



# Introduction to CLEWs

## Hands-on lecture 5: Introducing time-dependent elements

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### V1.3.0

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**Tags:** CLEWs; Climate; Land; Energy; Water; Systems Modelling; Integrated; Policy Coherence; Representation of time; Energy system model; Hands-on; Climate Compatible Growth; Open Source; Teaching Kit.

### Useful links:

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

### Pre-requisites:

- 1) Successful completion of Hands-on lecture 4



# Learning outcomes

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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

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**Before starting this exercise, copy the last model from Hands-on lecture 4 (if you do not recall how, kindly refer to the instructions in the same Hands-on).**

In Lecture 5, you learnt about the concept of TimeSlice and of YearSplit. However they are named, these concepts are often used in long-term energy system models. We have included for you the TimeSlices and the values for the YearSplit in your model template.

You can enter YearSplit by taking the following steps:

- Click '**Data entry**'
- Look for the parameter YearSplit and select it
- Scroll down to the table to enter data
- Check if 4 TimeSlices are shown in the table
- Enter the values shown in the table below, for all year.
- When entering the data for YearSplit, make sure that the sum of all the YearSplit values equals 1 for each year. (**You will have to round off the decimals accordingly**)

<b>TimeSlice</b>	<b>2019</b>	<b>2020</b>	<b>2021</b>	<b>2022</b>
SD (S11)	0.4457	0.4457	0.4457	0.4457
SN (S12)	0.2228	0.2228	0.2228	0.2228



WD (S21)	0.1657	0.1657	0.1657	0.1657
WN (S22)	0.1657	0.1657	0.1657	0.1657

Try to recall the meaning of **TimeSlice** and **YearSplit**. You will have to answer questions about it in the quiz annexed to this Hands-on session.

## Activity 2 – Add a Specified Annual Demand

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**Before starting this Activity, copy the latest model, i.e. the one from Activity 1 of Hands-on lecture 4 (if you do not recall how, kindly refer to the instructions in the same Activity).**

First step:

- Go to the **parameter** AccumulatedAnnualDemand and delete the four annual values now appearing for the commodity ELC002
- Click **Save data**

Second step:

- Go to the **parameter** SpecifiedAnnualDemand and add a demand of 100 (PJ) for each year (2019, 2020, 2021, 2022), for the commodity ELC002 □ Click **Save data**

Third step:

- Go to the **parameter** SpecifiedDemandProfile and add, for the commodity ELC002, the values shown in the table below, **for all years** (make sure that you select ELC002 as commodity!)
- Click **Save data**

<b>TimeSlice</b>	<b>Commodity: ELC002</b>
SD	0.32
SN	0.08
WD	0.18
WN	0.42

Try to remember the meaning of AccumulatedAnnualDemand, SpecifiedAnnualDemand and SpecifiedDemandProfile, **and go back to Lecture 5 if you do not recall them**. Also, repeat on your own how the YearSplit and



SpecifiedDemandProfile are calculated and reflect on the **difference between the two**. You will be asked questions about this in the Quizzes.

## Activity 3 – Run the model

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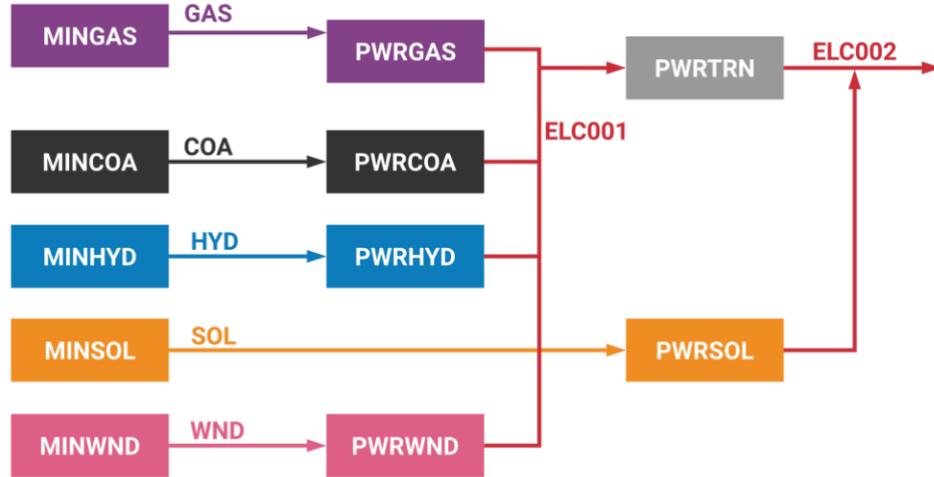
**Now, generate a Case for this model, download the data file and run it (if you do not recall how, kindly go back to Activity 3 of Hands-on lecture 3).**

## Activity 4 – Add renewable energy supply

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**Before starting this Activity, copy the latest model, i.e. the one from Activity 2 of this Hands-on (if you do not recall how, kindly go back to Activity 1 of Hands-on lecture 4).**

*With this activity, you will introduce in the model renewable energy supply technologies that could contribute to the electricity supply in parallel to the coal power plant and gas power plant. When this activity is completed, the Reference Energy System of your model will look like in the figure below. Compared to the previous stage, you will have added hydropower (PWRHYD), rooftop solar photovoltaic (PWR SOL) and wind turbines (PWRWND). Each of these taps into a resource (respectively, MINHYD, MINSOL, MINWND for hydro, solar and wind resource) and provides electricity to meet the demand.*



To start, you need to **add the new technologies and related commodities to the SETs.**

For the commodities:

- For the new model you just copied, go to configure model and click on COMMODITIES
- Add to the SET the following 3 commodities: HYD, SOL, WND
- The units for all these commodities will be the same as ones for the previous.
- Click **Save**

For the technologies:

- For the new model you just copied, go to the configure model and TECHNOLOGY
- Add the following 6 technologies: MINHYD, MINSOL, MINWND, PWRHYD, PWRSOL and PWRWND
- Assign the input and output commodities for the technologies based on the above figure
- The units for all these technologies will be the same as ones for the previous □  
Click **Save**

Now, **create the connections between the technologies and commodities** according to the figures. For creating the connections, you will need to use the InputActivityRatio and OutputActivityRatio parameters. You will assume that all these technologies have 100% efficiency. That corresponds to having **values of 1 PJ/PJ for both the InputActivityRatio and the OutputActivityRatio**. To recall how these parameters are entered, you may go back to Activity 1 in hands-on lecture 3 and recall how you did for PWRCOA and PWRGAS. Further hints are:

- MINHYD, MINSOL and MINWND will have only OutputActivityRatios, of value 1 PJ/PJ (PJ of output per PJ of exercise), respectively for the commodities shown in the figure above (with arrows going outwards). **They have no inputs. Be**



**well aware of this, as giving inputs to these technologies by mistake will make the model crash.**

- PWRHYD and PWRWND will have both InputActivityRatio and OutputActivityRatio, of value 1 PJ/PJ, respectively for the commodities shown in the figure above by the different inward-going and outward-going lines. Notice that the output electricity commodity for both these technologies is ELC001, that is, electricity that feeds into the transmission network.
- PWRSOL will have an InputActivityRatio of 1 PJ/PJ for commodity SOL and an OutputActivityRatio of 1 PJ/PJ for the commodity ELC002, that is, the electricity for final uses. Note that, as opposed to PWRHYD and PWRWND, there is no OutputActivityRatio for ELC001, the electricity feeding into the transmission network. This is because PWRSOL represents rooftop PV and is not connected to the transmission network.

Finally, **enter the techno-economic parameters for all these technologies.** First, enter values for the parameters in the table below. Remember to enter these values **for all years**. The **CapacityToActivityUnit** for MINHYD, MINWND, and MINSOL should be 1.

Parameter	Units	PWRHYD	PWRSOL	PWRWND
AvailabilityFactor	Fraction	1	1	1
CapitalCost	\$/kW	2500	1200	1600
FixedCost	\$/kW/yr	60	20	40
VariableCost	\$/GJ	0	0	0
OperationalLife	Yrs	80	20	20
CapacityToActivityUnit	PJ/GW	31.536	31.536	31.536

As per the table below, enter the capacity factors for the three electricity supply technologies, PWRHYD, PWRSOL and PWRWND. Also, in this case, remember to enter the values **for all years**.

TimeSlice	PWRHYD	PWRSOL	PWRWND
SD	0.30	0.45	0.30
SN	0.30	0.00	0.20



<b>WD</b>	0.50	0.35	0.25
<b>WN</b>	0.50	0.00	0.30

Remember that the capacity factors, in the case of renewable electricity supply, are what will indicate in the model that the resource is not always available and that only a part of the installed capacity may actually be used. Also, notice that the capacity factors have different values in different TimeSlices. This indicates that variable renewables might not always be there to meet the electricity demand, independently of what the demand profile is. That might cause other (non-renewable) power to be needed for meeting the demand. Reflect on all of this and go back to Lecture 5 for all the concepts. It will help you for the quiz of this hands-on.

## Activity 5 – Run the model

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**Now, generate a Case for this model, download the data file and run it (if you do not recall how, kindly go back to Activity 3 of Hands-on lecture 3).**

## Own reflection

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### Optional (no deliverable needed)

- What type of situation is your model representing now? What demands are included? What supply options are included?
- What changes in the results of exercise 2.4 compared to the previous exercise and why?
- What happens if the capacity factor of renewables changes, e.g. a change in hydro power or wind power capacity factors to ... (you may choose a reasonable value from national or international sources and re-run the model)
- What happens if the cost of a technology decreases, for instance, solar PV. Change the capital cost to... (you may choose a reasonable value from national or international sources and re-run the model).