Introduction to CLEWs

Hands-on lecture 5: Introducing time-dependent elements

V2.0

Kane Alexander [a], Diki Darmawan [b], Godswill Ifeanyi [b], Shreyas Savanur [b], Camilla Lo Guidice [b], Francesco Gardumi [b], Eunice Ramos [c], Thomas Alfstad [c], Leigh Martindale [ad]

[a] *Imperial College, London, United Kingdom*

[b] *KTH Royal Institute of Technology, Stockholm, Sweden*

[c] *United Nations Department of Economic and Social Affairs, New York, United States*

[d] *Loughborough University, Loughborough, United Kingdom*

Cite as: K. Alexander, D. Darmawan, G. Ifeanyi, S. Savanur, C. Lo Guidice, F. Gardumi, E. Ramos, T. Alfstad, 'Introduction to CLEWs Hands on lecture 5: Introducing time-dependent elements', Climate Compatible Growth, 2025. DOI: 10.5281/zenodo.8340849.

Tags: CLEWs; Climate; Land; Energy; Water; Systems Modelling; Integrated; Policy Coherence; Installation; Hands-on; Climate Compatible Growth; Open Source; Teaching Kit.

Useful links:

1) Energy Modelling Community (EMC) Discourse Forum – please use this for any CLEWs-related discussions, especially troubleshooting queries!
2) EMC LinkedIn.
3) CCG YouTube.

Pre-requisites:

1) Successful completion of Hands-on lecture 4.

Learning outcomes

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

1) Understand how time-varying demands and demand profiles are added to an energy system model
2) Introduce variable renewable energy sources and their techno-economic characteristics
3) Understand the influence of time-dependent supply and demand on the least-cost planning of an energy system

Activity 1 – Check the time definition in the model

There are several time-dependent elements in OSeMOSYS:

1. SET

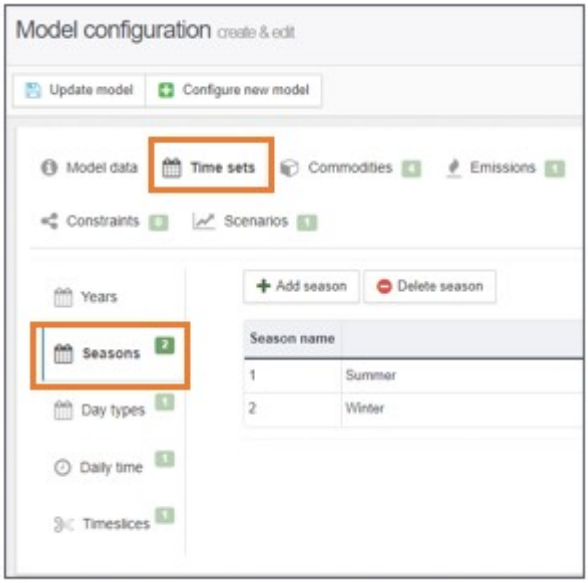
   "**Timeslices**" represents the number of parts a year is divided into.

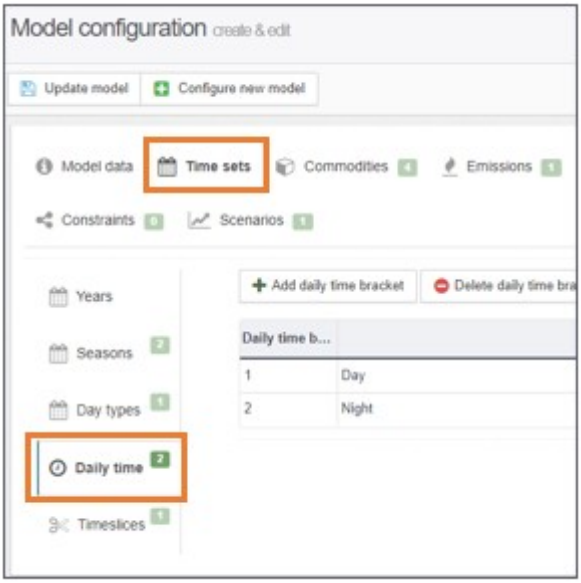
   In the previous exercises, there was only one timeslice, which corresponded to the entire year. In this exercise, you will create:

   - **2 seasons** (summer and winter)
   - **2 daily time brackets** (day and night), and
   - **4 timeslices** (2 seasons * 2 daily time brackets)

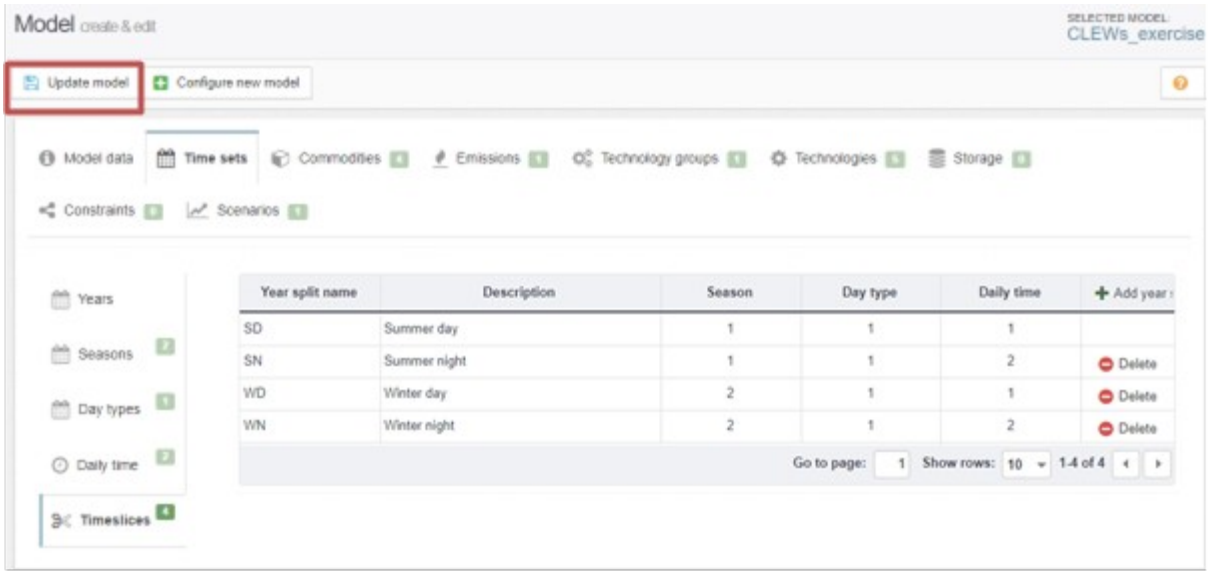
   Now follow these next steps:

   1. To change the number of timeslices, navigate to "Configure model" (left-hand side menu), and the tab "Time sets".
   2. In the section "**Seasons**", create two seasons: 1. Summer; 2. Winter.
   3. In the section "**Daily time bracket**", create two day parts: 1. Day; 2. Night.





4. In the section "**Timeslices**" add 4 timeslices corresponding to 2 seasons and 2 daily time brackets:
    - SD: Summer day
    - SN: Summer night
    - WD: Winter day
    - WN: Winter night
5. Click on "**Update model**" to save your edits



2. PARAMETERS

- **YearSplit**: represents the duration of each timeslice as a fraction of the year.

Calculation: You will now have to calculate each **Year Split** share starting from the number of **hours** and **days** corresponding to each Timeslice. Remember to be consistent with the number of hours and days in the description. **You can fill in the following table to help with your calculations.**

Year Split Assumption						
Timeslice	**Description**	**Months**	**Hours in day**	**Hours**	**Days**	**Year Split**
SD	Summer Day	May - Oct	7 am - 11 pm	16	184	
SN	Summer Night		11 pm - 7 am	8	184	
WD	Winter Day	Nov - Apr	7 am - 9 pm	14	181	
WN	Winter Night		9 pm - 7 am	10	181	

Example: Consider the year split corresponding to the first Timeslice (SD). This represents the share of all the hours in the summer months (assumed to be from May to October), during the day-hours (from 8 am – 11 am):

YearSplit (SD) = (16h*184d) / 8760
= 2944 / 8760
= 0.336 or 33.6% of the year

Now, calculate the remaining YearSplit by using the calculation above. ***Note that the summation of the YearSplit should be equal to 1.***

6. To add the "**YearSplit**" data, go to "**Data entry**" and search for "**YearSplit**". Update the default values (1.000) with the "YearSplit" in the values calculated. Click on "**Save Data**" to save your edits.

Activity 2 – Add a Specified Annual Demand

The **Specified Demand Profile** parameter is used to describe the variation in demand across different times of the year. More specifically, it sets the share of demand that occurs at each time slice, specified as a fraction of the total demand in that year.

1. To add the "**Specified Demand Profile**" data, go to "**Data entry**" and search for the parameter's name. This can be calculated using various pieces of information, but for the sake of time, please use the following data:

SD	0.314
SN	0.117
WD	0.378
WN	0.191

2. The Specified Demand Profile values in the table refer to the final electricity demand, which is represented by the commodity "**ELC002**". The filter option, next to "Commodity", can be used to select ELC002.

3. Update the default values (0.000) with the values obtained from the Spec Demand Profile. The values are the same for each year. **Click on "Save Data" to save your edits.**

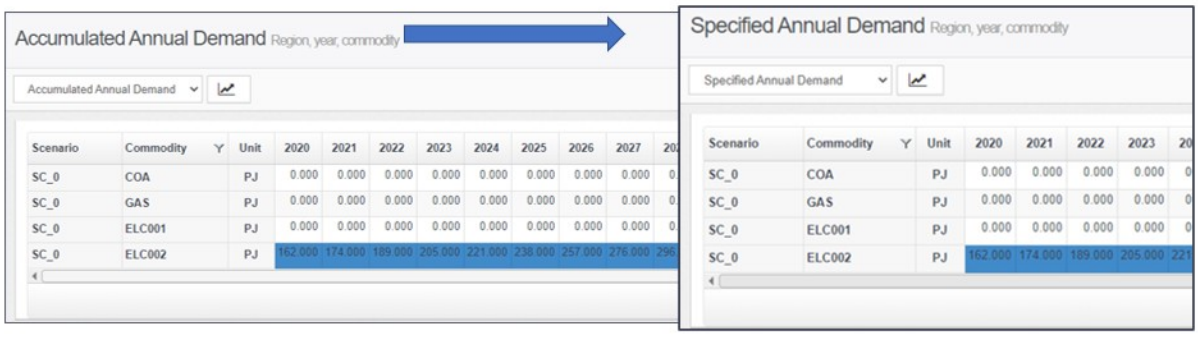
4. Transfer the demand values for **ELC002** added in "**Accumulated Annual Demand**" to the parameter "**Specified Annual Demand**".

5. Go to the "**Data entry**" menu and search for the parameter "**Accumulated Annual Demand**". Select the values for ELC002 by clicking on the cell for 2020, select the whole row (Shift+Ctrl+ right arrow) and then copy (Ctrl + c) values for all years shift the view to

the parameter "**Specified Annual Demand**" and paste (Ctrl + v) the values under the same commodity (ELC002).

6. Save the added values in "Specified Annual Demand" by clicking on **"Save data".** Go to "Accumulated Annual Demand" and delete the values in ELC002 (by pasting 0 over the full time series) and save.

(It also works if you "cut" and the values in "Accumulated Annual Demand", save data, then add the values in "Specified Annual Demand", and then save data.)



7. Now, generate a case for this model (HO5_A2) and **RUN IT** (if you do not recall how, kindly go back to the previous hands-on exercises). **View the same "Production by Technology by Mode" to see what has changed (?).**

If you had issues with YearSplit values (Step 2. parameters) and making them equal to 1. Please use the following and re-run the model.

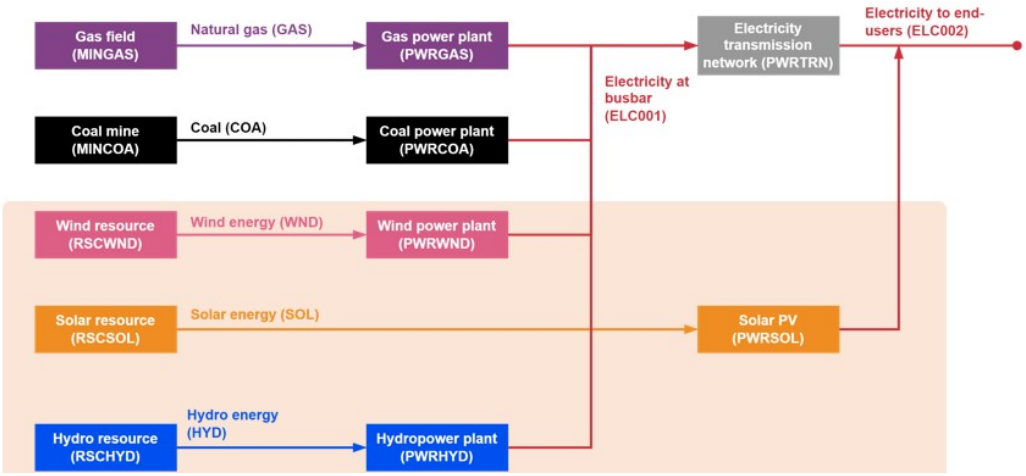
Timeslice	YearSplit
SD	0.336
SN	0.167
WD	0.288
WN	0.209

Activity 3 – Add renewable energy supply

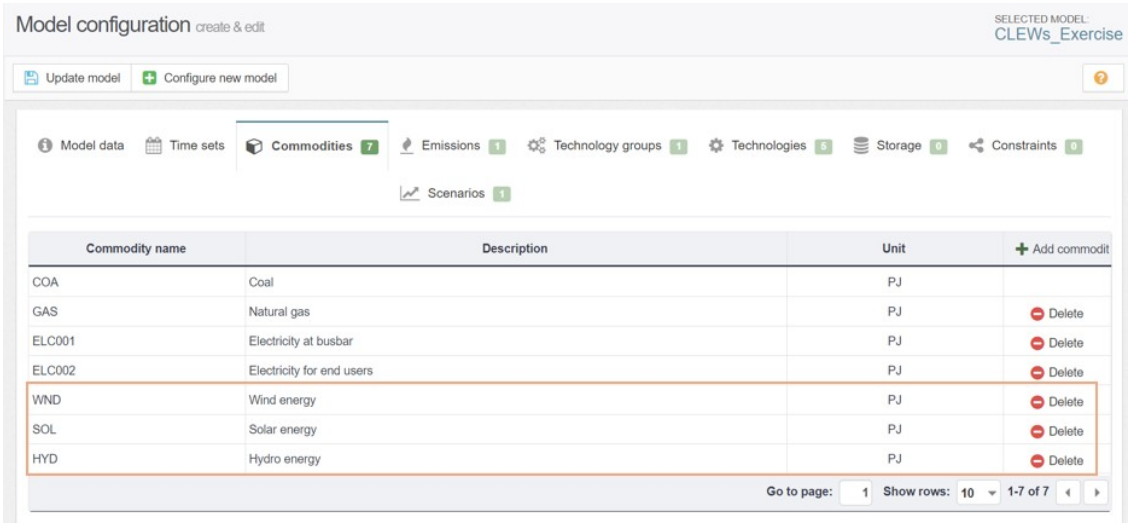
Before you begin Activity 3, create a copy of the model created after Activity 2 and save it, then continue on your new model.

Adding Renewable Energy Technologies (RETs)

1. When adding RETs and associated inputs and outputs, new "Sets" of technologies and commodities will be added to represent the RETs chains.

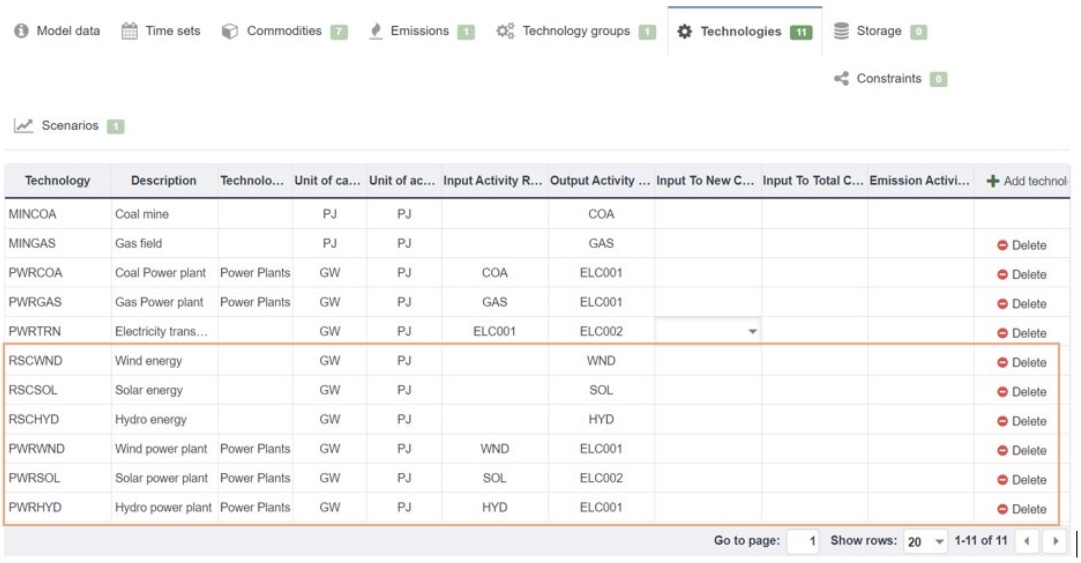


2. To add new commodities, go to "**Configure model**" in the left-hand side menu, and in "**Model configuration**", select the tab "**Commodities**".
3. Add the following commodities (WND, SOL, HYD) and their respective descriptions. Save by clicking "**Update model**" below the "**Model configuration**" title.



4. Now select the tab "**Technologies**" to add the new 6 technologies related to the RETs chain. The new 6 technologies are RSCSOL, RSCHYD, RSCWND, PWRHYD, PWRSOL and PWRWND.

5. Add the following technologies, their respective descriptions and characteristics (tech group, units, **inputs and outputs**). Save by clicking "**Update model**".

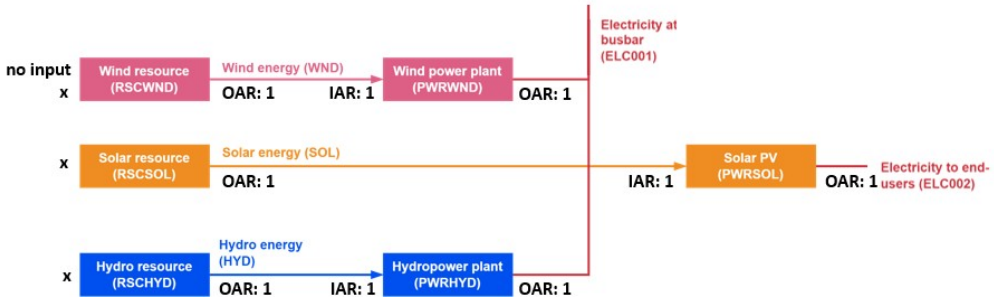


6. To see the changes to the RES, go to "Model Diagram" and select the views to be displayed.

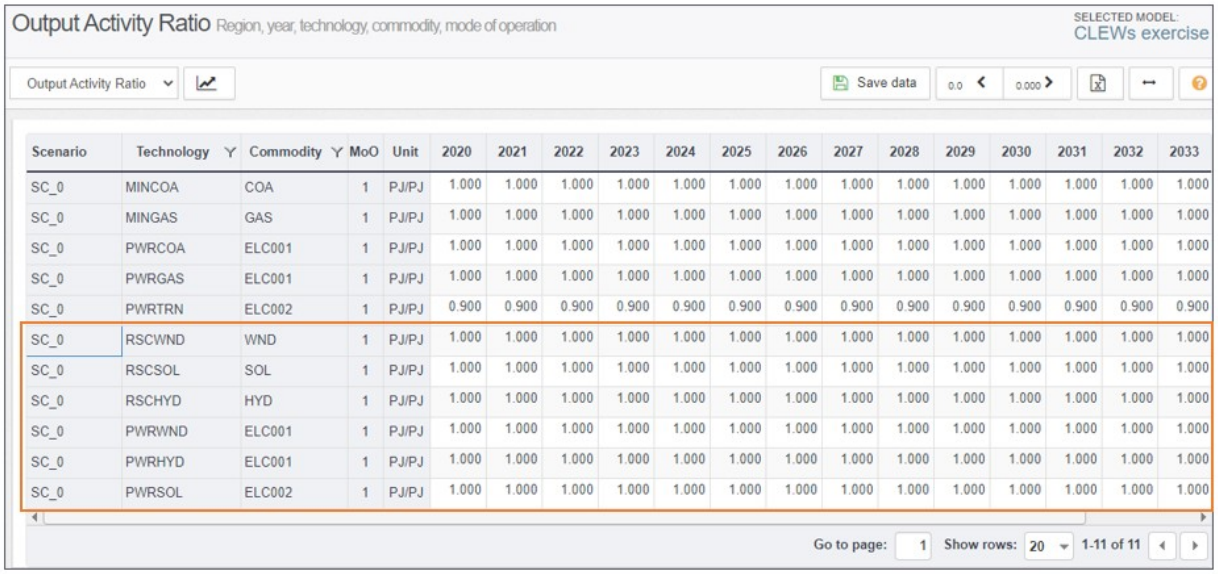
7. To characterise the functioning of the technologies added, you will follow a similar process to when you added the fossil fuel plants.

You will start by adding data to the parameters:

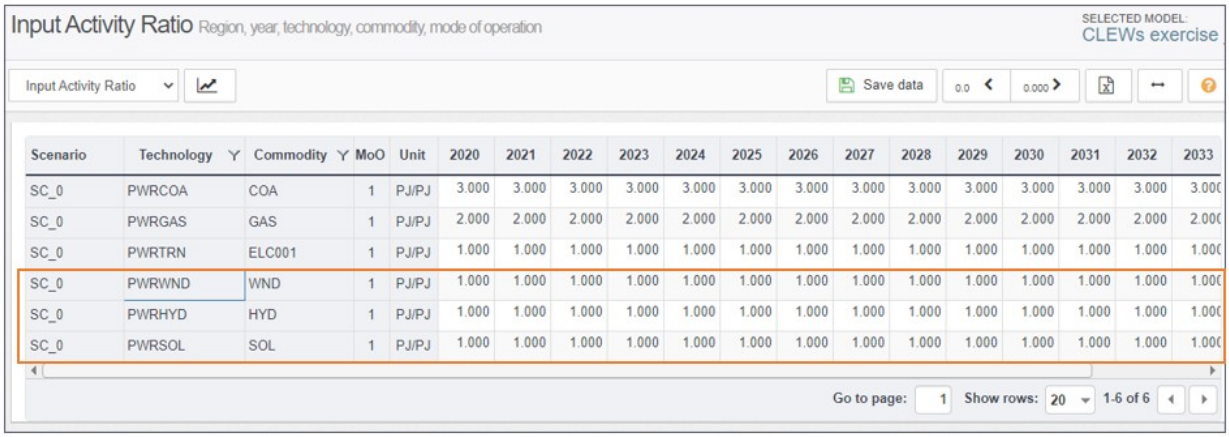
- Firstly, the "Input Activity Ratio" & "Output Activity Ratio"
- And then to the parameters linked to techno-economic information (e.g., Availability factor, Costs, Operational life, Capacity to Activity Unit, and **Capacity Factor**).



8. Add the "Output Activity Ratio" to all new technologies added.



9. Add the "Input Activity Ratio" to PWRWND, PWRSOL and PWRHYD.



10. Add the input data for each parameter according to the table below. Save data after moving to the next parameter.

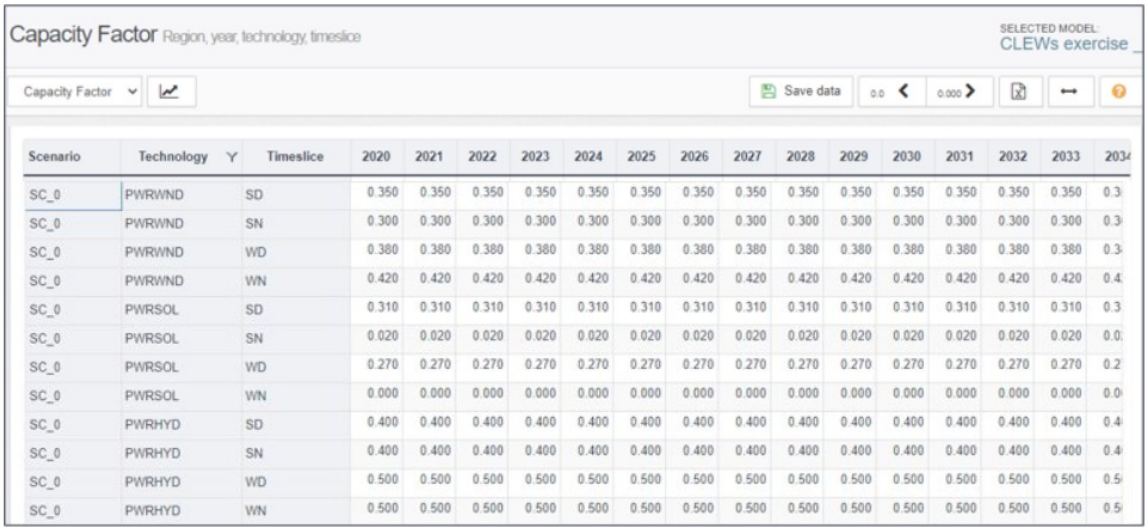
Parameter	Units	Timeslice	RSCWND	RSCSOL	RSCHYD	PWRWND	PWRSOL	PWRHYD
Availability Factor	Fraction	-	1 *	1 *	1 *	1 *	1 *	1 *
Capital Cost	M$/GW ($/kW)	-	0 *	0 *	0 *	1338	1720	2419
Fixed Cost	M$/GW ($/kW)	-	0 *	0 *	0 *	43	19	63
Variable Cost	M$/PJ ($/GJ)	-	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
Operational Life	Years	-	100	100	100	30	30	100
Capacity To Activity Unit	PJ/(PJ/yr), GJ/kW	-	1 *	1 *	1 *	31.536	31.536	31.536

11. New Parameter: **Capacity Factor.**

- This parameter can represent slightly different things for different technologies. In this case, for renewable energy technologies, we use it to represent the variability of renewable resources (and hence the potential maximum output of the technologies) in different parts of the day and of the year (i.e., in different time slices).

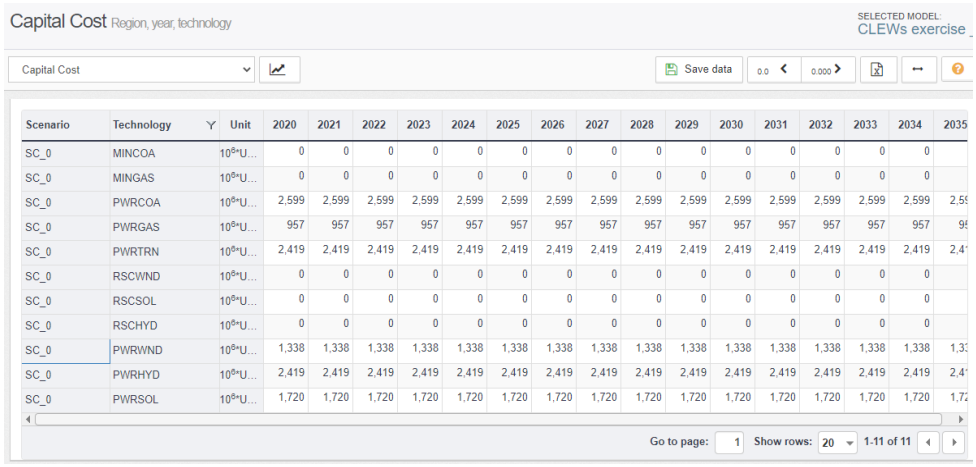
- To add data for "**Capacity Factor**", go to the left-hand side menu, and in "**Data entry**" search for or type "**Capacity Factor**". Add the values corresponding to the technologies **PWRWND, PWRSOL, and PWRHYD** according to what is indicated for the Capacity Factor in the table below, for all years. Save data.

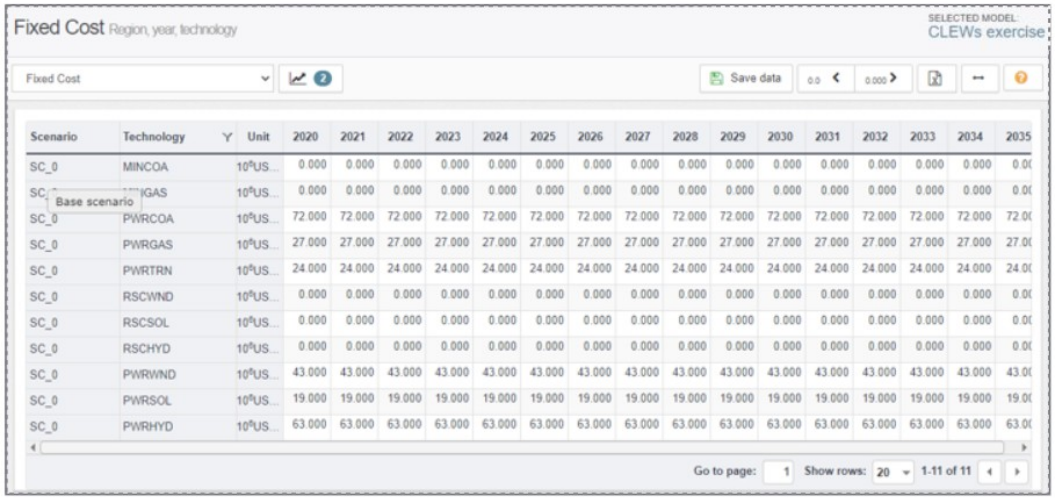
Parameter	Units	Timeslice	RSCWND	RSCSOL	RSCHYD	PWRWND	PWRSOL	PWRHYD
Availability Factor	Fraction	-	1 *	1 *	1 *	1 *	1 *	1 *
Capital Cost	M$/GW ($/kW)	-	0 *	0 *	0 *	1338	1720	2419
Fixed Cost	M$/GW ($/kW)	-	0 *	0 *	0 *	43	19	63
Variable Cost	M$/PJ ($/GJ)	-	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
Operational Life	Years	-	100	100	100	30	30	100
Capacity To Activity Unit	PJ/(PJ/yr), GJ/kW	-	1 *	1 *	1 *	31.536	31.536	31.536
Capacity Factor	Fraction	SD	1 *	1 *	1 *	0.35	0.31	0.40
		SN	1 *	1 *	1 *	0.30	0.02	0.40
		WD	1 *	1 *	1 *	0.38	0.27	0.50
		WN	1 *	1 *	1 *	0.42	0.00	0.50

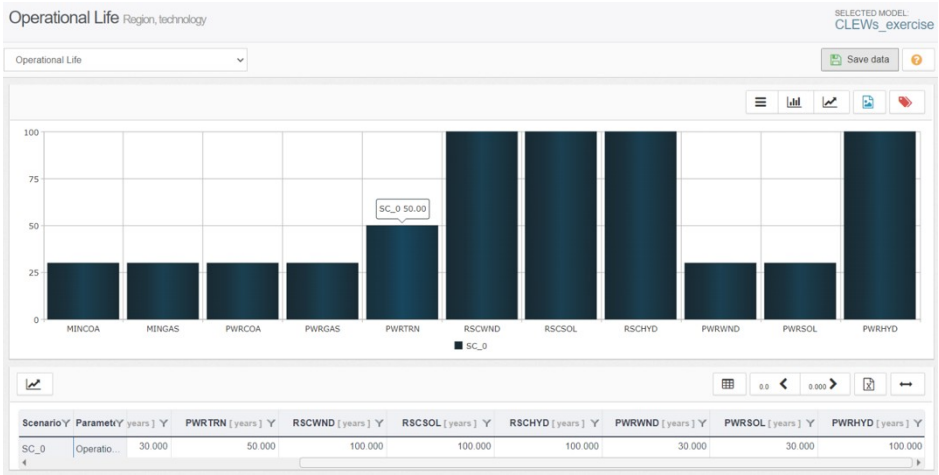


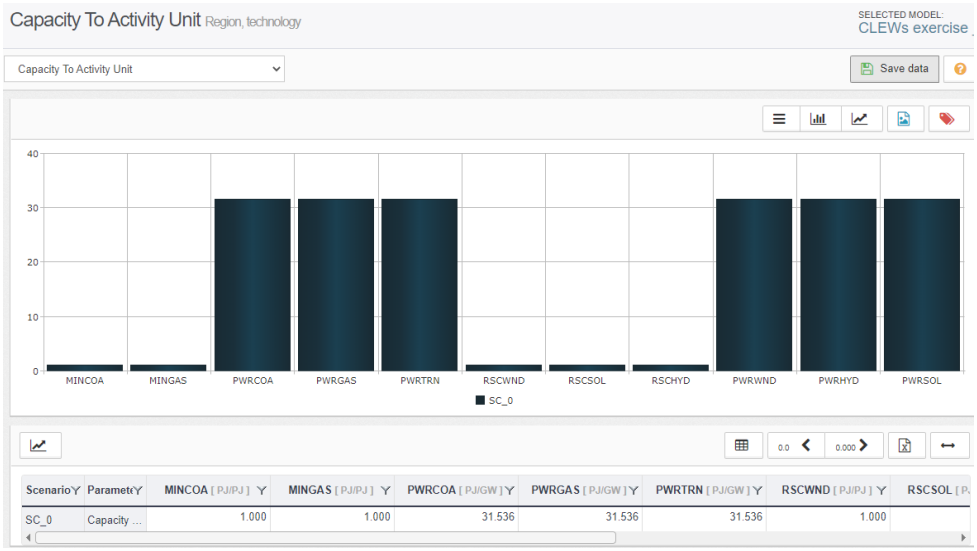
Scenario	Technology	Timeslice	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
SC_0	PWRWND	SD	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.350	0.3
SC_0	PWRWND	SN	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.3
SC_0	PWRWND	WD	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.380	0.3
SC_0	PWRWND	WN	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.420	0.4
SC_0	PWRSOL	SD	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.3
SC_0	PWRSOL	SN	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.020	0.0
SC_0	PWRSOL	WD	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.270	0.2
SC_0	PWRSOL	WN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
SC_0	PWRHYD	SD	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.4
SC_0	PWRHYD	SN	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.4
SC_0	PWRHYD	WD	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.5
SC_0	PWRHYD	WN	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.5

12. Now also input the data for the other techno-economic parameters as seen in the figures below (Capital cost, Fixed cost, etc.). ***Data can be obtained from the Excel file downloaded.***

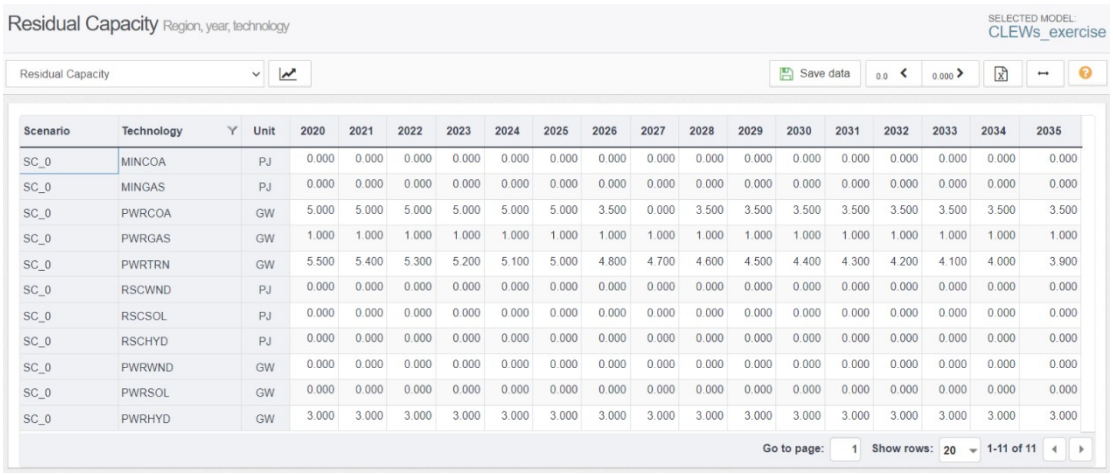

Capital Cost Region, year, technology
SELECTED MODEL:
CLEWs exercise
Capital Cost
Save data
Scenario
Technology
Unit
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
SC_0 MINCOA
SC_0 MINGAS
SC_0 PWRCOA
SC_0 PWRGAS
SC_0 PWRTRN
SC_0 RSCWND
SC_0 RSCSOL
SC_0 RSCHYD
SC_0 PWRWND
SC_0 PWRHYD
SC_0 PWRSOL
Go to page: 1
Show rows: 20
1-11 of 11


Fixed Cost Region, year, technology
SELECTED MODEL:
CLEWs exercise
Fixed Cost
Save data
Base scenario
Scenario
Technology
Unit
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
SC_0 MINCOA
SC_0 PWRCOA
SC_0 PWRGAS
SC_0 PWRTRN
SC_0 RSCWND
SC_0 RSCSOL
SC_0 RSCHYD
SC_0 PWRWND
SC_0 PWRSOL
SC_0 PWRHYD
Go to page: 1
Show rows: 20
1-11 of 11


Operational Life Region, technology
SELECTED MODEL:
CLEWs_exercise
Operational Life
Save data
100
75
50
25
0
SC_0 50.00
MINCOA
MINGAS
PWRCOA
PWRGAS
PWRTRN
RSCWND
RSCSOL
RSCHYD
PWRWND
PWRSOL
PWRHYD
SC_0
Scenario
Parameter
PWRTRN [years]
RSCWND [years]
RSCSOL [years]
RSCHYD [years]
PWRWND [years]
PWRSOL [years]
PWRHYD [years]
SC_0
Operatio...
30.000
50.000
100.000
100.000
100.000
30.000
30.000
100.000



13. Add existing capacity to the model using the parameter "**Residual Capacity**" for the coal, gas and hydro power plants. Consider the following values:
    - PWRCOA, 5 GW from 2020-2025, and 3.5 GW from 2026-2035
    - PWRGAS, 1 GW for all years
    - PWRHYD, 3 GW for all years
    - PWRTRN, copy values in the CLEWs data Excel (sheet "4.3. energy", line #205).



14. In this exercise, it will be assumed that the hydropower potential has been fully exploited (i.e., there can be no further investments in hydropower infrastructure) and wind power can expand a maximum of 1 GW every year.

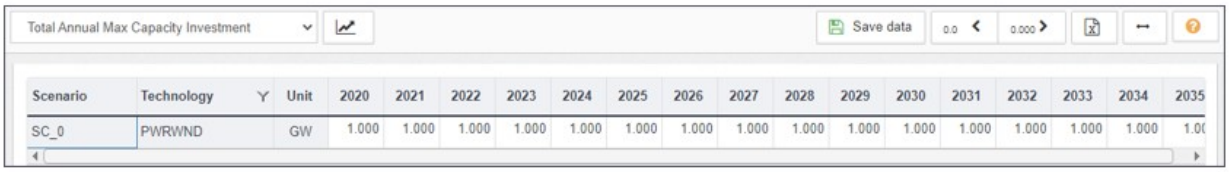
    In the case of hydropower (PWRHYD), the unavailability of hydro potential will be defined using the "Total Annual Max Capacity" parameter. Go to "**Data entry**" and search for

"**Total Annual Max Capacity**", find the technology "**PWRHYD**" and set the parameter value to **3 GW** (which corresponds to the existing capacity, as defined in "Residual Capacity").

Scenario	Technology	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	20
SC_0	PWRHYD	GW	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3

The limit to investments in wind power will be set with the parameter "Total Annual Max Capacity Investment". Go to "**Data entry**", find the parameter, search for the technology "**PWRWND**", and update the value to **1** throughout the modelling period.

15. **Now RUN THE MODEL as a new case (HO5_A3). View the same graph as before and compare**



Scenario	Technology	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
SC_0	PWRWND	GW	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.0

Note: On the screenshots, filters were applied to the column "Technology" to display only the specific technologies (PWRHYD and PWRWND).

results with previous model runs! Then check out the "Total Capacity by Technology" graph to see which power plants have the highest installed capacity…