CLEWs

Hands-on lecture 7: Introducing new parameters and the Water system

Useful links:

1) Link to open [Momani](#) in the local computer
2) [Discussion forum](#) for OSeMOSYS
3) [Results from this Hands-on](#)

Pre-requisites:
1) Successful completion of Hands-on lecture 6

Learning outcomes

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

1) Understand the usage of parameters that facilitate the implementation of capacity and activity constraints
2) Add technologies and commodities to represent the water system and its linkages

Overview

Until now, You have been building aspects of energy and land systems into the model. In this hands-on exercise, you will create commodities and technologies to represent the water system in the CLEWs model. Before representing the water system, we will have a short overview of some new parameters that facilitate the implementation of capacity and activity constraints. Following that, you will use these parameters in the first activity to implement some constraints on some land cover types. The following table presents four capacity and activity related parameters and their functionality.

Parameter	Limit on?	Description
TotalAnnualMinCapacity	Capacity	Total annual capacity must be higher than this value
TotalAnnualMinCapacityInvestment	Capacity	New annual capacity must be higher than this value
TotalAnnualMaxCapacity	Capacity	Total annual capacity cannot exceed this value
TotalAnnualMaxCapacityInvestment	Capacity	New annual capacity cannot exceed this value
TotalTechnologyAnnualActivityLowerLimit	Activity	Annual activity must be higher than this value
TotalTechnologyAnnualActivityUpperLimit	Activity	Annual activity cannot exceed this value
TechnologyActivityByModeLowerLimit	Activity	Annual activity in a specific mode must be higher than this value
TechnologyActivityByModeUpperLimit	Activity	Annual activity in a specific mode cannot exceed this value
TotalTechnologyModelPeriodActivityLowerLimit	Activity	Total activity over the entire model period must be higher than this value
TotalTechnologyModelPeriodActivityUpperLimit	Activity	Total activity over the entire model period cannot exceed this value

It must be taken into consideration that the parameters described above have different indices. Some may be defined for each mode of operation, whereas some may have to be defined for the technology as a whole. The table below gives the indices of the respective parameters. An understanding of the indices will also help in data-entry routines. They help in choosing the suitable drop-downs on Momani to enter the data. It is also important to note that each of these parameters has a default value in OSeMOSYS. Therefore, if the parameters are not specified explicitly, the default value is assumed. The table below also details the default value of the parameters.

Parameter	Indices	Default Value
TotalAnnualMinCapacity	Region,Technology, Year	0
TotalAnnualMinCapacityInvestment	Region,Technology, Year	0
TotalAnnualMaxCapacity	Region,Technology, Year	9999999
TotalAnnualMaxCapacityInvestment	Region,Technology, Year	9999999
TotalTechnologyAnnualActivityLowerLimit	Region,Technology, Year	0
TotalTechnologyAnnualActivityUpperLimit	Region,Technology, Year	9999999
TechnologyActivityByModeLowerLimit	Region,Technology, Mode of Operation, Year	0
TechnologyActivityByModeUpperLimit	Region,Technology, Mode of Operation, Year	9999999
TotalTechnologyModelPeriodActivityLowerLimit	Region,Technology	0
TotalTechnologyModelPeriodActivityUpperLimit	Region,Technology	9999999

An explanation for the use of activity limits

- They can be used to restrict or force the annual activity of a technology. For example, the maximum/minimum annual production capability (activity) of a biodiesel plant can be implemented using the following parameters. These parameters can be used to restrict the total activity of the technology. They are mode-independent.

Parameter	Y0	Y1	Y2	Yn
TotalTechnologyAnnualActivityUpperLimit	ValueMax	ValueMax	ValueMax	ValueMax
TotalTechnologyAnnualActivityLowerLimit	ValueMin	ValueMin	ValueMin	ValueMin

- They can be used to restrict or force the annual activity of the technology in a certain mode of operation. For example, the following parameters can determine the annual activity of a type of land cover. These modes-dependant parameters need to be used carefully, as they may compete with the technology activity limits.

Parameter	Mode	Y0	Y1	Y2	Yn
Technology Activity By Mode Upper Limit	Mode #	ValueMax	ValueMax	ValueMax	ValueMax
Technology Activity By Mode Lower Limit	Mode #	ValueMin	ValueMin	ValueMin	ValueMin

- They can also be used to define a technology's maximum activity for the entire model period. For example, suppose the exploitable quantity of oil reserves in a country is fixed. In that case, this parameter can give a maximum value for that number in a country. Similarly, the parameters can also be used in need of a minimum activity constraint.

Parameter	Model period
TotalTechnologyModelPeriod ActivityUpperLimit	ValueMax
TotalTechnologyModelPeriod ActivityLowerLimit	ValueMin

Activity 1 – Introducing activity constraints for built-up land and water bodies

In this activity, you will use the parameters introduced above to implement activity constraints for built-up land and water bodies. You will work with mode dependant activity upper and lower limits as detailed below.
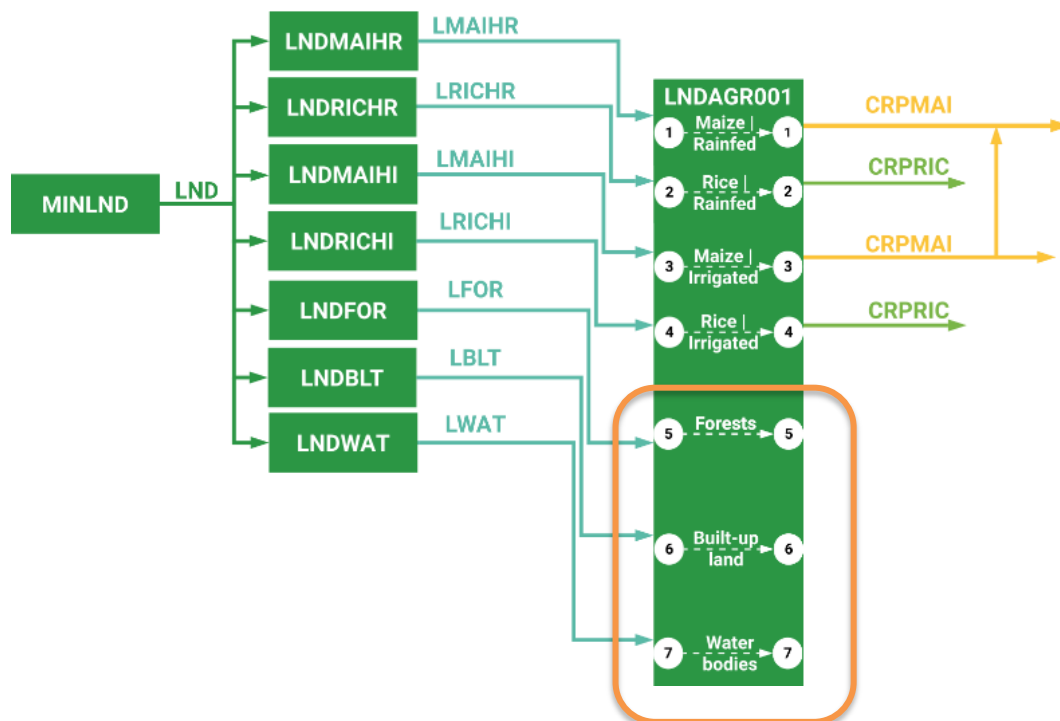

Let us assume that the land allocated to the built-up land category (mode 6) increases from 70 units in 2019 at an annual growth rate of 2% until 2022. i.e. the value in 2020 will be 70 * 1.02, and the value in 2021 will be 70 * 1.02 * 1.02 and so on. You will have to use the parameter **"TechnologyActivityByModeLowerLimit"**. Additionally, the land allocated to water bodies (mode 7) is expected to remain constant at 30 units from 2019 to 2022. Use the same parameter as the built-up land addition. When the changes mentioned above have been implemented, kindly re-run the model on the online platform and visualize the results.

Activity 2 – Introducing the water system linkages-part1

Kindly create a new version of the model by cloning the last one.

Before jumping into the water system, we will have a brief overview of the connections in the water system. At the end of this hands-on, you should have represented the following setup inside the CLEWs model.
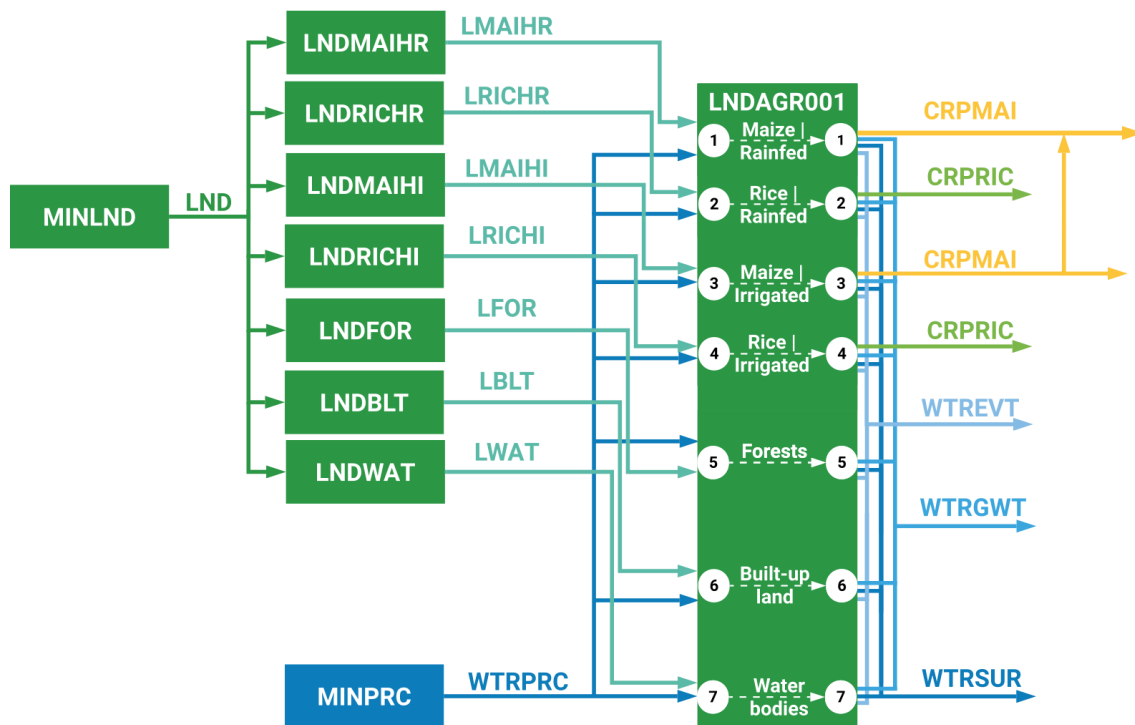
When it comes to the Water system, there are two main inputs and three main outputs that interact with the land system. The classification of agricultural land is actually a function of the type of water input. Based on the artificial supply of water, they are differentiated into irrigated or rainfed type land. The figure below illustrates the possible linkages with the example of Maize cultivation.

At first, you will explore the interactions for Maize crop in a rainfed setting and then gradually capture all the possible linkages for different land cover types. The following figure shows the water balance for Maize in rainfed conditions. It must be noted that all the water inputs and outputs for a land-use category must be in the same mode of operation (mode 1 in this example for Rainfed Maize). For this activity, we will need to add one new technology (MINPRC) and four new commodities (WTRPRC, WTREVT, WTRGWT, WTRSUR).
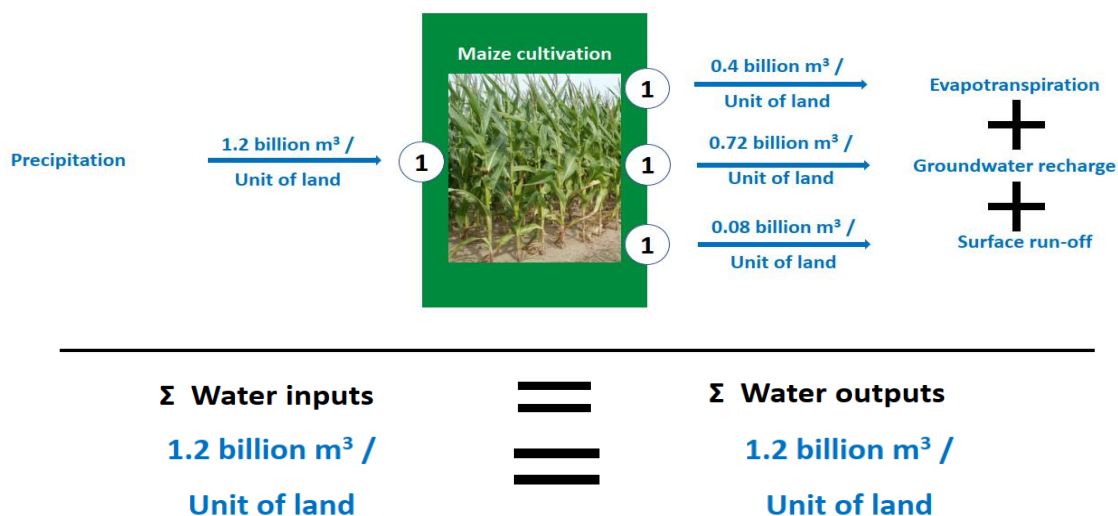
Naming convention	Entity	Description
MINPRC	Technology	Technology that produces rain
WTRPRC	Commodity	Precipitation water
WTREVT	Commodity	Water that is evapotranspirated
WTRGWT	Commodity	Water for groundwater recharge
WTRSUR	Commodity	Water in surface water sources

You need to make sure that all the commodities are always linked to a technology at their source. For example, the commodity WTRPRC in this model will have to be produced by a technology (MINPRC). In this activity, we will add only the inputs from precipitation and all the relevant outputs. The component for irrigated water is discussed in the following activity. The following table provides the input for this activity.

Technology	Commodity	Value	Parameter
MINPRC	WTRPRC	1 billion m^3 / billion m^3	OutputActivityRatio

As discussed above, you will first need to connect the commodity for precipitation with its source using the parameter **"OutputActivityRatio".** Following that, you will have to input the necessary links for the water system in the **"LNDAGR001"** technology. All the data in the following table needs to go into the same LNDAGR001 technology.

Input water commodities	Mode	Output water commodities		
WTRPRC		**WTREVT**	**WTRGWT**	**WTRSUR**
1.2	**1 (Maize, Rain-fed)**	**0.4**	**0.08**	**0.72**
1.2	**2 (Rice, Rain-fed)**	**0.6**	**0.06**	**0.54**
1.2	**3 (Maize, Irrigated)**	**0.5**	**0.1**	**0.9**
1.2	**4 (Rice, Irrigated)**	**0.75**	**0.09**	**0.81**
1.2	**5 (Forests)**	**0.85**	**0.03**	**0.32**
1.2	**6 (Built-up land)**	**0.75**	**0.04**	**0.41**
1.2	**7 (Water bodies)**	**0.4**	**0.08**	**0.72**

There are many ways to input the above data into the model. The simplest is to enter the data, one commodity at a time. The unit for all the above input is **billion m³ / 1000 sq. km**.

After adding all the inputs, run the model.

# Activity 3 – Introducing the water system linkages – part 2

In this activity, you will introduce the water used for irrigation and include new technologies and commodities to represent the amount of water used to meet the public demand. You will also differentiate between surface and groundwater resources. Your model structure for the land and water systems should look like the diagram illustrated below at the end of the activity.
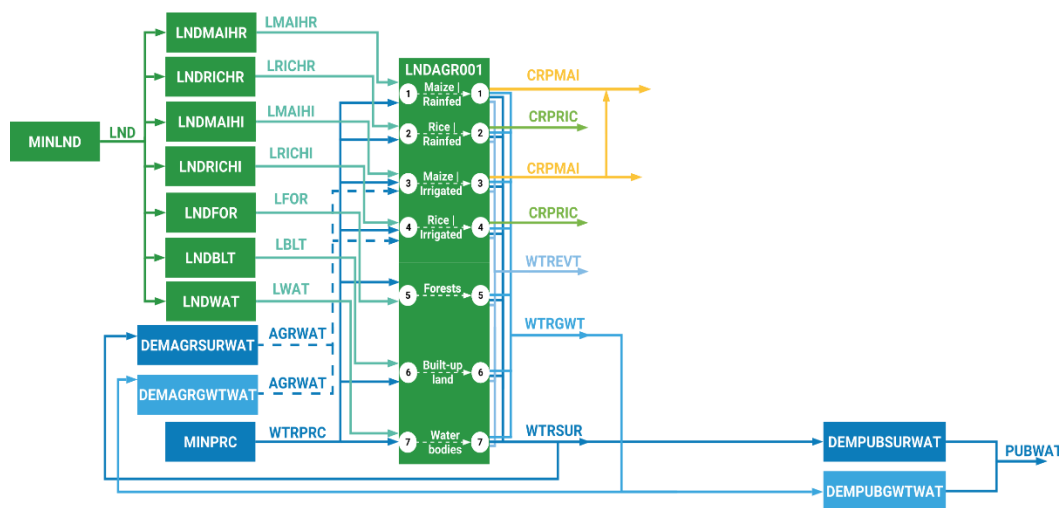
Before starting the activity, we will go through some of the inputs and output schematics to understand the linkages.
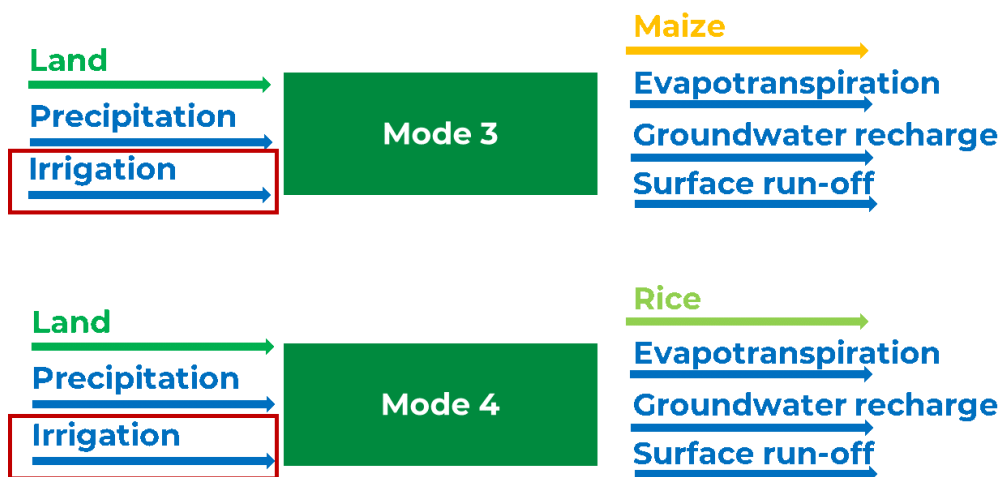
The commodity to represent the water for irrigation is called AGRWAT (Agricultural Water). You will need to add this new commodity. AGRWAT can be obtained from both surface water (WTRSUR) and groundwater (WTRGWT). Similarly, the water for public consumption (PUBWAT) can also be satisfied by the same two sources. To account for water consumption from different sources and differentiate the demands, we use four new technologies. Technologies **DEMAGRSURWAT** and **DEMAGRGWTWAT** cater to account for the water used for irrigation. Technologies **DEMPUBSURWAT** and **DEMPUBGWTWAT** account for the public water supply.
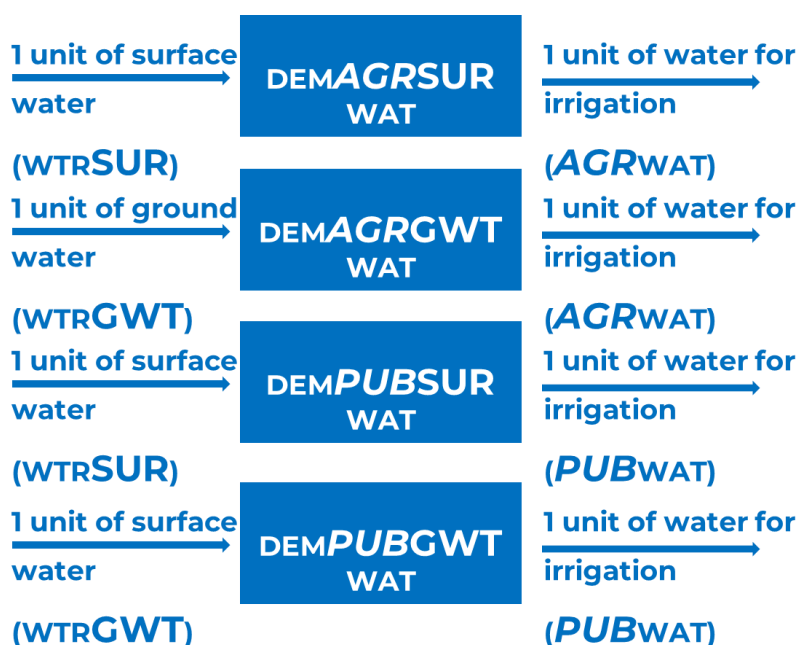
By now, you must be proficient in adding new technologies and commodities. Kindly add the following.

- New technologies: DEMAGRSURWAT, DEMAGRGWTWAT, DEMPUBSURWAT, DEMPUBGWTWAT
- New commodities: AGRWAT, PUBWAT

When plants are irrigated, their yields increase, and at the same time, evapotranspiration and other water outputs also increase. This can be observed in the following illustration for irrigated maize land. The balance still has to be maintained.
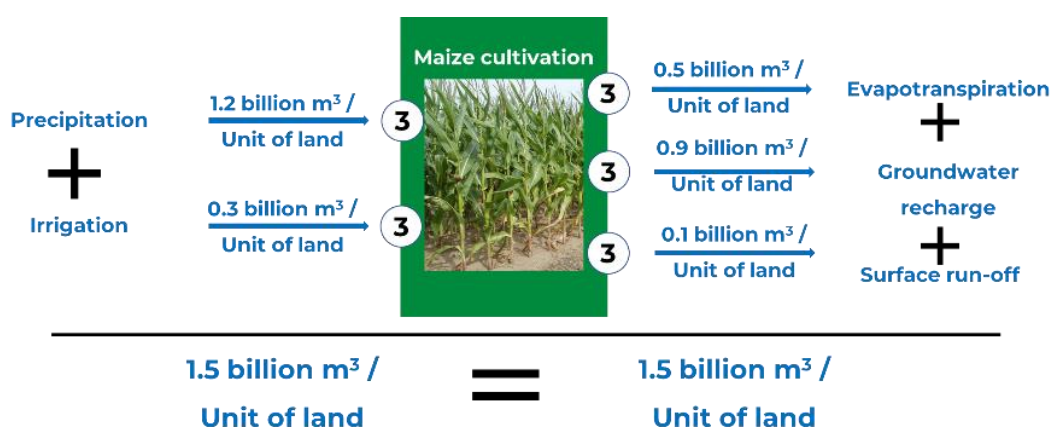
The following table provides the necessary ratios for AGRWAT input for the irrigated Maize and Rice land. The new inputs needed are marked in red. The table refers once more to the technology LNDAGR001. Once again, the unit for all the data in the table is **billion m³ / 1000 sq. km**.

Input water commodities		Mode	Output water commodities		
WTRPRC	AGRWAT		WTREVT	WTRGWT	WTRSUR
1.2		1 (Maize, Rain-fed)	0.4	0.08	0.72
1.2		2 (Rice, Rain-fed)	0.6	0.06	0.54
1.2	0.3	3 (Maize, Irrigated)	0.5	0.1	0.9
1.2	0.45	4 (Rice, Irrigated)	0.75	0.09	0.81
1.2		5 (Forests)	0.85	0.03	0.32
1.2		6 (Built-up land)	0.75	0.04	0.41
1.2		7 (Water bodies)	0.4	0.08	0.72

You will have to include the AGRWAT inputs in the respective modes (3 and 4). Additionally, you will also implement a new demand for public water. The parameter "**AccumulatedAnnualDemand**" will be used for this purpose. It is expected that the public water demand (PUBWAT) increases from 12 billion cubic meters (BCM) in 2019 at an annual growth rate of 2% until 2022. You will also need to make the connections between the water supply technologies to the demand centres. The following table details all the inputs and outputs that need to be established. Kindly note that all the water demand technologies specified below operate in mode-1.

DEMAGRSURWAT	Water supply technology that uses **1 unit** of **WTRSUR** to produce **1 unit** of **AGRWAT**	**InputActivityRatio & OutputActivityRatio**
DEMAGRGWTWAT	Water supply technology that uses **1 unit** of **WTRGWT** to produce **1 unit** of **AGRWAT**	**InputActivityRatio & OutputActivityRatio**
DEMPUBSURWAT	Water supply technology that uses **1 unit** of **WTRSUR** to produce **1 unit** of **PUBWAT**	**InputActivityRatio & OutputActivityRatio**
DEMPUBGWTWAT	Water supply technology that uses **1 unit** of **WTRGWT** to produce **1 unit** of **PUBWAT**	**InputActivityRatio & OutputActivityRatio**

Once all the data entry is complete, kindly re-run the model and visualize the results using the online platform.