Energy and Flexibility Modelling

OSeMOSYS Constraints: Definition and Simple Applications

Please use the following citation for:

- **This Exercise**

  Rodriguez-Arce Mariana (2023, January). Definition and Simple Applications: Energy and Flexibility Modelling (Version 3.0.). Zenodo.

- **clicSAND Software**

  Cannone, C., Allington, L., De Wet, N., Shivakumar, A., Goyns, P., Valderrama, C., Howells, M. (2022). clicSAND [computer software]. https://doi.org/10.5281/zenodo.6525441

- **OSeMOSYS Google Forum**

Please sign up for the help Google forum here. If you are stuck, please ask questions here. If you get ahead, please answer questions in the same forum. Please state that you are using the 'clicSAND' Interface.

Learning outcomes

By the end of this exercise, you will be able to do the following in OSeMOSYS:

1. Translate a renewable production target policy into constraints for modeling.
2. Limit electricity imports

Context

The Wakanda Generation Expansion Plan (WAGEP) aims to increase the deployment of solar generation technologies into the system's power matrix.

The creation of the Plan involved various participatory workshops in which sectoral experts, policymakers, and social society members proposed deploying more solar power technologies. With the insights from participants, the Energy Secretariat proposed generation targets for three different solar technologies: Utility-scale PV with 2-hour storage, Solar PV (Utility), and Solar PV (Distributed with Storage). The objective is that **at least** the percentages are reached in the established years, assuming a progressive growth until reaching the goals shown in Figure 1:

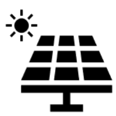
Code	Description	2023	2030	2050
	Utility-scale PV with 2-hour storage	0%	10%	18%
	Solar PV (Utility)	0%	10%	15%
	Solar PV (Distributed with Storage)	0%	5%	10%

Figure 1: WAGEP Targets

Also, WAGEP aims to promote power autonomy, and establishes a decrease in electricity imports until reaching in 2050 35% of the value of imports in 2023.

The Ministry of Environment created a model with multiple scenarios, and they want to incorporate an additional scenario that considers the Least Cost scenario and the goals established in WAGEP. The Least Cost Scenario will reflect the optimal configuration of the energy system under which the cost is minimized.

Thinking phase

Discuss how to model these policies. Be curious!

Run the scenario

In this section of the Hands-on, we will demonstrate the approach to translating the policy into a constraint to achieve the policy's target. There could be other ways, and this is just an example.

Policy 1: Deployment of photovoltaic generation

In this policy, we can use the **SpecifiedAnnualDemand** to calculate the targeted production from the relevant technologies. In this ClicSAND file, there is only non-zero **SpecifiedAnnualDemand** for **COMELC**, **RESELC**, and **INDELC**; therefore, the aggregated yearly demand for these fuel types will be used to calculate the values for the **TotalTechnologyAnnualActivityLowerLimit**.

An important consideration is that there are losses in the electricity system; therefore, we need to consider them when we define the **TotalTechnologyAnnualActivityLowerLimit** of each technology. Losses can be modeled using the OutputActivityRatio or the InputActivityRatio. Be careful and always check the method.

Before changing your data model, create a Data_prep file. To solve this problem, we need the following information:

- **SpecifiedAnnualDemand** of INDELC, RESELC and COMELC

Parameter	FUEL	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	20
SpecifiedAnnualDemand	INDELC	701.344617	728.82346	756.725054	784.626648	812.105491	840.0070852	872.136194	904.2653021	936.3944105	968.523519	1
SpecifiedAnnualDemand	RESELC	476.052352	494.704192	513.642984	532.581775	551.233615	570.172407	591.980712	613.7890179	635.5973234	657.4056288	6
SpecifiedAnnualDemand	COMELC	472.460736	490.971856	509.767762	528.563669	547.074788	565.8706947	587.514466	609.1582366	630.8020075	652.4457784	6

- **InputActivityRatio and OutputActivityRatio** of PWRTR and PWRDIST.

Parameter	REGION	TECHNOLOGY	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
InputActivityRatio	RE1	PWRTRN	1	1	1	1	1	1	1	1	1	1
InputActivityRatio	RE1	PWRDIST	1	1	1	1	1	1	1	1	1	1
OutputActivityRatio	RE1	PWRTRN	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
OutputActivityRatio	RE1	PWRDIST	0.89	0.89	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.91

We need to modify:

- **TotalTechnologyAnnualActivityLowerLimit** of PWRSOL001, PWRSOL001S, and PWRSOL002

We need to check:

- **TotalTechnologyAnnualActivityUpperLimit** of PWRSOL001, PWRSOL001S, and PWRSOL002

Parameter	REGION	TECHNOLOGY	Time indipendent variables	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
TotalTechnologyAnnualActivityLowerLimit	RE1	PWRSOL001		0	0	0	0	0	0	0	0	0	0
TotalTechnologyAnnualActivityLowerLimit	RE1	PWRSOL001S		0	0	0	0	0	0	0	0	0	0
TotalTechnologyAnnualActivityLowerLimit	RE1	PWRSOL002		0	0	0	0	0	0	0	0	0	0
TotalTechnologyAnnualActivityUpperLimit	RE1	PWRSOL001		99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
TotalTechnologyAnnualActivityUpperLimit	RE1	PWRSOL001S		99999	99999	99999	99999	99999	99999	99999	99999	99999	99999
TotalTechnologyAnnualActivityUpperLimit	RE1	PWRSOL002		99999	99999	99999	99999	99999	99999	99999	99999	99999	99999

Below is an example of the **TotalTechnologyAnnualActivityLowerLimit** for 2050. You will need to repeat this exercise for the entire time horizon.

First, sum the electricity consumption of INDELC, RESELC, AND COMELC.

Fuel	Demand (PJ)
INDELC	2011.03
RESELC	1365.03
COMELC	1354.73
Total Demand = INDELC + RESELC + COMELC	= 4730.79

This total demand must be modified by the efficiency of the transformation of **ELC001** to **ELC002** and **ELC002** to **ELC003,** this occurs through the technologies **PWRTRN** and **PWRDIST** respectively.

First, let´s remember how we can relate the total generation with the demand:

Losses = Pin - Pout

Losses [%] = 100%*(Pin - Pout)/Pin

Losses [%] = 100% - 100*Pout/Pin

Losses [%] = 100% - efficiency [%]

generation = demand + losses

generation = demand + generation*(1 - efficiency)

generation - generation*(1 - efficiency)= demand

generation*efficency=demand

generation=demand/efficiency

Using this last equation and the efficiency, we can determine the total electricity generation.

The efficiency is given by:

$$\eta_{tot} = \eta_{PWRTRN} \cdot \eta_{PWRDIST} = 0.95 \cdot 0.94 = 0.893$$

Therefore,

generation(2050)= 4730.79/(0.95*0.94)=5297.6372

We need to redistribute according to the proposed percentages established in WAGEP using the **TotalTechnologyAnnualActivityLowerLimit**.

The table shows only the goals for 2030 and 2050, but the policy mentions progressive growth, so it is enough to make a linear projection between these years to determine the percentage of generation of each technology in the intermediate years.

Once the calculation is done, substitute the values in **TotalTechnologyAnnualActivityLowerLimit**.

It is crucial to check that the **TotalTechnologyAnnualActivityUpperLimit** is greater than the **TotalTechnologyAnnualActivityLowerLimit.** Otherwise, the solution will not be optimal.

Always check that the **TotalTechnologyAnnualActivityLowerLimit** is lower than the **TotalTechnologyAnnualActivityUpperLimit**

How does the way of modeling this policy change if the system has electricity exports?

Policy 2: Power Autonomy

This policy can be modeled using the **TotalTechnologyAnnualActivityLowerLimit** and the **TotalTechnologyAnnualActivityUpperLimit**. What we need to do is to limit the imports. For this, we need to calculate the decrease in electricity imports until reaching 35% of the value of imports in 2023.

Parameter	REGION	TECHNOLOGY	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
TotalTechnologyAnnualActivityLowerLimit	RE1	PWRTRNIMP	124.45	124.45	124.45	119.7	119.7	119.7	119.7	119.7	119.7	119.7
TotalTechnologyAnnualActivityUpperLimit	RE1	PWRTRNIMP	131	131	131	126	126	126	126	126	126	126

First, calculate the 35% **TotalTechnologyAnnualActivityLowerLimit** of PWRTRN in 2023 and make a linear projection from 2023 to 2050. Do the same for the **TotalTechnologyAnnualActivityUpperLimit.**

Reduction goal in 2050	**35%**	2023	2050
TotalTechnologyAnnualActivityUpperLimit		126	81.9

Reduction goal in 2050	**35%**	2023	2050
TotalTechnologyAnnualActivityLowerLimit		119.7	77.805

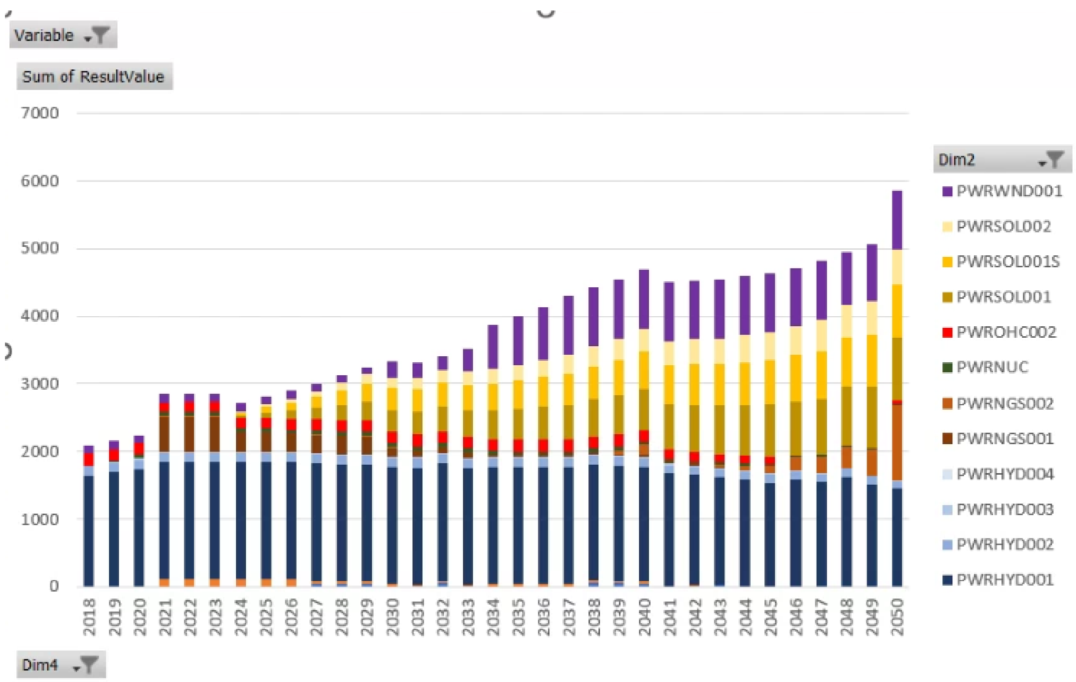
Once the projection is made, substitute the values in the **TotalTechnologyAnnualActivityLowerLimit,** and the **TotalTechnologyAnnualActivityUpperLimit**

> Always check that the **TotalTechnologyAnnualActivityLowerLimit** is lower than the **TotalTechnologyAnnualActivityUpperLimit**

Run the model in clicSAND Desktop or OSeMOSYS cloud and review the results.

Results

Policy 1: Deployment of photovoltaic generation



Policy 2: Increase power Autonomy