Introduction to CLEWs

Hands-on lecture 8: Introducing the water system

V2.0

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Disclaimer: These worksheets have been adapted from work kindly provided by the United Nations Department of Economic and Social Affairs (UNDESA) and KTH Royal Institute of Technology.

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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.
4) Hands-on Solutions can be found here.

Pre-requisites:

1) Successful completion of all the activities under Hands-on Lecture 7.

Learning outcomes

In this exercise, you will learn how to represent the water system in a CLEWs model. You will do the following:

1) Learn how to represent water flows and resources in OSeMOSYS.
2) Reflect on the components of a water balance and learn how to represent the water balance in land technologies, using OSeMOSYS parameters.
3) Represent exogenous and endogenous water demands.

The following provides some key context around the variables that make up the water balance in your model:

Precipitation

The first component in the water balance is precipitation. Precipitation is any product of the condensation of atmospheric water vapour that falls under gravity from clouds. Common forms of precipitation include rain, snow and hail. The figure here presents the long-term monthly mean precipitation worldwide in mm per month. We can notice in a graphical form how the monthly precipitation varies, the darker colour indicating more rain and vice-versa. Many countries experience a single wet and dry season per year, but in some countries, two wet and dry seasons per year may occur signalling a bimodal precipitation pattern. According to the latest weather information, the wettest place on earth is a small town called Masynram in India with a monthly precipitation of approximately 12000 mm. The driest place is in the Atacama desert in Chile.

Evapotranspiration

The second component is called Evapotranspiration. It combines two processes: land surface evaporation and plant surface transpiration. Evaporation is the process whereby liquid water is converted to water vapour, also called vaporization, and removed from a surface, also called vapour removal. Water evaporates from a variety of surfaces, such as lakes, rivers, pavements, soils, and wet vegetation. Transpiration consists of vaporising liquid water in plant tissues and removing vapour from the atmosphere. Crops predominately lose their water through their stomata. These are small openings on the plant leaf through which gases and water vapour pass. Evapotranspiration is a function of many meteorological factors. Solar radiation and air temperature assist in the process of absorbing energy from the evaporating surfaces. Air humidity regulates the amount of moisture that the air can hold.

Humidity and Temperature are also related. The higher the air temperature, the greater the moisture capacity in the air, which eventually results in higher evapotranspiration. Wind speed increases the rate of transpiration from leaf surfaces.

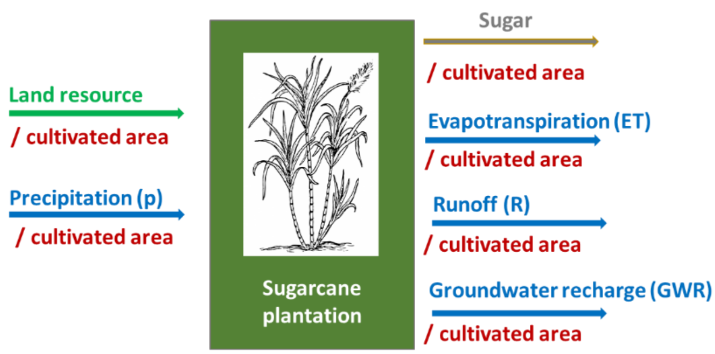
(Surface water) Runoff

Runoff is that portion of the precipitation that makes its way downstream in a catchment or watershed in the form of stream channels, lakes, or oceans as surface flow. It has different components ranging from surface and sub-surface runoff to base flow, which is underground. A set of meteorological factors governs the quantity of the runoff. The first is the type of precipitation in the form of rain, snow, sleet, etc. Rain falling on the earth's surface gets transformed into surface runoff based on the slope and the saturation level of soil moisture in the region. Snow falling on the ground will either remain as snow or melt and transform into the water to flow downstream. The intensity of precipitation affects runoff. The quantity and duration of a precipitation event could have disastrous effects like flash floods. The distribution of rainfall varies across a watershed and thereby affects the runoff. In a large watershed, there is a high chance that precipitation in the form of snow is more prevalent at high altitudes and as rainfall in low-lying areas.

Groundwater recharge

Groundwater is the water present beneath the earth's surface in soil pore spaces and the fractures of rock formations. Just below the surface, there is an unsaturated zone in the soil through which the water seeps. The water table starts at the point where the unsaturated zone ends. There are two types of aquifers underground. Unconfined aquifers are those that are not confined by any impermeable rocky layer. The confined aquifers are those separated from the other layers by hard impermeable rocks, also called aquitards. The unconfined aquifers are also easily accessible, and our modern water pumps usually tap water from this layer. The confined aquifers usually require deep and artesian wells to access the water within. It is also interesting to note that about 30% of global freshwater is in the form of groundwater. And 40% of all the irrigation in the world is from groundwater sources.

How does the water balance work in the model?

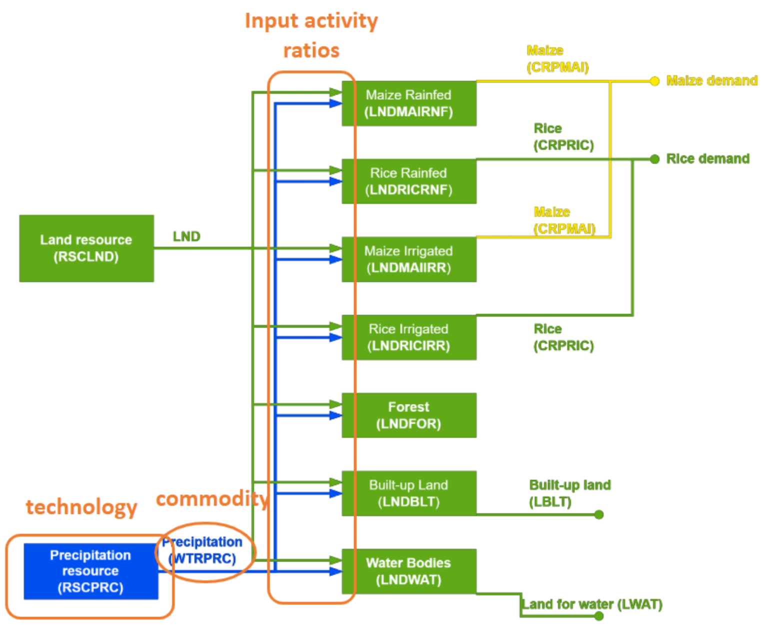


$$P = ET + R + GWR$$

The figure above illustrates the representation of the model after adding elements of climate, water and land. Here, the example of a rainfed sugarcane plantation is provided. All four components discussed previously are represented. The respective ratios will be calculated for each of the inputs and outputs, specific to the crop and the region and implemented inside the model. For the irrigated option, there will be an extra input of artificially supplied water, which will include its energy requirements for pumping. It is important to bear in mind that the water balance exists for all land cover types. It is not specific to agricultural land. In the model, groundwater recharge rates are usually kept constant, assuming that certain geology will have only a constant recharge rate. This assumption is used to simplify the representation of groundwater recharge in the example model. In country scale models, measured values can be used to accurately represent the actual recharge rate.

Activity 1 – Adding precipitation as a water source

1. In the section "Model configuration", select the tab "Commodities" to add the commodity: **WTRPRC**, precipitation, $10^9 m^3$ (or BCM – Billion Cubic Metres).



2. Select "**Update model**" to save your edits.

3. In the tab "**Technologies,**" add the technology "**RSCPRC**" representing the annual precipitation (water resource). Add **WTRPRC** as an output. Update your model.

4. On the Technologies tab, add the commodity **"WTRPRC"** as an input to all land cover technologies (except RSCLND). "Update model" to save your edits.

5. *The parameter **"Total Technology Annual Activity Upper Limit"** expresses the maximum precipitation available yearly.*

   The historic average annual precipitation is 1,200 mm, which, multiplied by the country's area (300 x $10^3 km^2$), indicates a maximum water volume from precipitation is 360 * $10^9 m^3$. Since $10^9 m^3$ is the unit considered for water volume, the value 360 is introduced in the "**Total Technology Annual Activity Upper Limit**" parameter.

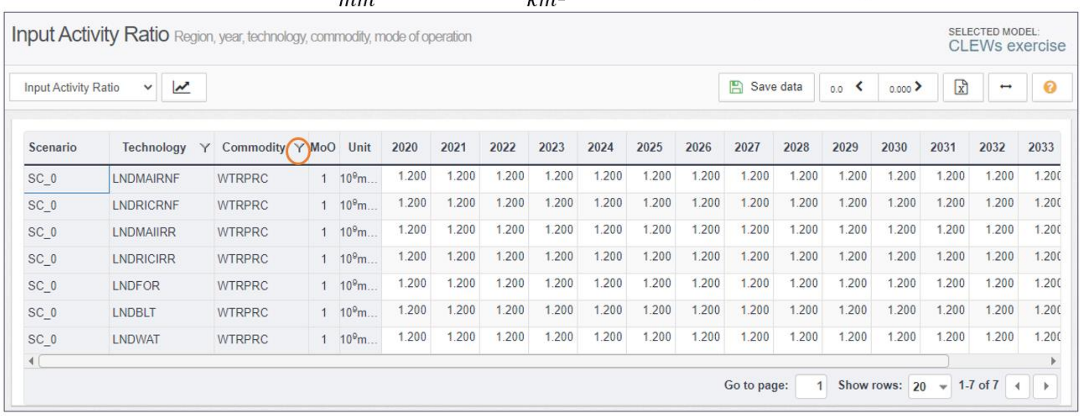
6. Update the “**Operational Life**” of the technology **“RSCPRC”** to 100.

7. Add the “**Output Activity Ratio**” for the precipitation resource technology (**RSCPRC**), and commodity “WTRPRC”, with value 1. “Save data” after your edits.

8. Add the **“Input Activity Ratio”** for the commodity precipitation **(WTRPRC)** to all the land cover technologies. The input is 1.2 x $10^9$$m^3$/unit of land area. “Save data” after your edits.

   The reason for the same number (per unit of area) being added to all the land technologies is that, for simplicity, we are assuming that precipitation is the same everywhere in our case. This could be different in a real application, if you had more spatially disaggregated data and had a model divided into different regions.

$$1200\ mm\ \times \frac{10^{-3}m}{mm} \times 10^3 km^2 \times \frac{10^6 m^2}{km^2} = 1.200 \times 10^9 m^3\ (or\ 1.2\ km^3)$$

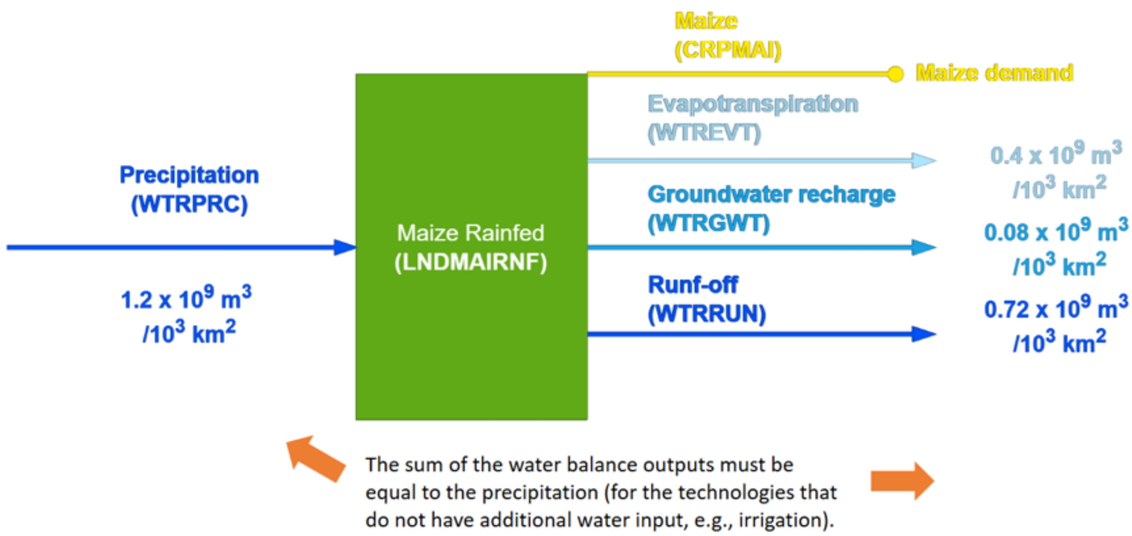


Scenario	Technology	Commodity	MoO	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
SC_0	LNDMAIRNF	WTRPRC	1	10^9m...	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.20
SC_0	LNDRICRNF	WTRPRC	1	10^9m...	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.20
SC_0	LNDMAIIRR	WTRPRC	1	10^9m...	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.20
SC_0	LNDRICIRR	WTRPRC	1	10^9m...	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.20
SC_0	LNDFOR	WTRPRC	1	10^9m...	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.20
SC_0	LNDBLT	WTRPRC	1	10^9m...	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.20
SC_0	LNDWAT	WTRPRC	1	10^9m...	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.20

Note: a filter was applied to the column “Commodity” to display the technologies with the commodity “WTRPRC” as an input.

9. **You do not need to run the model yet - but you could check out the model diagram (dynamic) to see what has changed in your RCLEWs…**

Activity 2 – Representing the water balance in land technologies

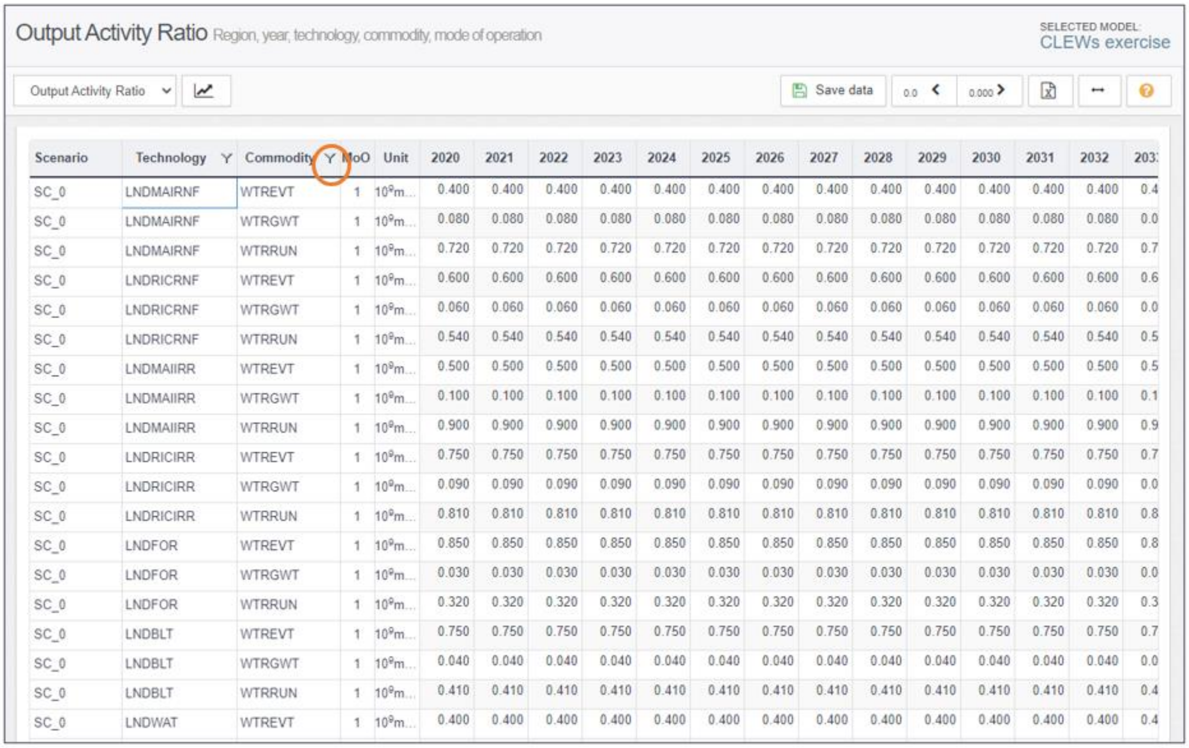


1. Create the additional commodities that represent the water balance (WTREVT, WTRGWR, WTRRUN) in the **"Configure model"** view and the tab **"Commodities".** Consider the following descriptions and units:
   - **WTREVT**, Evapotranspiration, 10^9 m^3
   - **WTRGWT**, Groundwater recharge, 10^9 m^3
   - **WTRRUN**, Run-off, 10^9 m^3

2. Still in "Model Configuration", go to the "Technologies" tab, and add the **outputs** of WTREVT, WTRGWT, and WTRRUN to all the land cover technologies (excluding RSCLND). "Update model" to save your edits.

3. Open the "CLEWs OU Data File" in Excel, and in the **sheet "4.2. Land",** go to the land cover technologies, and find the water balance elements that are outputs of all land technologies (WTREVT, WTRGWT and WTRRUN). Every land technology, that has WTRPRC has an input, will have WTREVT, WTRGWT and WTRUN as outputs. **Copy and paste directly from the Excel sheet, to reduce risk of error!**

4. Add the data for each technology in the “**Output Activity Ratio**” using the “Data Entry” in MUIO. “**Save data”** after the edits.



Scenario	Technology	Commodity	MoO	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	203
SC_0	LNDMAIRNF	WTREVT	1	10^9m...	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	LNDMAIRNF	WTRGWT	1	10^9m...	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.0
SC_0	LNDMAIRNF	WTRRUN	1	10^9m...	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.7
SC_0	LNDRICRNF	WTREVT	1	10^9m...	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.6
SC_0	LNDRICRNF	WTRGWT	1	10^9m...	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.0
SC_0	LNDRICRNF	WTRRUN	1	10^9m...	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.540	0.5
SC_0	LNDMAIIRR	WTREVT	1	10^9m...	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	LNDMAIIRR	WTRGWT	1	10^9m...	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.1
SC_0	LNDMAIIRR	WTRRUN	1	10^9m...	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.9
SC_0	LNDRICIRR	WTREVT	1	10^9m...	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.7
SC_0	LNDRICIRR	WTRGWT	1	10^9m...	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.090	0.0
SC_0	LNDRICIRR	WTRRUN	1	10^9m...	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.8
SC_0	LNDFOR	WTREVT	1	10^9m...	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.8
SC_0	LNDFOR	WTRGWT	1	10^9m...	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.0
SC_0	LNDFOR	WTRRUN	1	10^9m...	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.320	0.3
SC_0	LNDBLT	WTREVT	1	10^9m...	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.7
SC_0	LNDBLT	WTRGWT	1	10^9m...	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.0
SC_0	LNDBLT	WTRRUN	1	10^9m...	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.4
SC_0	LNDWAT	WTREVT	1	10^9m...	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

Note: a filter was applied to the column “Commodity” to display the technologies with the output commodities with name starting with “WTR”.

5. **Now RUN your model!** For the results, the **variables below** will be explored:

- **Use by Technology By Mode:** This shows the use of input commodities to a technology by mode of operation. Adjust the fields and filters to visualize the precipitation input per land cover type.

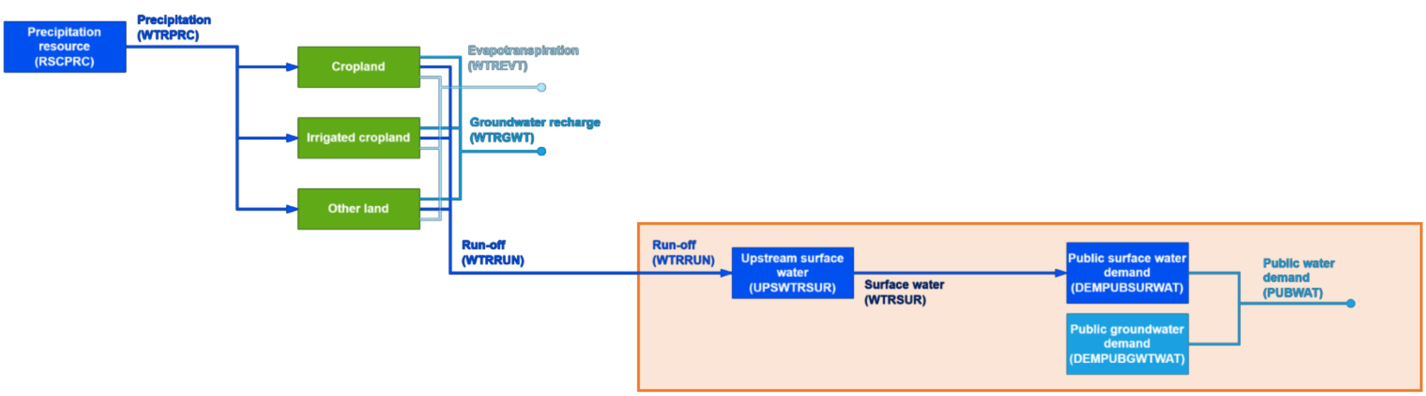
a) Change the graph from default (Accumulated New Capacity) to **‘Use by Technology by Mode’.**
b) Filter case (right click and go to field settings) to only the case run for HO8_A2.
c) Add Technology Description and untick Tech from **Columns** (or leave as tech if you want the naming conventions on your graph).
d) Add Commodity to **Filters** and filter out for only **WTRPRC**.

e) You should now see a result for how much water (precipitation) is being used by each land type. **Create a view** and give it a nice title, then you can save that view and download the graph if you wish!

- **Production By Technology By Mode**: This shows the number of outputs produced by a technology. In this exercise, it will be manipulated to visualize water balance outputs.

a) Add commodity to **columns** and untick tech.
b) **Filter for commodities and select** 'WTREVT', 'WTRGWT' and 'WTRRUN'.
c) You should now see a result for how much water is produced and by which commodity. **Create a view** and give it a nice title, then you can save that view and download the graph if you wish!

Activity 3 – Adding exogenous and endogenous water demands



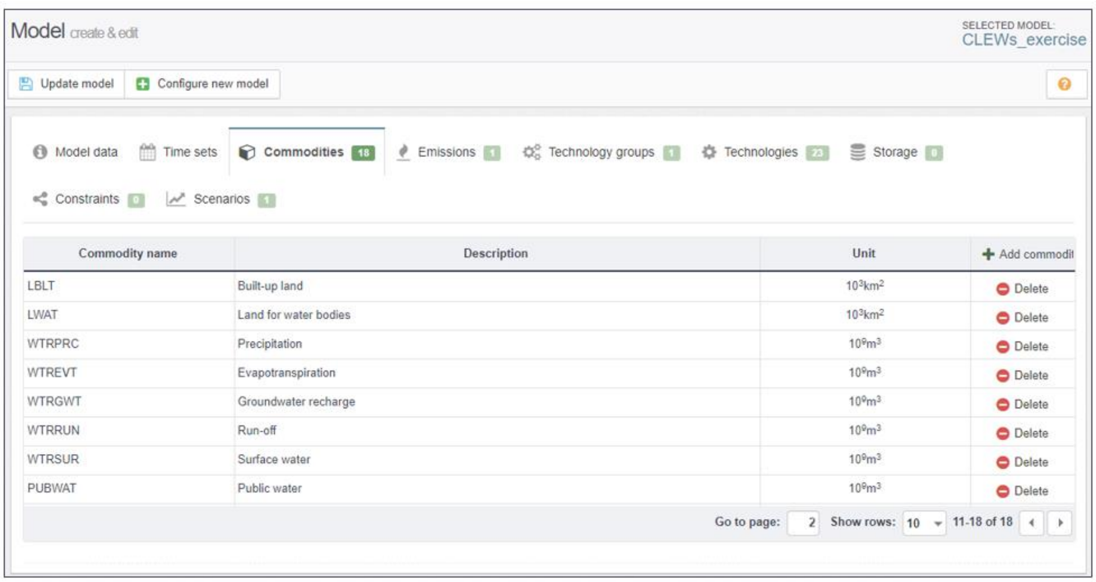
In the first part of this activity, you will add:

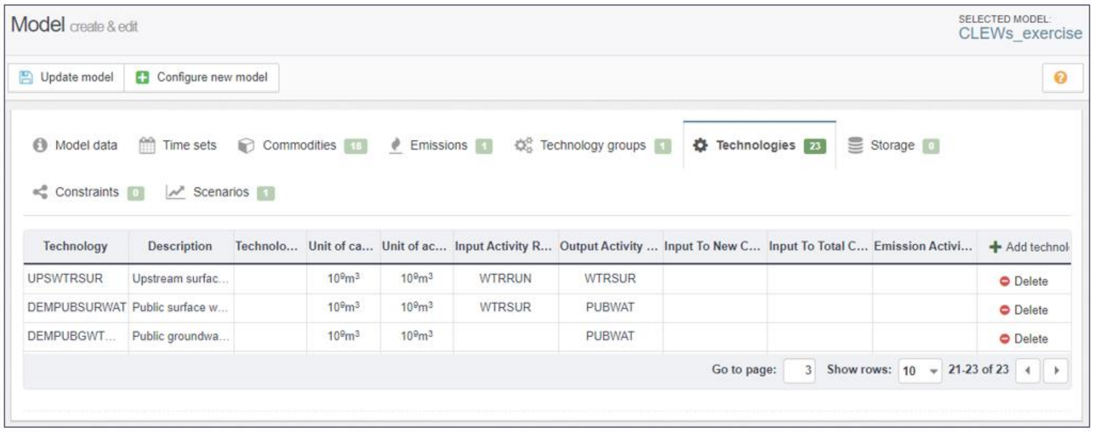
1) **2 commodities:** WTRSUR and PUBWAT
2) **3 technologies:** UPSWTRSUR, DEMPUBSURWAT, DEMPUBGWTWAT

1. In the section “Model configuration”, select the tab “Commodities” to add the commodities:
    - **WTRSUR**, Surface water, 10^9 m^3
    - **PUBWAT**, Public water, 10^9 m^3
    - Select “**Update model**” to save your edits.

2. In the tab “**Technologies**”, add the technologies “UPSWTRSUR”, “DEMPUBSURWAT” and “DEMPUBGWTWAT considering the information below. Select “**Update model**” to save your edits.

Technology	**Description**	**Unit Capacity**	**Unit Activity**	**Input Activity Ratio**	**Output Activity Ratio**
UPSWTRSUR	Upstream surface water	10^9 m^3	10^9 m^3	WTRRUN	WTRSUR
DEMPUBSURWAT	Public surface water demand	10^9 m^3	10^9 m^3	WTRSUR	PUBWAT
DEMPUBGWTWAT	Public groundwater demand	10^9 m^3	10^9 m^3	-	PUBWAT





Model create & edit

SELECTED MODEL: CLEWs_exercise

Update model | Configure new model

Model data | Time sets | Commodities 18 | Emissions 1 | Technology groups 1 | Technologies 23 | Storage 0 | Constraints 0 | Scenarios 1

Technology	Description	Technolo...	Unit of ca...	Unit of ac...	Input Activity R...	Output Activity ...	Input To New C...	Input To Total C...	Emission Activi...	Add technol
UPSWTRSUR	Upstream surfac...		10^9m^3	10^9m^3	WTRRUN	WTRSUR				Delete
DEMPUBSURWAT	Public surface w...		10^9m^3	10^9m^3	WTRSUR	PUBWAT				Delete
DEMPUBGWT...	Public groundwa...		10^9m^3	10^9m^3		PUBWAT				Delete

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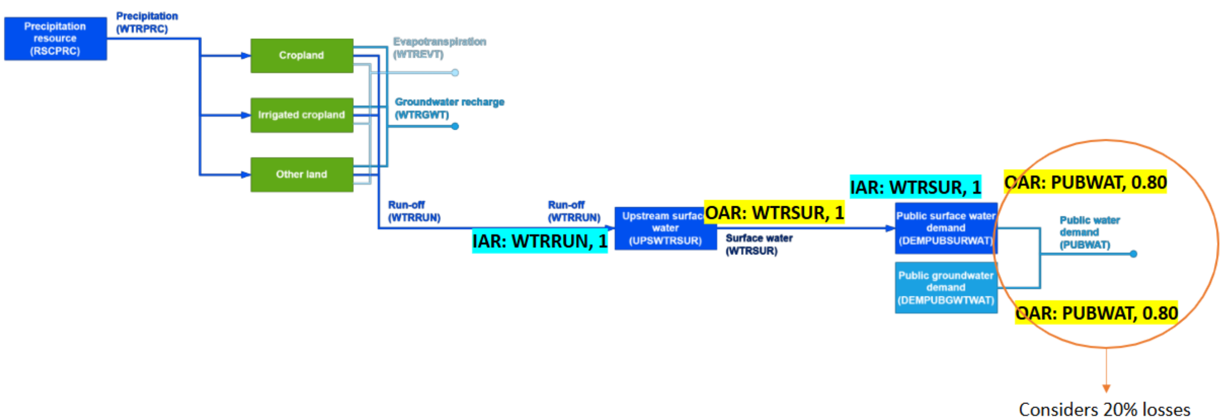
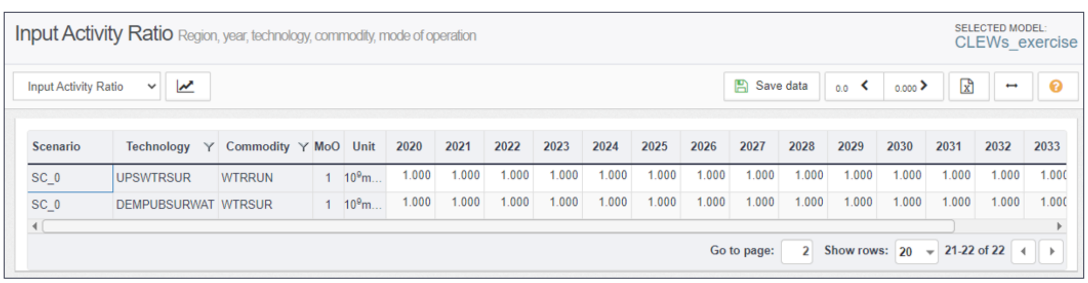
3. Add the respective **Input** and **Output Activity Ratios**, searching for the parameter in “Data entry”. **Save** your edits.





Input Activity Ratio Region, year, technology, commodity, mode of operation

SELECTED MODEL: CLEWs_exercise

Input Activity Ratio | Save data | 0.0 | 0.000

Scenario	Technology	Commodity	MoO	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
SC_0	UPSWTRSUR	WTRRUN	1	10^9m...	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	1.00(
SC_0	DEMPUBSURWAT	WTRSUR	1	10^9m...	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	1.00(

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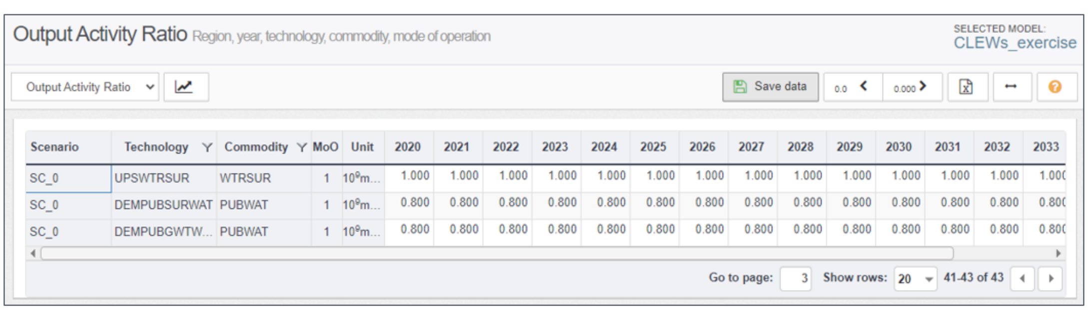

Output Activity Ratio Region, year, technology, commodity, mode of operation

SELECTED MODEL: CLEWs_exercise

Output Activity Ratio | Save data | 0.0 | 0.000

Scenario	Technology	Commodity	MoO	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
SC_0	UPSWTRSUR	WTRSUR	1	10^9m...	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	1.00(
SC_0	DEMPUBSURWAT	PUBWAT	1	10^9m...	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.80(
SC_0	DEMPUBGWTW...	PUBWAT	1	10^9m...	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.80(

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4. Add the respective techno-economic data, according to the information in the table below, and search for the parameters in "Data entry". **Save** your edits.

5. For the parameter "**Residual Capacity**", go to the CLEWs data Excel file, and in sheet **"4.4.Water",** search for the technologies added in this exercise and retrieve the **Residual Capacity** values, uploading them to the model. Save your edits.

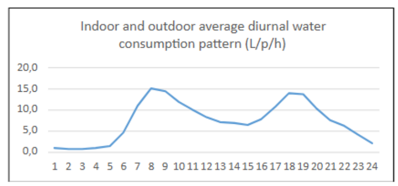
Parameter	Units	UPSWTRSUR	DEMPUBSURWAT	DEMPUBGWTWAT
Capital Cost	MUSD / 10^9 m^3	0.0001*	395	332
Fixed Cost	MUSD / 10^9 m^3	0.0001*	4	17
Variable Cost	MUSD / 10^9 m^3	0.0001*	0.0001*	0.0001*
Operational Life	Years	100	20	20
Residual Capacity	See CLEWs data Excel file, sheet "4.4. Water", searching for the corresponding technologies.			

* Default value

Public water demand assumptions:

- Public water consumption in 2020:
  - 175 litres per day in urban areas
  - 92 litres per day in rural areas
- Public water demand trends (2021-2035):
  - Increases with GDP/capita in urban areas
  - In rural areas, increases linearly until 75% of urban consumption rate in 2035
- Industrial and commercial water consumption correspond to 10% and 3% of public water demand, respectively

Public water consumption profile:



Timeslice	hours in day	hours/ day	days/ year	Consumption (Lpd)	Consumption (L/p/year)	Specified Demand Profile (PUBWAT)
SD	8 am (inc) - 11 pm (inc)	16	184	145.6	26790.4	0.443
SN	12 am - 7 am	8	184	20.1	3698.4	0.061
WD	8 am - 9 pm	14	181	136	24616.0	0.407
WN	10 pm - 7 am	10	181	29.7	5375.7	0.089
				331.4	60480.5	1.000

Specified Demand Profile = Consumption [timeslice] / Total consumption
e.g., for timeslice SD (summer day)
Specified Demand Profile = 26,790.4 / 60,480.5 = 0.443

6. Add the "**Specified Demand Profile**" for the commodity "**PUBWAT**" considering the values in the previous slide. Navigate to "Data entry" to find the parameter. **Save your edits.**

Specified Demand Profile Region, year, commodity, timeslice

SELECTED MODEL:
CLEWs exercise

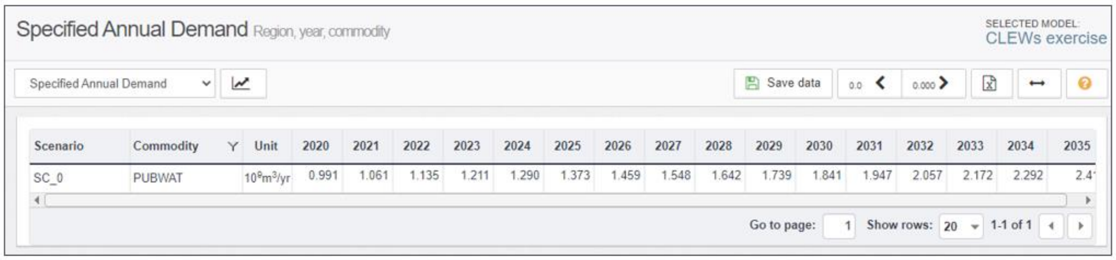
Specified Demand Profile | Save data | 0.0 | 0.000

Scenario	Commodity	Timeslice	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
SC_0	PUBWAT	SD	%/100	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.443	0.4
SC_0	PUBWAT	SN	%/100	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.0
SC_0	PUBWAT	WD	%/100	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.407	0.4
SC_0	PUBWAT	WN	%/100	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.0

Go to page: 1 Show rows: 20 1-4 of 4

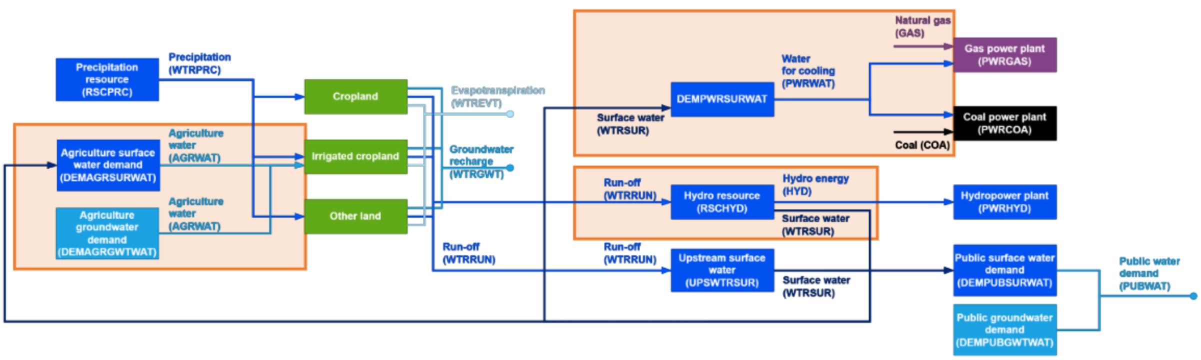
Note: A filter was applied in the column "Commodity" to show only "PUBWAT".

7. For the parameter “**Specified Annual Demand**”, go to the CLEWs data Excel file and in sheet “Assumptions”, and in line #226 (Exogenous demands), find the demand for PUBWAT. Copy those values and insert them in the model in “Specified Annual Demand” for the commodity “PUBWAT”.



Scenario	Commodity	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
SC_0	PUBWAT	$10^9 m^3/yr$	0.991	1.061	1.135	1.211	1.290	1.373	1.459	1.548	1.642	1.739	1.841	1.947	2.057	2.172	2.292	2.4

Note: A filter was applied in the column “Commodity” to show only “PUBWAT”.



NOTE: You could run the model now if you want, but you do not need to.

In the second part of this activity, you will add:

- **2 new commodities:** AGRWAT, PWRWAT
- **3 new technologies:** DEMAGRSURWAT, DEMAGRGWTWAT, DEMPWRSURWAT

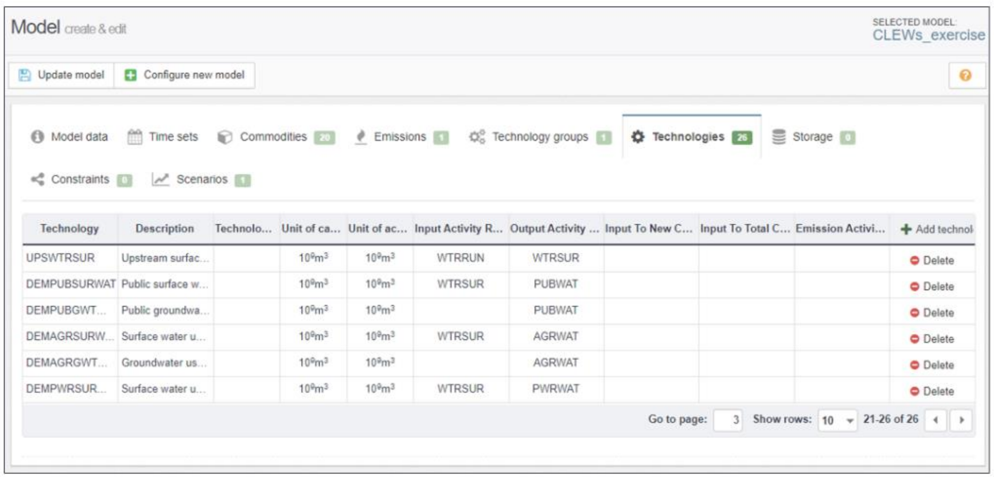
Then you must establish technology and commodity links and update existing entries (RSCHYD, WTRSUR; AGRWAT to irrigated technologies; PWRWAT to thermal power plants)

8. In the section “Define model configuration”, select the tab “Commodities” to add the commodities:

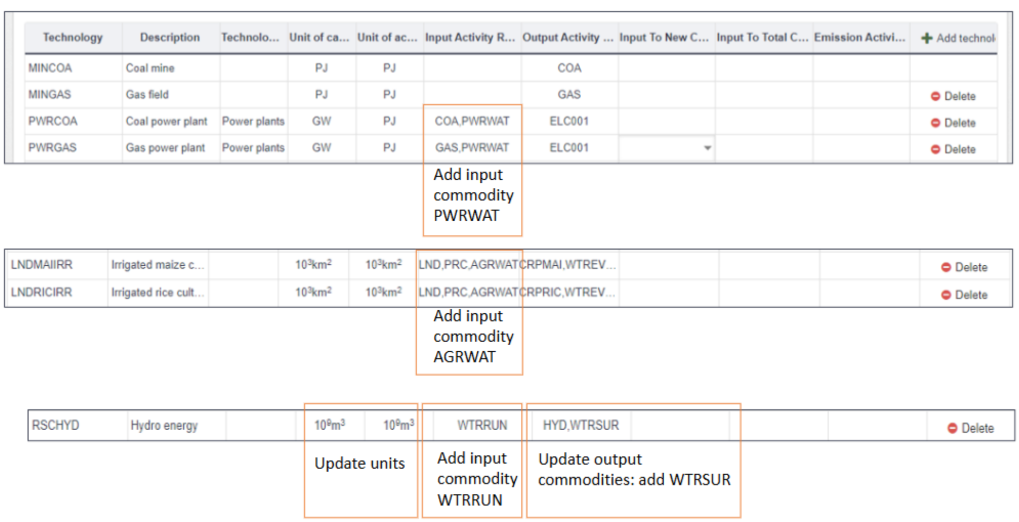
    - **AGRWAT**, “Water for agriculture”, 10^9 m^3
    - **PWRWAT**, “Water for the power sector”, 10^9 m^3
    - Select “Update model” to save your edits.

9. In the tab “**Technologies**”, add the technologies “DEMAGRSURWAT”, “DEMAGRGWTWAT”, and “DEMPWRSURWAT considering the described below. Select “**Update model**” to save your edits.

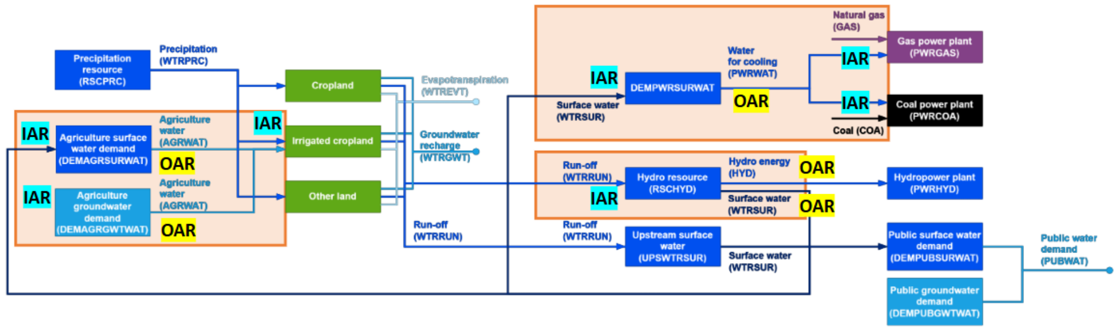
Technology	Description	Unit Capacity	Unit Activity	Input Activity Ratio	Output Activity Ratio
DEMAGRSURWAT	Surface water used in agriculture	10^9 m³	10^9 m³	WTRSUR	AGRWAT
DEMAGRGWTWAT	Groundwater used in agriculture	10^9 m³	10^9 m³	-	AGRWAT
DEMPWRSURWAT	Surface water used in the power sector	10^9 m³	10^9 m³	WTRSUR	PWRWAT



Updates to existing technologies:



10. You will now add information to the parameters “Input Activity Ratio” and “Output Activity Ratio”.



11. Go to "**Data entry**" and add "**Input Activity Ratio**" data (for all years), according to the table below. **Save** your edits.

Technology	Commodity	Mode of Operation	Unit	Input Activity Ratio (2020-2035)
DEMAGRSURWAT	WTRSUR	1	10^9 m³ / 10^9 m³	1
DEMPWRSURWAT	WTRSUR	1	10^9 m³ / 10^9 m³	1
RSCHYD	WTRRUN	1	10^9 m³ / 10^9 m³	1
LNDMAIIRR	AGRWAT	1	10^9 m³ / 10^9 m³	0.30
LNDRICIRR	AGRWAT	1	10^9 m³ / 10^9 m³	0.45
PWRCOA	PWRWAT	1	10^9 m³ / PJ	0.0007
PWRGAS	PWRWAT	1	10^9 m³ / PJ	0.0002

Note:

0.0007 and 0.0002 might not appear as they are very small numbers. Type on the upper right command to display more decimals

12. Go to "**Data entry**" and add data for "**Output Activity Ratio**", according to the information in the table below. **Save** your edits.

Technology	Commodity	Mode of Operation	Unit	Output Activity Ratio (2020-2035)
DEMAGRSURWAT	AGRWAT	1	10^9 m³ / 10^9 m³	0.70
DEMAGRGWTWAT	AGRWAT	1	10^9 m³ / 10^9 m³	0.70
DEMPWRSURWAT	PWRWAT	1	10^9 m³ / 10^9 m³	0.80
RSCHYD	WTRSUR	1	10^9 m³ / 10^9 m³	1
	HYD	1	PJ / 10^9 m³	0.40

NOTE: The two outputs from the hydro energy resource technology represent the volume of surface water available downstream (WTRSUR) measured in billion cubic meters (10^9 m^3) and the hydroelectric energy potential (HYD) available for power generation measured in Petajoules.

Scenario	Technology	Commodity	MoO	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
SC_0	RSCHYD	HYD	1	PJ/10...	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
SC_0	RSCHYD	WTRSUR	1	10^9m^3...	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
SC_0	LNDWAT	LWAT	1	10^3km...	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
SC_0	LNDWAT	WTREVT	1	10^9m^3...	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000	0.4000
SC_0	LNDWAT	WTRGWT	1	10^9m^3...	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800	0.0800
SC_0	LNDWAT	WTRRUN	1	10^9m^3...	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200	0.7200
SC_0	DEMPUBSURWAT	PUBWAT	1	10^9m^3...	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
SC_0	DEMPUBGWTWAT	PUBWAT	1	10^9m^3...	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000
SC_0	DEMAGRSURWAT	AGRWAT	1	10^9m^3...	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000
SC_0	DEMAGRGWTWAT	AGRWAT	1	10^9m^3...	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000	0.7000
SC_0	DEMPWRSURWAT	PWRWAT	1	10^9m^3...	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000	0.8000

Note: Filters were applied to "Technology" to show technologies with "WAT" in the name or "RSCHYD".

13. Add the respective techno-economic data, according to the information in the table below, and search for the parameters in "**Data entry**". **Save** your edits.

Parameter	Units	DEMAGRSURWAT	DEMAGRGWTWAT	DEMPWRSURWAT	RSCHYD
Capital Cost	MUSD / 10^9 m^3	137	332	395	0.0001 *
Fixed Cost	MUSD / 10^9 m^3	7	17	4	0.0001 *
Variable Cost	MUSD / 10^9 m^3	0.0001 *	0.0001 *	0.0001 *	0.0001 *
Operational Life	Years	20	20	20	100
Residual Capacity	10^9 m^3	CLEWs data Excel file , sheet "4.3. Water"			0 *

* Default value.

14. For the parameter "**Residual Capacity**", go to the CLEWs data Excel file and in sheet "4.4.Water", search for the technologies added in this exercise and retrieve the "Residual Capacity" values, uploading them to the model. **Save** your edits.

Scenario	Technology	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
SC_0	LNDWAT	10^3km^2	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000	25.000
SC_0	DEMPUBSURWAT	10^9m^3	0.920	0.850	0.790	0.730	0.670	0.610	0.550	0.490	0.430	0.370	0.310	0.240	0.180	0.120	0.060	0.000
SC_0	DEMPUBGWTWAT	10^9m^3	0.830	0.770	0.720	0.660	0.610	0.550	0.500	0.440	0.390	0.330	0.280	0.220	0.170	0.110	0.060	0.000
SC_0	DEMAGRSURWAT	10^9m^3	1.000	0.930	0.870	0.800	0.730	0.670	0.600	0.530	0.470	0.400	0.330	0.270	0.200	0.130	0.070	0.000
SC_0	DEMAGRGWTWAT	10^9m^3	0.500	0.470	0.430	0.400	0.370	0.330	0.300	0.270	0.230	0.200	0.170	0.130	0.100	0.070	0.030	0.000
SC_0	DEMPWRSURWAT	10^9m^3	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140	0.140

Activity 4 – Running the Model

This is the first time running the model containing the energy system, the land system and the water system, before interlinkages, in the CLEWs model.

NOTE: Refer back to the steps in Activity 2 if you have forgotten how to view results.

Something you may need to do here is tick 'Show Column Totals', to see the totals per year for each graph visualised in MUIO.

In this activity, the results for the **variables below** should be explored:

1. **Use by Technology by Mode:** This shows how much of a commodity is used by a technology**.** Visualise **ONLY** the water usage (AGRWAT & PWRWAT) of technologies for irrigation and cooling systems of thermal power plants.

2. **Production By Technology By Mode**: This shows the number of outputs produced by a technology. Visualise **ONLY** the water produced by irrigation, cooling systems of thermal power plants, and for public water supply.

3. **Production By Technology By Mode**: Visualise **ALL** water production (except WTRPRC). Compare this to the results from HO8 Activity 2.

4. **Annualized Investment Costs:** The annualised (yearly) costs of an investment.

a) For Hands-on 8 Activity 4, you can see how much annually it will cost to run **DEMAGRSURWAT, DEMPUBSURWAT** and **DEMPWRSURWAT**.
b) Add Tech Desc into columns and filter for the technologies in Step a).
c) Now you can create a view with a suitable title, so you can refer back to it at any time!