



Introduction to CLEWs

Hands-on lecture 3: Creating a simple energy model with OSeMOSYS

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V1.3.0

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Tags: CLEWs; Climate; Land; Energy; Water; Systems Modelling; Integrated; Policy Coherence; Energy system model; Reference Energy System; Model run; Hands-on; Climate Compatible Growth; Open Source; Teaching Kit;

Useful links:

- 1) [Discussion forum](#) for CLEWs
- 2) [Results from this Hands-on](#)

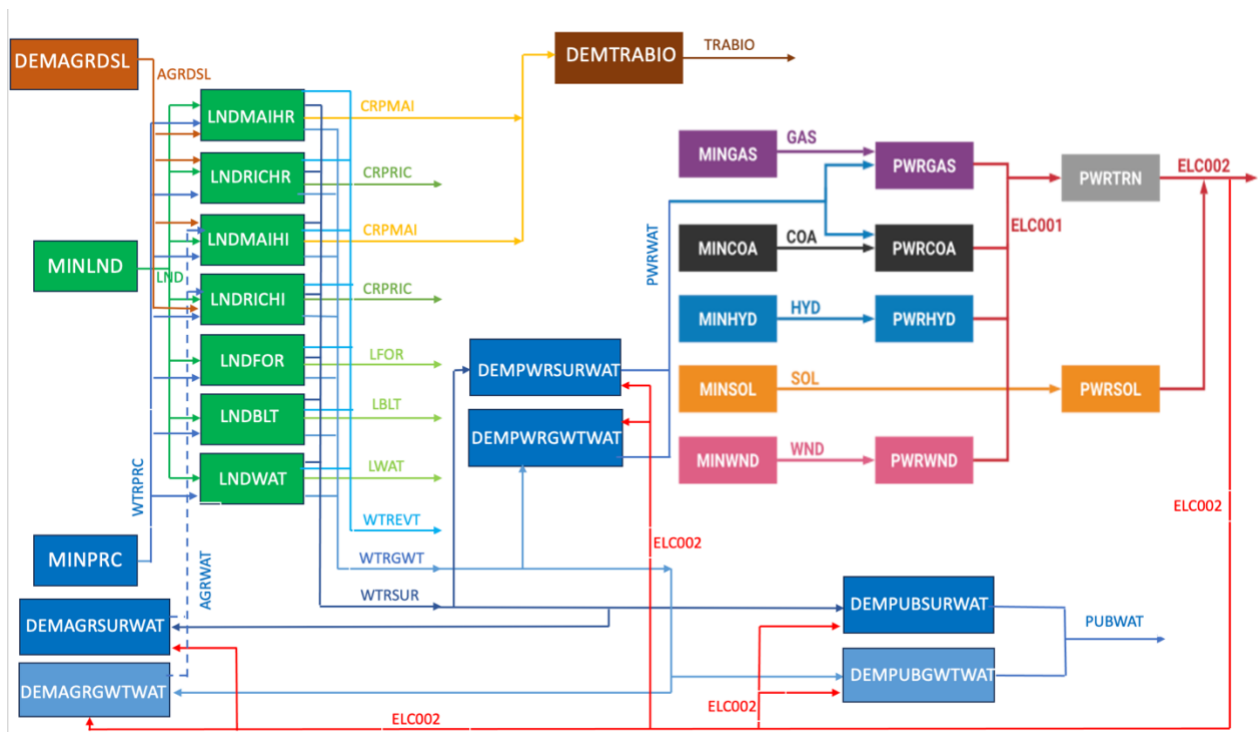
Learning outcomes

By the end of this exercise you will be able to:

- 1) Create a simple energy supply-demand chain
- 2) Understand and use key numerical data for the technologies and commodities
- 3) Run a simple model and analyse the results

Overview

The figure below gives an overview of the CLEWs model you will create by the end of all the hands-on sessions. You will build it little by little starting with this Hands-on session. The figure shows a Reference CLEWs Diagram (RCD). As discussed in the lecture material, the boxes represent technologies, processes or physical assets. The lines represent flows of commodities.





The names of the technologies and commodities follow a specific naming convention that **you will have to maintain throughout the exercise**, otherwise you will not be able to visualize the results of your exercises!

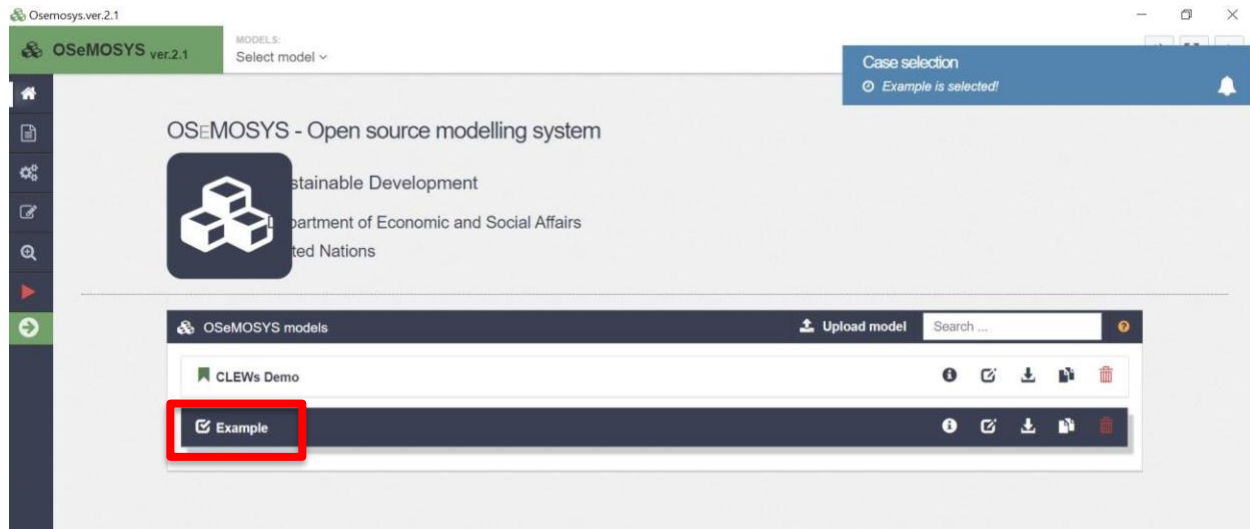
The summary of the naming convention is given in the table below. You do not have to memorise it, you will be gradually introduced to it with every hands-on session. However, you can always come back to this table if you are uncertain. It includes all technologies and commodities that you will encounter through all hands-on sessions.

Name	Description
<i>Technologies</i>	
MINLND	Land resource
LNDMAIHR	Land representing rainfed maize cultivation
LNDRIHR	Land representing rainfed rice cultivation
LNDMAIHI	Land representing irrigated maize cultivation
LNDRIHI	Land representing irrigated rice cultivation
LNDFOR	Land representing forests
LNDBLT	Land representing built-up land
LNDWAT	Land representing water bodies
MINPRC	Precipitation water resource
MINGAS	Gas extraction
MINCOA	Coal extraction
MINHYD	Hydro resource for power
MINSOL	Solar resource for power
MINWND	Wind resource for power
PWRGAS	Gas power plant
PWRCOA	Coal power plant
PWRHYD	Hydro power plant
PWRSOL	Rooftop solar photovoltaic
PWRWND	Wind turbines
PWRTRN	Transmission and distribution network
DEMAGRDSL	Diesel used in the agriculture sector
DEMAGRSURWAT	Surface water supply for agriculture
DEMAGRGWTWAT	Ground water supply for agriculture
DEMPWRSURWAT	Surface water supply for power plants

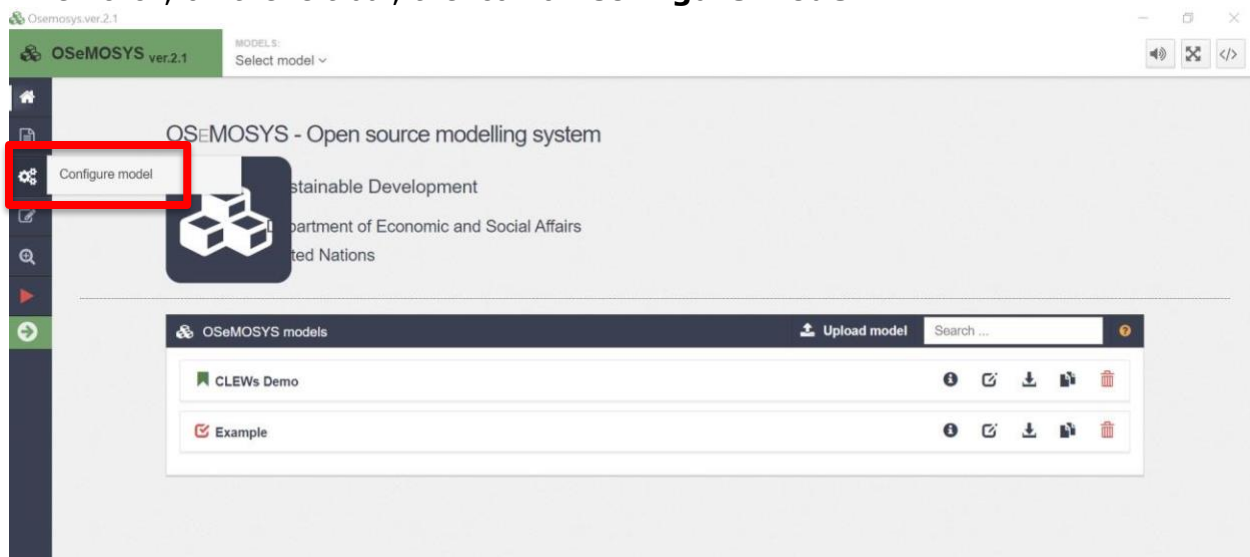
DEMPWRGWTWAT	Ground water supply for power plants
DEMPUBSURWAT	Surface water supply for public use
DEMPUBGWTWAT	Ground water supply for public use
DEMTRABIO	Biofuel for transport
Commodities	
LND	Land
CRPMAI	Maize
CRPRIC	Rice
WTRPRC	Precipitation water
AGRWAT	Agricultural water
WTREVT	Evapotranspired water
WTRGWT	Ground water
WTRSUR	Surface water
PWRWAT	Water for power plants
PUBWAT	Public water
GAS	Natural gas
COA	Coal
HYD	Hydro
SOL	Solar
WND	Wind
ELC001	Electricity fed to transmission and distribution network
ELC002	Electricity for final uses
AGRDSL	Diesel used in the agriculture sector
LFOR	Land representing forests
LBLT	Land representing built-up land
LWAT	Land representing water bodies
TRABIO	Biofuel for transport

Activity 1 – Introduce new technologies and commodities

The starting point for this activity is to open the model you created in Hands on lecture 1. To do this, when you open the interface (if you do not remember how, please go back to Hands on lecture 1) and select the case you created in the previous hands on (in our case called 'Example').



Then click, on the left bar, the icon of '**Configure model**'.



In the previous exercise you had already named the model, inserted a brief description and set the time domain (2019-2022).

In this exercise, you will go on by creating the first small part of the RCD shown in the figure above. The part you create is one part of the electricity supply chain and it includes a demand, the transmission and distribution network, two types of power

plants and the primary supply of fuels for those power plants. This is shown in the figure below. In the coming exercises you will add more pieces to this.



To create the above, you will add technologies and commodities to the SETs of your model and assign the first numerical parameters for each of them.

Add 4 commodities:

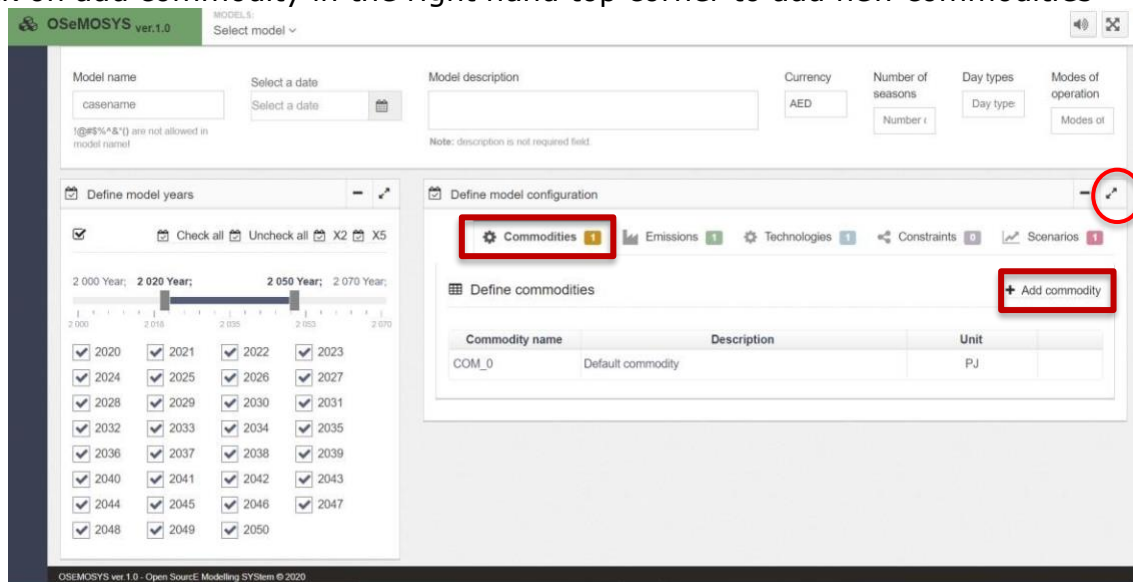
- **GAS** (Natural gas)
- **COA** (Coal)
- **ELC001** (Electricity fed to the transmission and distribution network)
- **ELC002** (Final electricity, delivered by the transmission and distribution network)

For creating technologies and commodities, in the OSeMOSYS UI window:

Click on the tab '**Commodities**' in the '**Define model configuration**' Tab. You can expand the technology window by clicking on the expand button on the left top corner in the define model configuration tab

There will be a default commodity defined. You can rename it as needed.

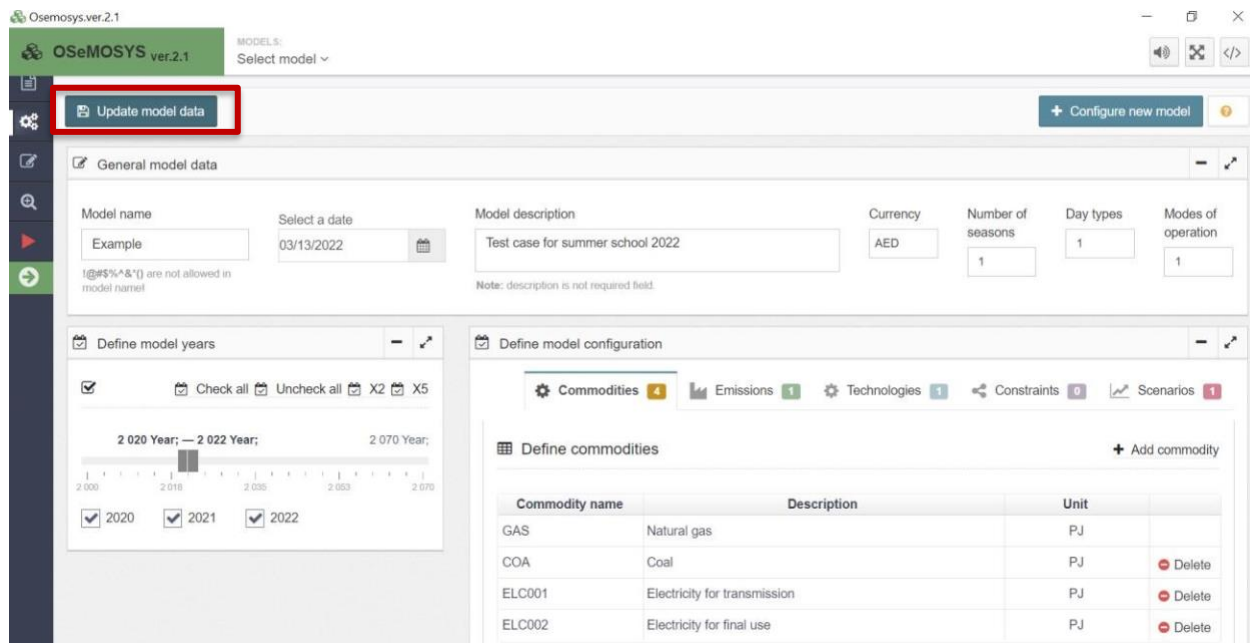
Click on add commodity in the right hand top corner to add new commodities



1. You will have to add 4 commodities (exactly as indicated above, with no spaces in the name, nor special characters – any deviation from the names indicated

above may make the model crash and/or prevent you from visualizing results later on):

- **GAS** (Natural gas)
 - **COA** (Coal)
 - **ELC001** (Electricity fed to the transmission and distribution network)
 - **ELC002** (Final electricity, delivered by the transmission and distribution network)
2. For all the commodities, the unit can be entered as PJ (this means that the energy flows of these commodities will be measured in PJ)
 3. Click on '**Update model data**' on the top left of the configure model tab.
(always do it, at the end of any step, with any element you modify!)



Commodity name	Description	Unit	
GAS	Natural gas	PJ	
COA	Coal	PJ	Delete
ELC001	Electricity for transmission	PJ	Delete
ELC002	Electricity for final use	PJ	Delete

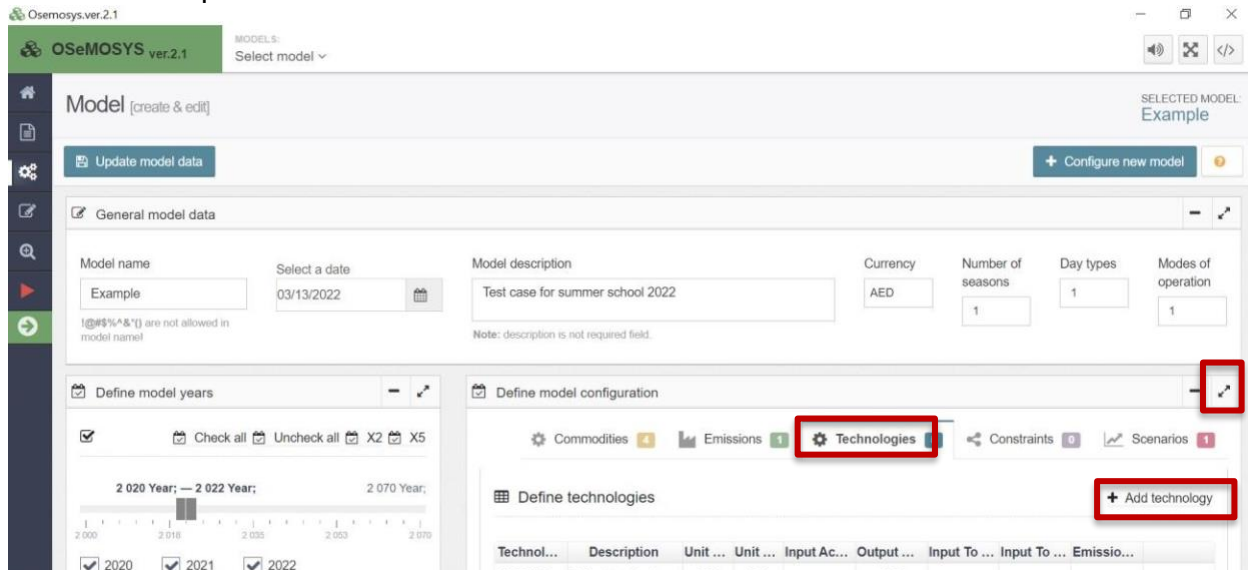
The next step is to add 5 technologies (the 5 boxes in the figure above):

- **MINGAS** (supply of gas for the power sector)
- **MINCOA** (supply of coal for the power sector)
- **PWRGAS** (gas-fired power plant)
- **PWRCOA** (coal-fired power plant)
- **PWRTRN** (electricity transmission and distribution network)

1. Click on the tab '**Technologies**' in the '**Define model configuration**' Tab
2. There will be a default technology defined. You can rename it as needed.
3. Then, click on '**Add technology**' to add more technologies to the model

You can expand the technology window by clicking on the expand button on the left top corner in the define model configuration tab. We suggest to do this, since it may

happen that, if you do not expand the window, you are not able to carry out properly the next step.



In the table that appears, insert the names of the technologies as indicated above, and then the input and output commodities in the cells 'Input activity ratio' and 'Output activity ratio'. These are needed to create links between the technologies. I.e. to define which commodities flow in and out of which technologies in order to create an energy supply chain. The supply chain you will create is shown again in the figure below, for your convenience.



This chain indicates that (starting from the right): there is a demand for electricity (ELC002); this electricity is supplied to the consumers through the transmission and distribution network (PWRTRN); gas power plants (PWRGAS) and coal power plants (PWRCOA) are the two technologies supplying electricity to the network (for now); for supplying the electricity, the gas power plants are fed with natural gas (GAS) and the coal power plants with coal (COA); gas and coal come from extraction activities, respectively represented by MINGAS and MINCOA.

Once you have included inputs and outputs in the table, it will look like in the figure below.

Define model configuration

Commodities Emissions Technologies Constraints Scenarios

Define technologies + Add technology

Technology	Description	Unit of capacity	Unit of activity	Input Activity Ratio	Output Activity Ratio	Input To New Capacity Ra...	Input To Total Capacity R...	Emission Activity Ratio	
MINGAS	Gas extraction	PJ	PJ		GAS				
MINCOA	Coal mining	PJ	PJ		COA				Delete
PWRGAS	Gas power plant	MW	PJ	GAS	ELC001				Delete
PWRCOA	Coal power plant	MW	PJ	COA	ELC001				Delete
PWRTRN	Transmission technology	MW	PJ	ELC001	ELC002				Delete

N.B. In the UI, the supply chain must always start with a technology. I.e. there must be a technology making the needed commodity available. In this case, at the start of the supply chain there are two technologies representing extraction of gas and of coal. **Failing to start a supply chain with a technology will make that supply chain not work and the model, potentially, crash.**

- For all the technologies, enter GW as the unit of capacity and PJ as the unit of energy (note that we have entered the same unit of energy as for the commodities, for consistency)
- Click **Update model data (always do it, at the end of any step, with any element you modify!)**

With these steps, you have introduced in the model new technologies and new commodities. You have also created links between technologies, i.e. we have defined how the commodities flow between the different technologies. Now, we must define the parameters that characterize the link between technologies and commodities.

In order to characterize the links between technologies and commodities, it is useful to recall some concepts:

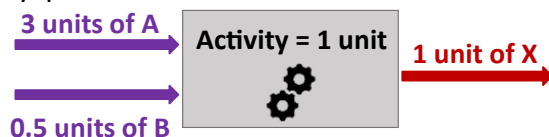
- Activity:** it refers to any process occurring within a technology (e.g. fuel combustion, water treatment, crude oil refining, crop harvesting)
- InputActivityRatio:** ratio between an input commodity and technology activity
- OutputActivityRatio:** ratio between an output commodity and technology activity

Examples follow.

Example 1: Multiple inputs, single output

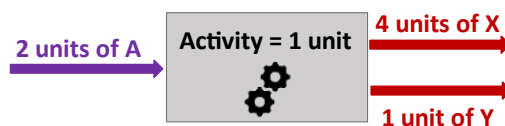
- 1 unit of activity requires 3 units of commodity A and 0.5 units of commodity B

- 1 unit of activity produces 1 unit of X



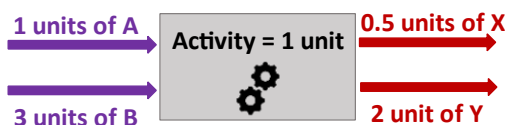
Example 2: Single input, multiple outputs

- 1 unit of activity requires 2 units of commodity A
- 1 unit of activity produces 4 units of X and 1 unit of Y

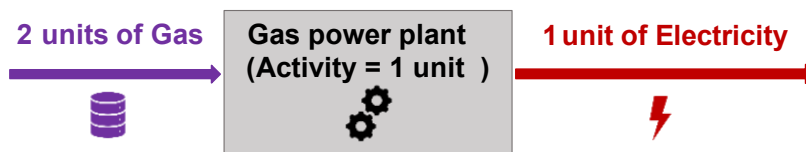


Example 3: Multiple inputs, multiple outputs

- 1 unit of activity requires 1 unit of commodity A and 3 units of commodity B □
- 1 unit of activity produces 0.5 units of X and 2 unit of Y



N.B. When defining the InputActivityRatio and the OutputActivityRatio, **you automatically also define the efficiency of the technology**. See the example below:



The efficiency of the process of electricity generation is the ratio between the output and the input. In this case:

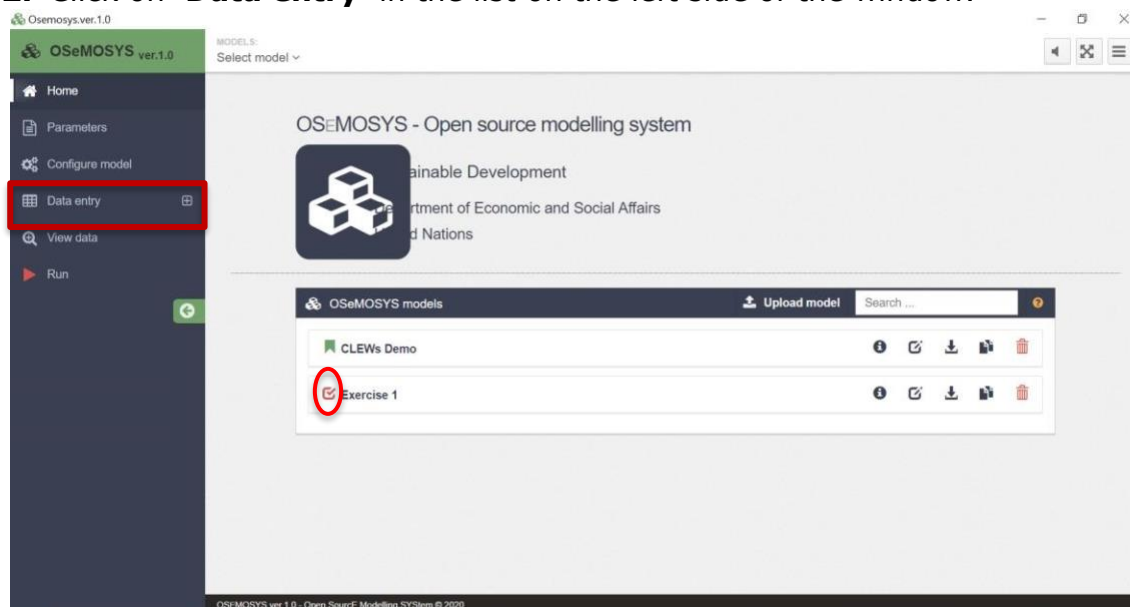
$$Efficiency = \frac{1 \text{ unit of electricity}}{2 \text{ units of Gas}} = 50\%$$

If the output and the input have the same type of unit (e.g. PJ), the efficiency will be a ratio with no unit. If the output and the input have different types of units, then the efficiency will have units. The choice of the units lies with you. For the labs, we will always indicate the exact values you need to input and in which units they are intended.

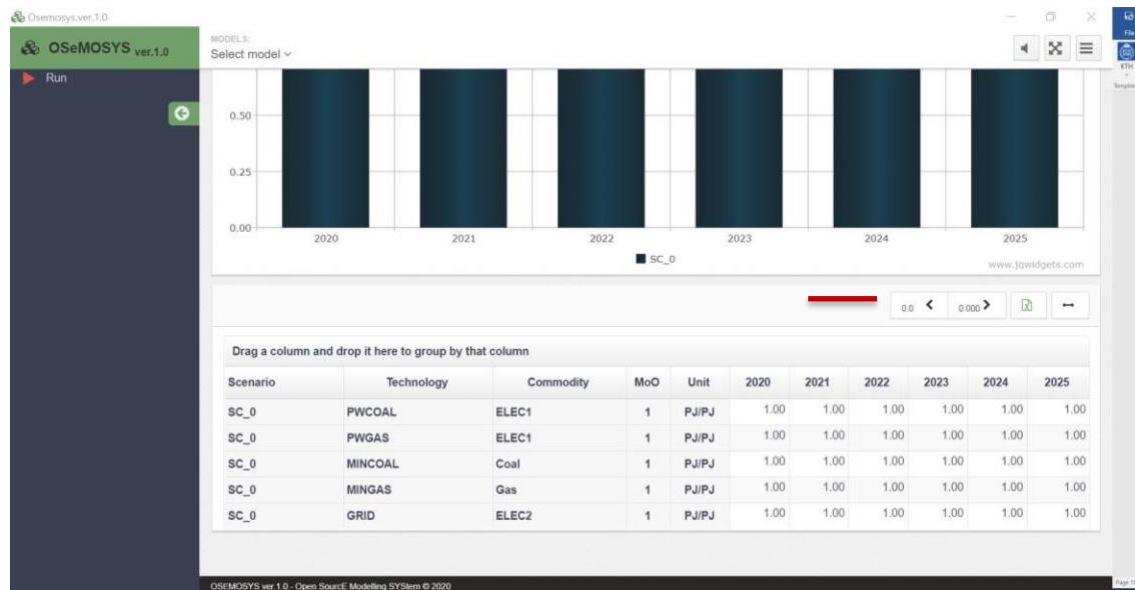
Continuing the exercise, you are now asked to introduce the **InputActivityRatio** and **OutputActivityRatio** for PWRGAS and PWRCOA so that they both produce 1 PJ of electricity, with efficiency respectively of 50% and 33%. You will also enter data for the other technologies, so that they all have efficiency 100%.

Start from the **OutputActivityRatio**:

1. Go back to home and make sure you have selected the right model. In this case, the model name must be exercise one. The currently selected model is marked with a red tick mark as shown in the figure below.
2. Click on '**Data entry**' in the list on the left side of the window.



3. Search for the parameter **OutputActivityRatio** and scroll down to the table to enter the data
4. The table will contain several different columns as shown in the figure. The columns technology and commodity are linked based on the data entered in the configure model tab where you specified the input and output fuel for each technology.



5. You will have to enter the data given in the table below, **for all years**. The table below shows which technology you give the value for each year. For instance, for MINCOA, the commodity COA is already fixed, and you will give the value 1 PJ/PJ (PJ output per PJ activity) for all years. By doing so, you will be defining that the technology MINCOA (coal extraction) provides 1 unit of COA (coal) for every unit of its activity. This corresponds to the figure above, where COA is drawn as an output of MINCOA
6. Click **Save data** after entering the values for all the couples technology commodity shown below. You do not need to save before then.

Technology	Value to be given	Output commodity
MINGAS	1	GAS
MINCOA	1	COA
PWRGAS	1	ELC001
PWRCOA	1	ELC001
PWRTRN	1	ELC002

Note that we always prefer setting the output as 1. This means that, for efficiencies < 100%, the input will be a number higher than 1. The reason for setting the output as 1 is linked to the structure of OSeMOSYS and requires an advanced explanation. If you are curious, you may ask the question on the Q&A!

Now move to the **InputActivityRatio**:

7. Click on '**Data Entry**' in the list on the left of the window. Search for the parameter **InputActivityRatio** and scroll down to the table to enter the data
 - A data table will appear for each with all the technologies with inputs in the model listed **for all years**. Enter data for each
 - You will have to enter the data given in the table below
 - Click **Save data**

Technology	Value to be given	Input commodity
PWRGAS	2	GAS
PWRCOA	3	COA
PWRTRN	1	ELC001

Note that the value 2 PJ/PJ for the gas power plant comes from 1/50% and the value 3 PJ/PJ for the coal power plant comes from 1/33%. That is, the efficiencies can be used to calculate the 'InputActivityRatio' of power plants.

Since we are building a very simple model in this exercise, we have not entered data for all the parameters in OSeMOSYS. However, there are some mandatory parameters which are crucial to run the model. We must give the *default value* for all these parameters in order to run the model. You will come back later in the exercise to give more specific values to these parameters. The detailed description of these parameters is given later in the exercise. For now, we need to enter a default value in order to run the model. The parameter needed to run this model is called '**CapacityToActivityUnit**'. It defines how much activity a unit of capacity of a technology can have over the span of a year. Check that for this parameter all the values are by default 1 (i.e. none is 0). If they are not, the model will not work.

The next parameter that is essential for running the model is called '**YearSplit**'. This parameter deals with the disaggregation of time in the model. This will be explained in more detail later. Also for this, check that the default values are all 1.

Additional learning notes

Model structure in OSeMOSYS

The several essential parts of the model in OSeMOSYS are explained below

- **Sets**

To define the model structure – Technologies, Commodities, modelling years, time resolution etc.

- **Parameters**

Define the numerical inputs to the model – Costs, demands, constraints for capacity etc.

Indexed over the sets, for example: **Cost (Technology, Year)**: This represents a matrix of costs for every technology and every year

- **Variables**

To make the decision within the model – Variables are used to change the energy generation and try to reach the model objective

Indexed over the sets, for example: **Generation (Technology, Year)**: This represents a matrix of generation by every technology in every year

Activity 2 – Introduce a demand for electricity

Now you have set up the supply side of the energy chain. However, the power plants will supply electricity (and compete in the supply) only if there is demand for electricity. In this activity you will introduce a demand for electricity, so that, driven by the demand, the model will try and find the best supply option(s) and will suggest how much the power plants should operate.

In OSeMOSYS, demands are user-defined (exogenous) and can be set for one or more commodities. They “drive” the optimization process, that is, the objective of the model is to minimize the cost of meeting them.

The user can introduce two types of demand in OSeMOSYS:

- **AccumulatedAnnualDemand:** it must be balanced by the supply on an annual basis
- **SpecifiedAnnualDemand:** it must be met based on a “time-of-use” profile such as daily fluctuations in electricity demand.

You will learn more about the difference between them in the following labs. For now, you will introduce values only for the AccumulatedAnnualDemand. In this way, you will define a value of demand for each year of the time domain. The supply chain needs to meet this demand over the year.

Introduce a value of 100 PJ as AccumulatedAnnualDemand for electricity ELC002 in every year, in the following way:

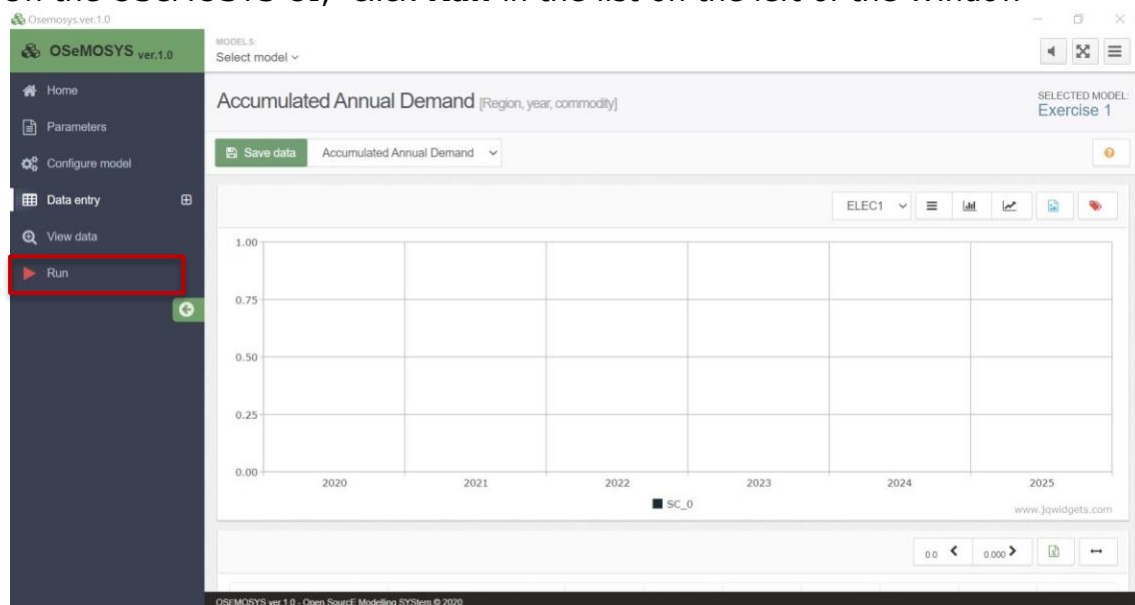
- Click on **‘Data Entry’** in the list on the left of the window. Search for the parameter **AccumulatedAnnualDemand** and scroll down to the table to enter the data. You will see a table with a list of all fuels and cells to enter data for each fuel for all the years.
- Enter data for ELC002 as suggested in the table below.
- Click **Save data**.

Commodity	2019	2020	2021	2022
ELC002	100	100	100	100

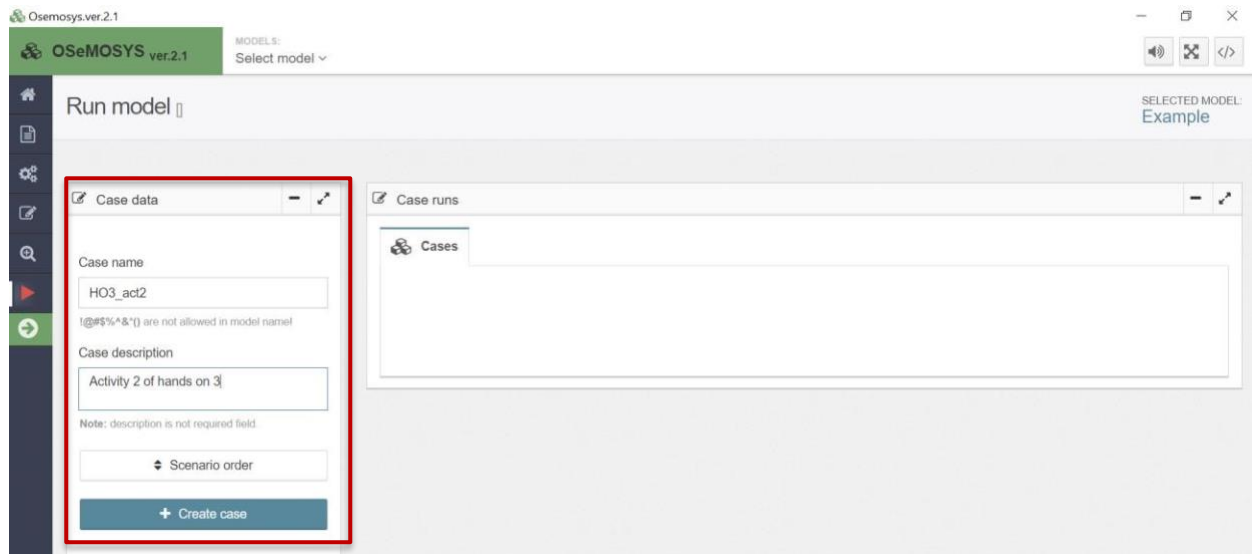
Activity 3 – Run the model and visualize the results

If you have carried out all the above steps correctly, you are now ready to run the optimisation and see which technology or technologies will be chosen to meet the electricity demand. At this stage, we have given very little input. Therefore, the optimisation will unlikely give very meaningful results. However, it is good to go through the process of running a model, checking if the run completes and understanding how to read the results. For running the model and visualizing the results, take the following steps:

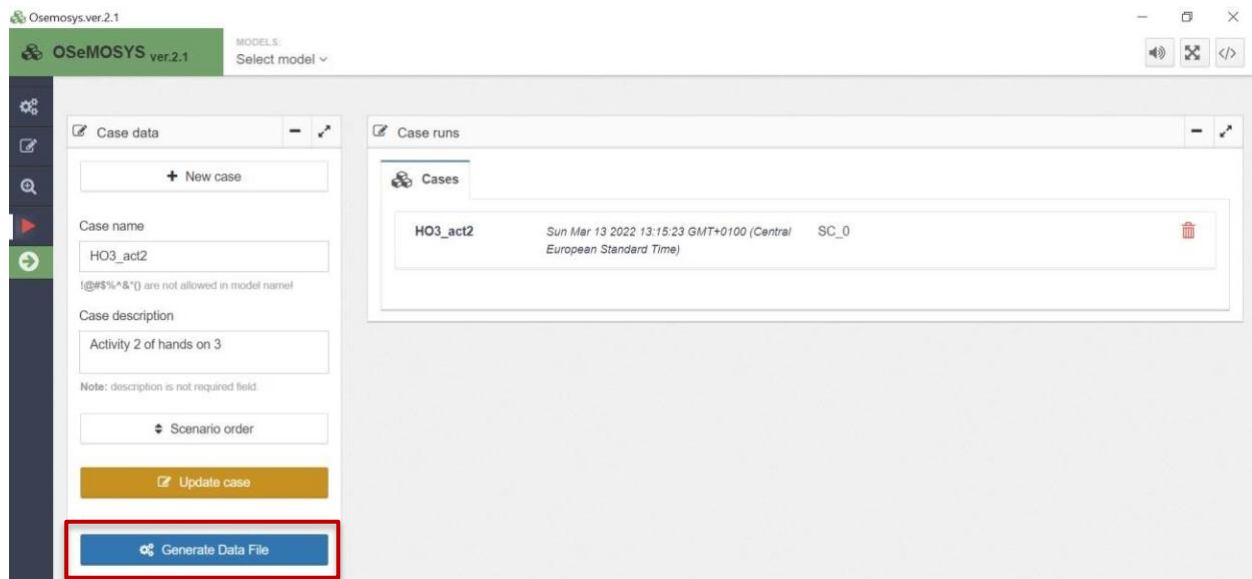
1. On the OSeMOSYS UI, click **Run** in the list on the left of the Window



2. You will now have to generate a 'Case' before running the model, or in other words a scenario. The interface allows you to create, for the same model, several scenarios, so that you may change some parameters in each and then compare the results. We will not use this feature in this course, but it will become much more useful when you build your own applications. For creating a case, give it a name and a description, then Click **+ Create case**.

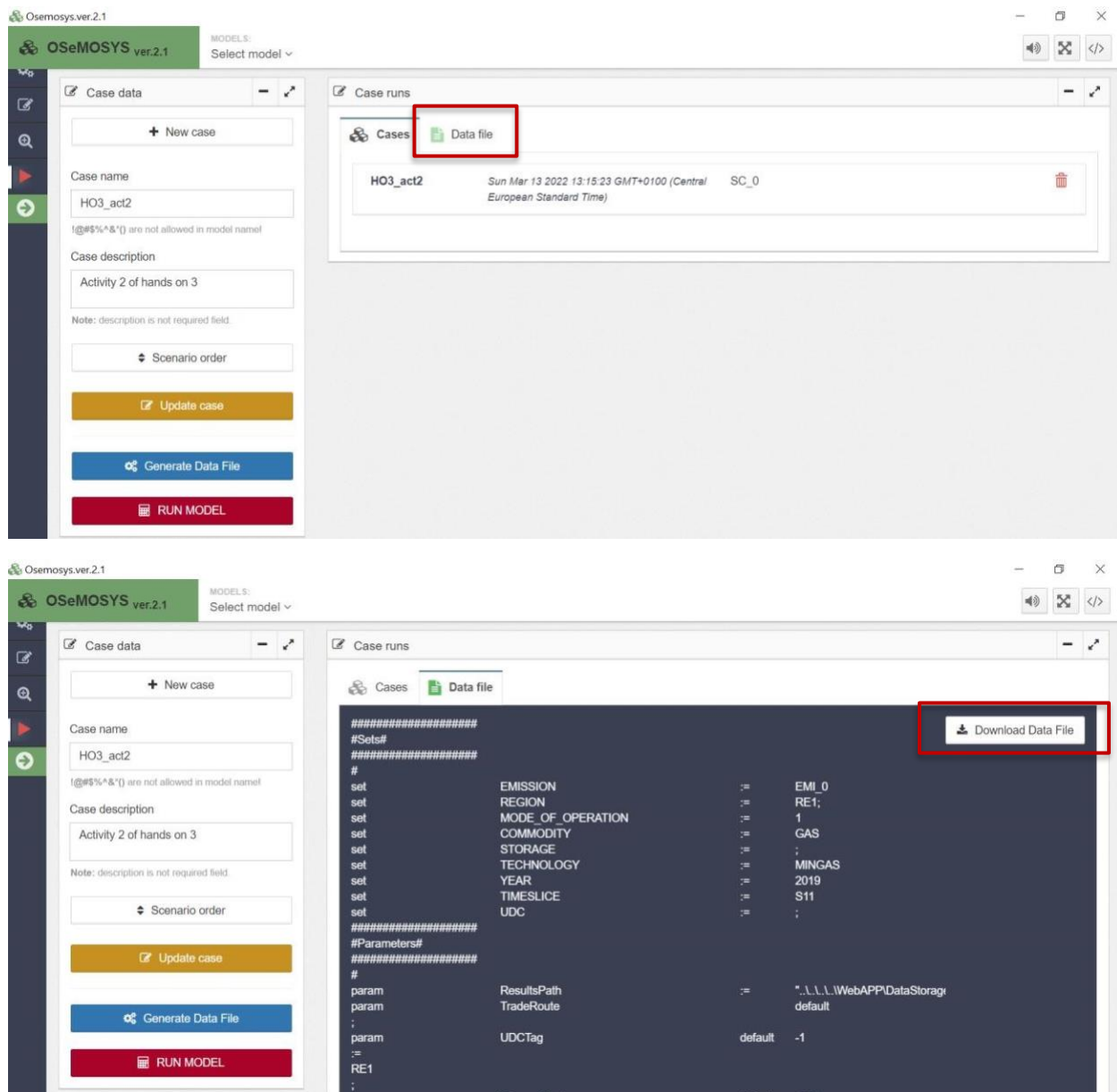


3. Click on **Generate Data File**.

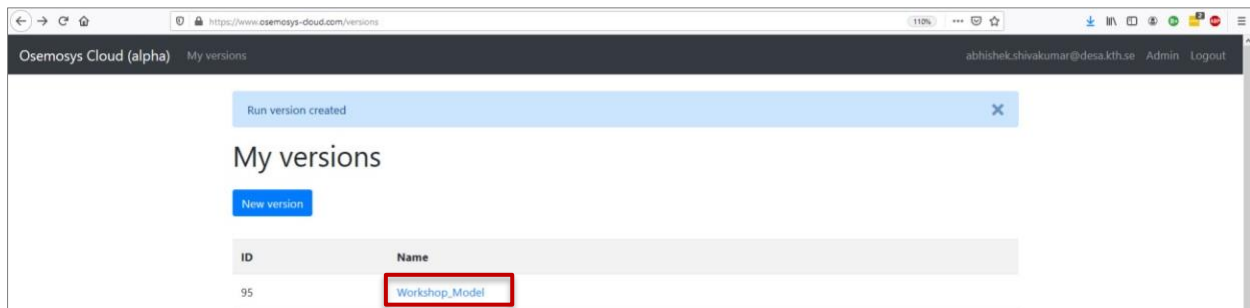


This will generate a Tab on the top left, called **Data file**.

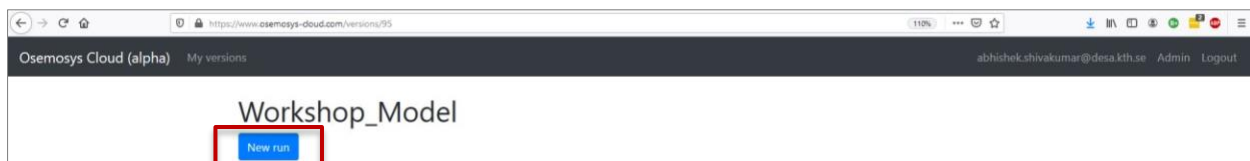
4. You may Click on that, open it, then click **Download Data File**. This will download the data of the model you just generated, in a format that is compatible with the OSeMOSYS Cloud.



5. Save the data file in a folder of your choice. Remember where you put it.
6. Now, connect to <https://www.osemosys-cloud.com/> and sign in with your email and password.
7. Click on the model and then the version you created in Hands-on lecture 1.



8. Click on **New run** to create a model run.



9. Enter a name for your model run (do not use spaces or special characters!). You may also add a short description, but that is not necessary

New run

Model: (No Model)

Version: Workshop_model_2021_10

Name *

Model file

Choose File

No file chosen

Data file

Choose File

No file chosen

Description

Language

English

Server type

Small server

☒ Send me an email when the run finishes

Create run



10. Next to the writing 'Model file', you will need to upload the **model.txt** file. You will find the model.txt file needed for this operation [here](#). This is a version of the OSeMOSYS code that is compatible with the exercise in this hands-on. Other versions of OSeMOSYS may not work. Download it and place it in a folder of your choice (e.g. the same as the data.txt file). You will need this specific model.txt file for all the following exercises, so keep it safe, remember where you put it and do not change it.
11. Now click **Browse** and upload the model.txt file you just obtained.

New run

Model: (No Model)
Version: Workshop_model_2021_10

Name *

Model file

Choose File No file chosen

Data file

Choose File No file chosen

Description

Language

English ✓

Server type

Small server

☒ Send me an email when the run finishes

Create run

12. Next to the writing 'Data file', click **browse** to look for and upload the **data.txt** file that you downloaded from the OSeMOSYS UI.



New run

Model: (No Model)

Version: Workshop_model_2021_10

Name *

Model file

Choose File

No file chosen

Data file

Choose File

No file chosen

Description

Language

English ✓

Server type

Small server ▼

☒ Send me an email when the run finishes

Create run

13. You may un-check the box 'Send me an email when the run finishes', in case you do not want to receive emails.



New run

Model: (No Model)

Version: Workshop_model_2021_10

Name *

Model file

Choose File

No file chosen

Data file

Choose File

No file chosen

Description

Language

English ✓

Server type

Small server ▼

☒ Send me an email when the run finishes

Create run

14. You will also see a drop down menu to choose the Server type. The default setting there will be **Small server**. Please do maintain that setting for this exercise.

15. Click **Create run** (see below)



New run

Model: (No Model)
Version: Workshop_model_2021_10

Name *

Model file

No file chosen

Data file

No file chosen

Description

Language

English

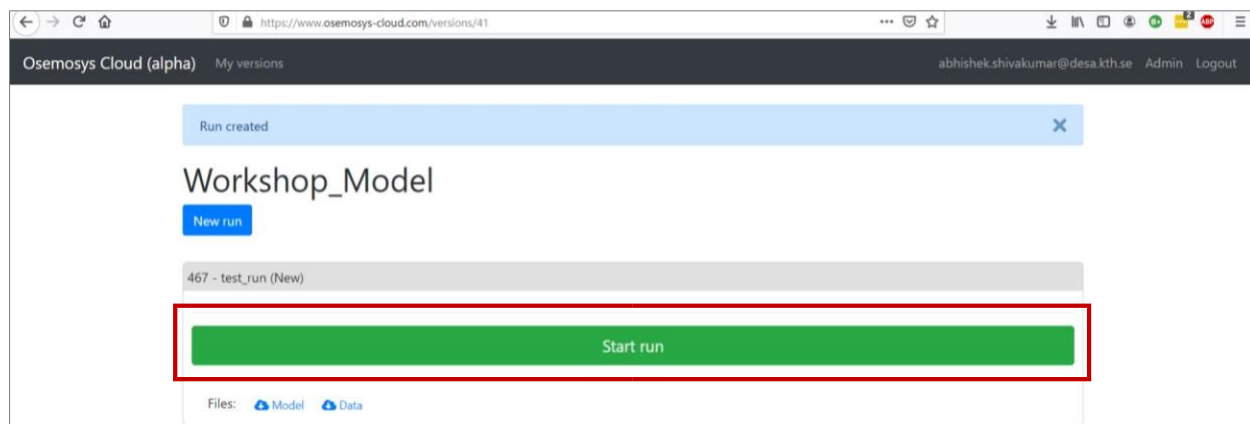


Server type

Small server

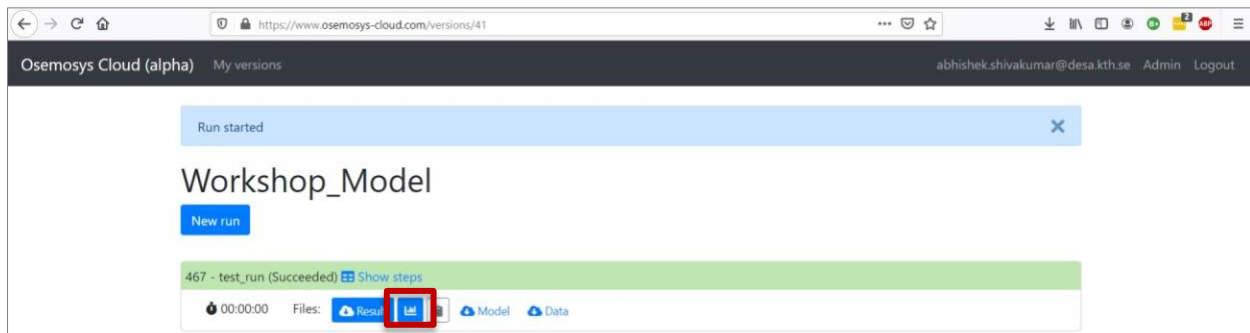
☒ Send me an email when the run finishes

16. Click **Start run**



This will start the run, which should take a couple of seconds to complete. If the run is completed successfully, the bar of the run will be green and will show the message (Succeeded) next to the name of the run (see below). If after some time you do not see the below, you may need to refresh the page.

To view the results of this run, **click on the symbol with the little graph**.



What do you see? If there is any result shown, are you able to understand what is being shown? Answer the quiz for this exercise!

N.B. You will have to repeat this operation for all the times you will be asked to run the model in the next exercise. Every time you will have to create a New run (we suggest you give them meaningful names, so that you are able to distinguish all steps from each other)

Own reflection

Optional (no deliverable needed)

- Briefly explain the model you developed (describe the supply chain)
- What type of situation is your model representing? What demands are included? What supply options are included?
- What does the Reference Energy System (RES) show? *Note you have only built a small RES so far and you will build up to the RCD.*
- If more supply options are included in the model, what do you expect to see?