheet of 48757 rows, which includes the entry points for each OSeMOSYS Parameter for each of the 200 Technologies that the Interface can include, each of these that can operate with 50 different fuels and emit five types of emission. The modelling period is set to 55 years, from 2015 to 2070. Each year is divided into 96 equal time slices, for a better representation of an hourly profile and therefore potentially enabling a future faster storage implementation. The main feature of this Sheet is that the user can input data by using Excel filters in each of the columns of the page. For example, by filtering out the parameter Year Split in Column A, the user can input data for each of the Timeslices, that represents 1 hour. Therefore, CCG-SAND Interface allows for replicating up to 24 hours for each of the four seasons in each of the modelling years, as all days in one season are assumed to be identical. More information of the time representation in CCG-SAND Interface is given in 9.3.

To give another example: all demands flows need to be added as Commodities in the SETS Sheet. As for OSeMOSYS, they can either be added using the parameter AccumulatedAnnualDemand or SpecifiedAnnualDemand. The first is used when the demand

does not follow a daily load curve, and it is not time-dependent, i.e. yearly demand for biomass energy. The second is instead employed when the demand varies across the day, i.e. electricity. The OSeMOSYS parameter SpecifiedDemandProfile is defined for the latter scope.

More information on OSeMOSYS parameters and on how to build an energy model are available on the web page of OSeMOSYS [36].



Parameter	REGION	TECHNOLOGY	EMISSION	MODE_OF_OPERATION	FUEL	TIMESLICE	STORAGE	REGION2	Time indipendent variables	2015	2016	2017
AccumulatedAnnualDemand	RE1				COM001					0	0	0
AccumulatedAnnualDemand	RE1				COM002					0	0	0
AccumulatedAnnualDemand	RE1				COM003					0	0	0
AccumulatedAnnualDemand	RE1				COM004					0	0	0
AccumulatedAnnualDemand	RE1				COM005					0	0	0
AccumulatedAnnualDemand	RE1				COM006					0	0	0
AccumulatedAnnualDemand	RE1				COM007					0	0	0
AccumulatedAnnualDemand	RE1				COM008					0	0	0
AccumulatedAnnualDemand	RE1				COM009					0	0	0
AccumulatedAnnualDemand	RE1				COM010					0	0	0
AccumulatedAnnualDemand	RE1				COM011					0	0	0
AccumulatedAnnualDemand	RE1				COM012					0	0	0
AccumulatedAnnualDemand	RE1				COM013					0	0	0
AccumulatedAnnualDemand	RE1				COM014					0	0	0
AccumulatedAnnualDemand	RE1				COM015					0	0	0
AccumulatedAnnualDemand	RE1				COM016					0	0	0
AccumulatedAnnualDemand	RE1				COM017					0	0	0
AccumulatedAnnualDemand	RE1				COM018					0	0	0
AccumulatedAnnualDemand	RE1				COM019					0	0	0
AccumulatedAnnualDemand	RE1				COM020					0	0	0
AccumulatedAnnualDemand	RE1				COM021					0	0	0
AccumulatedAnnualDemand	RE1				COM022					0	0	0
AccumulatedAnnualDemand	RE1				COM023					0	0	0
AccumulatedAnnualDemand	RE1				COM024					0	0	0
AccumulatedAnnualDemand	RE1				COM025					0	0	0
AccumulatedAnnualDemand	RE1				COM026					0	0	0
AccumulatedAnnualDemand	RE1				COM027					0	0	0
AccumulatedAnnualDemand	RE1				COM028					0	0	0

Figure 36: Parameters Page CCG-SAND Interface [46].

9.2.5. To Data File

Thanks to how CCG-SAND Interface was developed, when the user input data in the "Parameters" Sheet it is automatically shown in the respective cell in "ToDataFile" Sheet. As shown in Figure 37, this page has the format needed by the solver to read the data and calculate the objective function. As highlighted in yellow, all the names in "ToDataFile" are read from the "SETS" Sheet. The user can change those as many time as needed but only from the "SETS" Sheet, as explained previously.

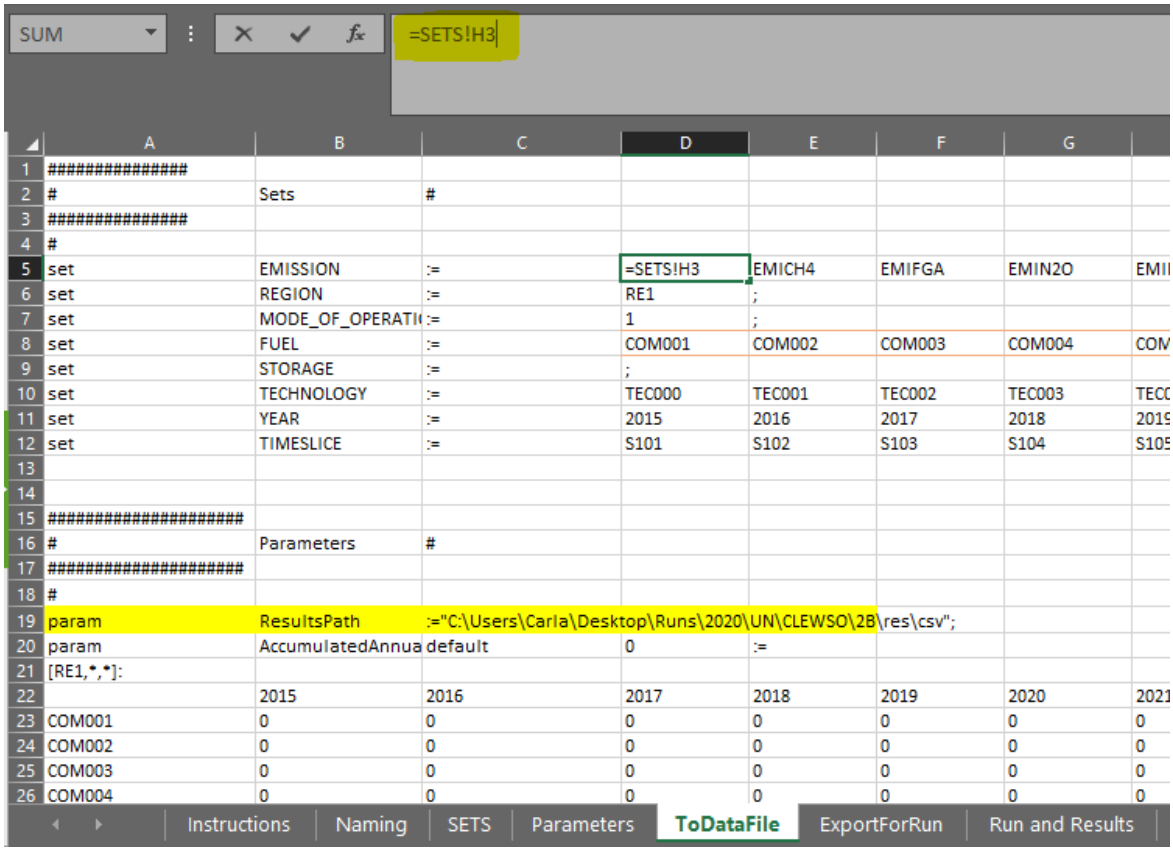


Figure 37: ToDataFile Preview Page [46].

9.2.6. Export for Run

In this Sheet, as shown in Figure 38, there is an instruction to proceed to the run of the model. Therefore, when the user has inserted all the data needed, it is required to copy-paste the entire "ToDataFile" Sheet in a new Data File (i.e. Notepad) which has the .txt format. The "Data File.txt" and the "Fast code.txt", is read by the GLPK solver. As highlighted in yellow, the "ResultPath" parameter was added in this Sheet. It is linked to the cell H11 in SETS sheet, that is the only place where the user needs to define the path of the result folder where he/she wants to save the results obtained from the computational effort, i.e. ResultsPath:= "file/path/to/my/results".

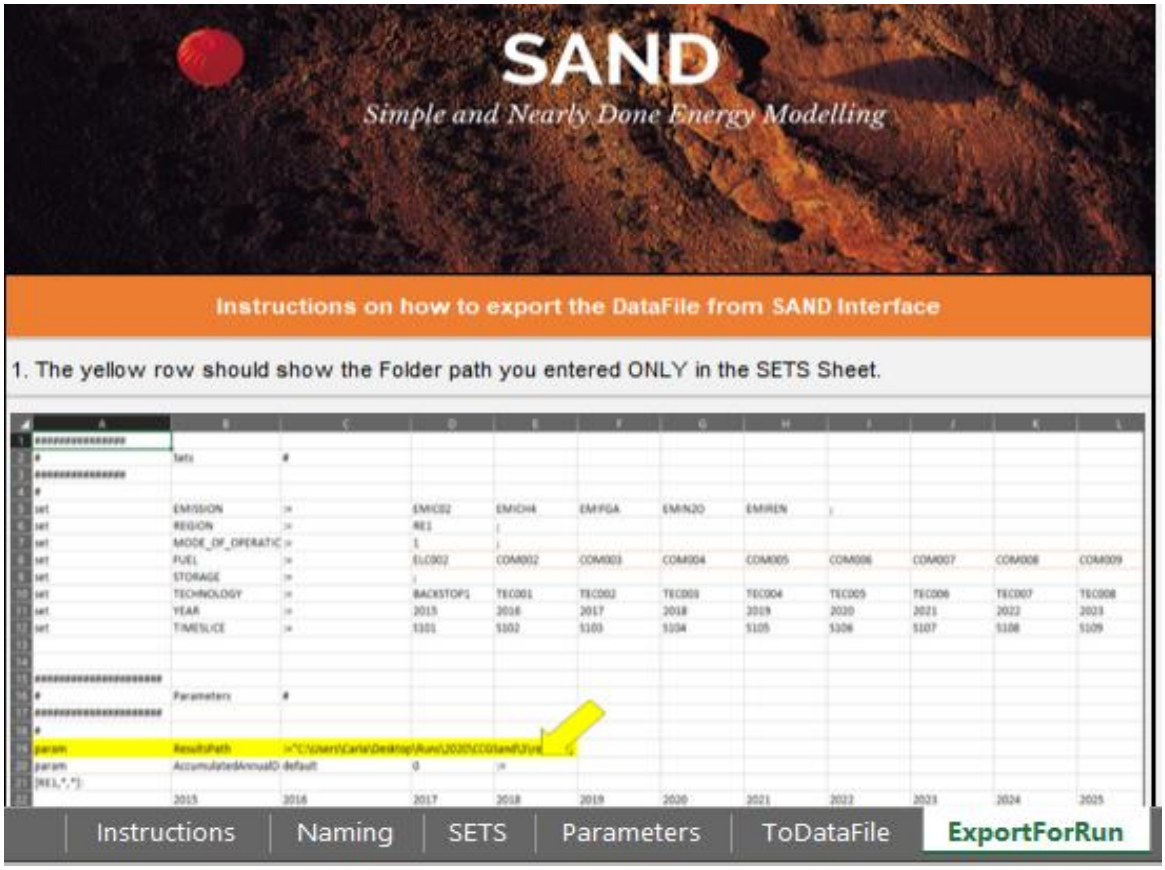


Figure 38: Preview of ExportForRun Sheet [46].

9.2.7. Run and results

The results generated from the GLPK solver are a .txt file where it is possible to read the total discounted cost and a folder of .csv files per each of the variables specified in the code. Figure 39 shows a preview of the instructions available in CCG-SAND Interface to complete the run and visualize the results.

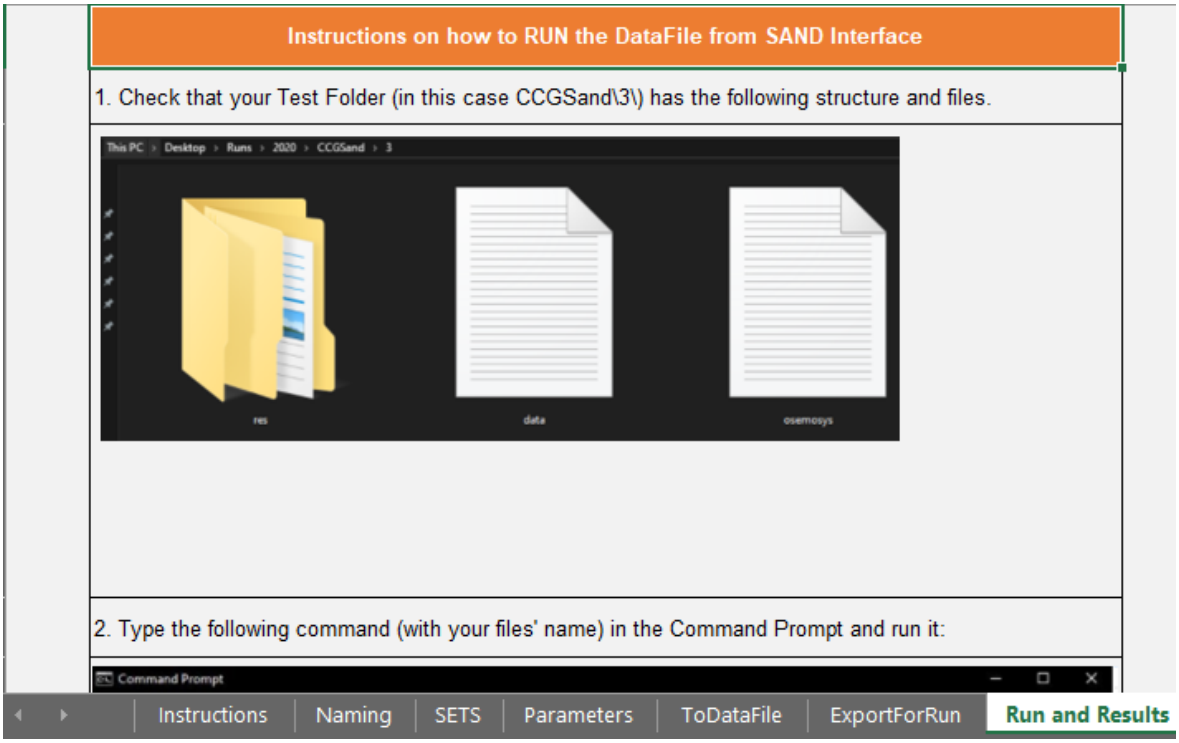


Figure 39: Preview CCG-SAND how to run it [46].

9.2.8. Complementary materials

In this Section, it is described the complementary materials developed to reduce the learning curve of the CCG-SAND Interface, one for the data collection phase and the other for the visualization of results.

9.2.9. Data preparation template

As already mentioned in 2.3, a “Data Preparation Template” was developed to standardize the data collection phase and help to manipulate the values before adding them in CCG-SAND. A Sheet per each Technology is created, and it is then linked to the main page called “Raw Data”.

For example, using this template, it is possible to calculate the Residual Capacity, or in other words the remained capacity available from before the modelling period, that depends on Construction Time, Overnight Cost and Discount rate. A preview of this template is shown in Figure 40.

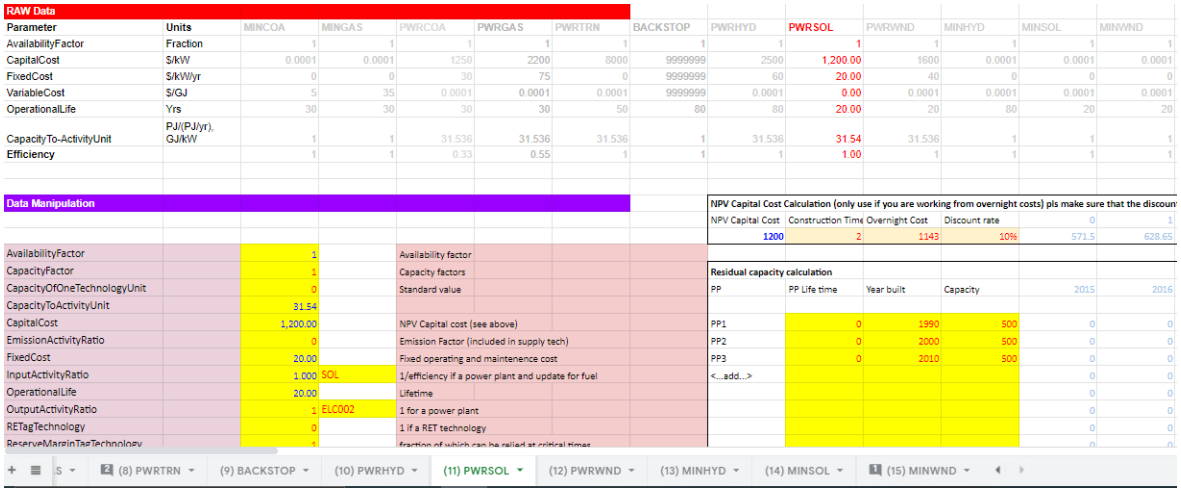


Figure 40: Preview Data preparation template CCG-SAND Interface [47].

9.2.10. Results visualization

A 'Results Viewer Template' was created to visualize the CSV results in the form of graphs, and it is available for download at this link. A preview is shown in Figure 41, whereas detailed instruction on how to use this template is available in the online file. The user needs to copy-paste the CSV result of interest (i.e. ProductionByTechnologyAnnual) in the respective Sheet. Moreover, it is necessary to copy-paste also Column B and Column C of the SETS Sheet, to let the template understand which technologies have been included in that specific model and to print the names (Description) of each of them in the Graphs. The 'Results Viewer Template' offers the possibility to generate the following graphs:

a) ProductionByTechnology: Production of fuel f by technology t in time slice l.

b) TotalCapacityAnnual: Total existing capacity of technology t in year y (sum of cumulative newly installed and pre-existing capacity).

c) AnnualFixedOperatingCost: Annual fixed operating cost of technology t. Derived from the TotalCapacityAnnual and the parameter FixedCost.

d) AnnualVariableOperatingCost: Annual variable operating cost of technology t. It is derived from the TotalAnnualTechnologyActivityByMode and the parameter VariableCost.

e) CapitalInvestment: Undiscounted investment in a new capacity of technology t. It is a function of the NewCapacity and the parameter CapitalCost. | Monetary units

f) TotalDiscountedCost: Sum of the TotalDiscountedCostByTechnology over all the technologies.

g) ProductionByTechnologyAnnual: Annual production of fuel f by technology t.

Moreover, it was added to the features of showing the total demand in the graph as a line. Operating technology always tries to supply this demand.

With CCG-SAND Interface, as previously with MoManI, the user can run different scenarios and compare the results, with the final goal of informing policymakers in the development of energy strategies and support them with capacity building activities. In contrast to MoManI, however, CCG-SAND interface offers a much intuitive experience for the user, and it is easier to learn to approach the energy modelling exercise for the first time.

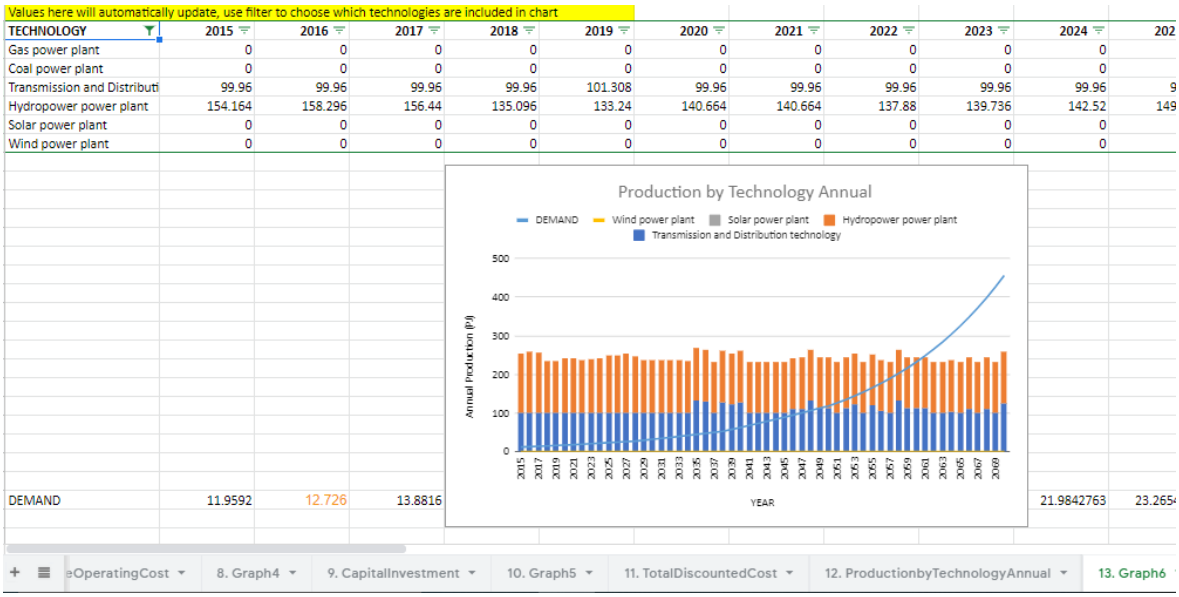


Figure 41: Preview of the Results Viewer template [47].

9.2.11. Detailed future work and improvements

As mentioned before in this chapter, in CCG-SAND, the user can freely modify as many times as needed the name of each Technology, Commodity and Emission and their descriptions in the SETS Sheet. However, in this first version, it is not possible to change the following items:

a) the name of the Timeslices which go from S101, …, S124 to S401, …, S424;

b) the name of the years, from 2015 until 2070;

Indeed, for time constraints reasons, the names of these entries were not linked to the SETS Sheet; thus, the user cannot automatically modify their names. Future improvements of CCG-SAND Interface could aim at completing the linking process to offer a completely flexible tool to the user. Furthermore, it is also set to a specific number:

c) the number of timeslices: which are 96. However, as explained in Chapter 6, the user is free to use as many Timeslices as needed ensuring that the sum of the values entered for the Timeslices using the Year Split parameters sum up to 1;

d) the number of years that in CCG-SAND is 55. Again, if the user needs to model a shorter time, he/she does not need to fill in all the data until 2070. The model reads only the available data, i.e. if the modelling time is from 2015 until 2050, the user inputs the data only until the correspondent column “The Year 2050”.

Another limitation of the current version of CCG-SAND Interface is the lack of the OSeMOSYS parameters linked to the Storage technologies. They were deliberately not included during the development of the Interface as the Storage equations in the OSeMOSYS code are planned to be changed soon. To overcome this deficiency, it was studied a set of assumptions to represent a storage technology that includes, among other ideas:

a) add a fictitious technology which operates as storage (i.e. for solar panels, this technology produces electricity during the night when the sun is not shining). By mean of the 96 hourly timeslices and employing the CapacityFactor OSeMOSYS parameter, the user can specify in which hour of that representative day of the year technology is operating or not;

b) account for the storage introduction with higher costs (capital, fixed, variable) both of the power plant (i.e. solar panel with storage) and of the transmission and distribution lines that have to cope with the storage technologies penetration and be adequately planned.

Future work includes testing these different options and finds the optimal solution to represent storage technologies in the energy system.

9.3. Annexe C

Annexe C includes the specific assumptions taken to validate CCG-SAND Interface with Tier 1 and Tier 2 Models.

9.3.1. Year Split

Firstly, the year was divided into four representative periods, namely Timeslices: Summer Day (SD), Summer Night (SN), Winter Day (WD) and Winter Night (WN). Then, with the parameter YearSplit, it was assigned the duration of each timeslice. For example, there are Summer Day (SD) conditions for 44% of the time in a year, Summer Night (SN) conditions for 22%. The sum of the values assigned to YearSplit in each Year should always sum up to 1, being equal to the entire year.

In addition to the YearSplit, it is essential to define the Specified Demand profile (for example of electricity ELC002). Therefore, a value of demand should be assigned to each Timeslices as done before, to account for periods of higher or lower demand. As shown in Table 23, in Winter Night (WN), there is the highest demand of 42% of the annual total whereas, during SummerNight, the electricity demand is only 8%.

Table 23: Specified demand profile for electricity.

RAW Data				
	Year Split		**Specified demand profile for electricity**	
	TimeSlice	value	TimeSlice	ELC002
	SD	0.4457	SD	0.32
	SN	0.2228	SN	0.08
	WD	0.1657	WD	0.18
	WN	0.1657	WN	0.42
Total	Year	1	Year	1

9.3.2. Data manipulation

The data presented in Table 23 were manipulated to exploit the full potential of CCG-SAND Interface. In the tool, there are by default 96 Timeslices, meaning that each year is divided into 96 periods instead of the previous 4. It was assumed an equal season length of 3 months each and an average hourly split per season (24h representative). Therefore obtaining:

4 Seasons/year * 24h of a representative day = 96 Timeslices/Year

This assumption leads to the YearSplit results in case of 96 Timeslices as reported in Table Y. Each Timeslice is a fraction of the Year in the following way:

1 Year / 96 Timeslices = 0.0104

As explained previously, the electricity demand is not constant during the different periods of the year. It is crucial also, in this case, to define the SpecifiedDemandProfile. To do so, it was employed the following methodology:

1) It was calculated how many hours there are in each TimeSlices using the raw data in Table 23, i.e. for a Summer Day (SD):

0.4457/ (0.4457 + 0.2228) = 33%

Which on 24 hours Summer Day is equal to:

0.33 * 24 = 8 hours

Therefore, a Summer Night has a duration of 8 hours. The same procedure can be repeated for the other periods of the year obtaining the following Table 24:

Table 24: Timeslice Lenght in Hours

Timeslice Length in Hours				
	33%	or	8.0	hrs are on a summer night (SN)
	50%	or	12.0	hrs are on a winter night (WN)
	50%	or	12.0	hrs are on a winter day (WD)
	67%	or	16.0	hrs are in summer day (SD)

2) It was calculated the percentage of average demand in each Timeslice, i.e. in a Summer Day (SD):

Specified demand profile for electricity in SD / YearSplit in SD =

= 0.32 / (0.4457*Bennett Factor) = 0.80 = 80%

Bennett Factor is a parameter used to be sure that the sum of the SpecifiedDemandProfile is always 1. Repeating the same procedure for the other Timeslices, it was obtained the following Table 25:

Table 25: Percentage of average demand in each timeslice

Timeslice	% of average demand in each timeslice	
SD	80%	
SN	40%	
WD	121%	
WN	281%	
Bennett Factor		1.1094

3) The Specified Demand Profile was calculated as follows, and for clarity, are provided two examples:

a) Winter Night (WN):

YearSplit for WN * % of the average demand in WN =

= 0.0104 * 2.81 = 0.0293

And

b) Summer Day (SD):

YearSplit for SD * % of the average demand in SD =

= 0.0104 * 0.8 = 0.0083

4) Lastly, as shown in Table 23, the percentage of days in a year that can be defined as Summer Day (SD) or Summer Night (SN) together account for almost 67% of the entire year.

Therefore, it was assumed that 3 of the representative days (S2, S3 and S4) would be Summer and S1 is Winter.

In Table 26, are presented all the data used for the YearSplit and the SpecifiedDemandProfile parameters. It is worth mentioning that the user can modify the assumptions above depending on a specific case-study of interest. Moreover, using CCG-SAND Interface does not imply that the user is required to manipulate the data from 4 to 96 Timeslices. He/she can also use the first 4 Timeslices available carefully checking that the input values sum up to 1 both for the YearSplit and for the SpecifiedDemandProfile. Here it was offered an example of one way to exploit the 96 Timeslices available in CCG-SAND fully.

Table 26: Yeat Split and Specified Demand Profile for 96 Timeslices

Data Manipulation			
		Year Split	**Specified Demand Profile**
WN	S101	0.0104	0.0293
WN	S102	0.0104	0.0293
WN	S103	0.0104	0.0293
WN	S104	0.0104	0.0293
WN	S105	0.0104	0.0293
WN	S106	0.0104	0.0293
WD	S107	0.0104	**0.0126**
WD	S108	0.0104	**0.0126**
WD	S109	0.0104	**0.0126**
WD	S110	0.0104	**0.0126**
WD	S111	0.0104	**0.0126**
WD	S112	0.0104	**0.0126**
WD	S113	0.0104	**0.0126**
WD	S114	0.0104	**0.0126**
WD	S115	0.0104	**0.0126**

WD	S116	0.0104	**0.0126**
WD	S117	0.0104	**0.0126**
WD	S118	0.0104	**0.0126**
WN	S119	0.0104	0.0293
WN	S120	0.0104	0.0293
WN	S121	0.0104	0.0293
WN	S122	0.0104	0.0293
WN	S123	0.0104	0.0293
WN	S124	0.0104	0.0293
SN	S201	0.0104	0.0041
SN	S202	0.0104	0.0041
SN	S203	0.0104	0.0041
SN	S204	0.0104	0.0041
SD	S205	0.0104	**0.0083**
SD	S206	0.0104	**0.0083**
SD	S207	0.0104	**0.0083**
SD	S208	0.0104	**0.0083**
SD	S209	0.0104	**0.0083**
SD	S210	0.0104	**0.0083**
SD	S211	0.0104	**0.0083**
SD	S212	0.0104	**0.0083**
SD	S213	0.0104	**0.0083**
SD	S214	0.0104	**0.0083**
SD	S215	0.0104	**0.0083**
SD	S216	0.0104	**0.0083**
SD	S217	0.0104	**0.0083**

SD	S218	0.0104	**0.0083**
SD	S219	0.0104	**0.0083**
SD	S220	0.0104	**0.0083**
SN	S221	0.0104	0.0041
SN	S222	0.0104	0.0041
SN	S223	0.0104	0.0041
SN	S224	0.0104	0.0041
SN	S301	0.0104	0.0041
SN	S302	0.0104	0.0041
SN	S303	0.0104	0.0041
SN	S304	0.0104	0.0041
SD	S305	0.0104	**0.0083**
SD	S306	0.0104	**0.0083**
SD	S307	0.0104	**0.0083**
SD	S308	0.0104	**0.0083**
SD	S309	0.0104	**0.0083**
SD	S310	0.0104	**0.0083**
SD	S311	0.0104	**0.0083**
SD	S312	0.0104	**0.0083**
SD	S313	0.0104	**0.0083**
SD	S314	0.0104	**0.0083**
SD	S315	0.0104	**0.0083**
SD	S316	0.0104	**0.0083**
SD	S317	0.0104	**0.0083**
SD	S318	0.0104	**0.0083**
SD	S319	0.0104	**0.0083**

SD	S320	0.0104	**0.0083**
SN	S321	0.0104	0.0041
SN	S322	0.0104	0.0041
SN	S323	0.0104	0.0041
SN	S324	0.0104	0.0041
SN	S401	0.0104	0.0041
SN	S402	0.0104	0.0041
SN	S403	0.0104	0.0041
SN	S404	0.0104	0.0041
SD	S405	0.0104	**0.0083**
SD	S406	0.0104	**0.0083**
SD	S407	0.0104	**0.0083**
SD	S408	0.0104	**0.0083**
SD	S409	0.0104	**0.0083**
SD	S410	0.0104	**0.0083**
SD	S411	0.0104	**0.0083**
SD	S412	0.0104	**0.0083**
SD	S413	0.0104	**0.0083**
SD	S414	0.0104	**0.0083**
SD	S415	0.0104	**0.0083**
SD	S416	0.0104	**0.0083**
SD	S417	0.0104	**0.0083**
SD	S418	0.0104	**0.0083**
SD	S419	0.0104	**0.0083**
SD	S420	0.0104	**0.0083**
SN	S421	0.0104	0.0041

SN	S422	0.0104	0.0041
SN	S423	0.0104	0.0041
SN	S424	0.0104	0.0041