# Energy and Flexibility Modelling

## Hands-on 15

Please use the following citation for:

- **This exercise**

Cannone, Carla, Allington, Lucy, & Howells, Mark. (2021, March). Hands-on 15: Energy and Flexibility Modelling (Version 3.0.). Zenodo. https://doi.org/10.5281/zenodo.4610005

- **clicSAND Software**

Cannone, C., Allington, L., de Wet, N., Shivakumar, A., Goynes, P., Valderamma, C., & Howells, M. (2021, March 10). ClimateCompatibleGrowth/clicSAND: v1.1 (Version v1.1). Zenodo. http://doi.org/10.5281/zenodo.4593100

- **OSeMOSYS Google Forum**

Please sign up to 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.

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# Learning outcomes

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

1) Gather data from SAND Interface and OSeMOSYS model results and manipulate them to create input data for FlexTool

# OSeMOSYS output as a FlexTool input

We will now learn how to manipulate OSeMOSYS data for use as input data for FlexTool. We will proceed analysing each of the tabs in FlexTool and giving instructions for the data you need to

add. In FlexTool, we need to define a specific year to analyze the flexibility of the system. We will choose the year 2030.

## 1. GridNode Tab

| **OSeMOSYS name and location** | **FlexTool**<br><br>**Name and location** | **Manipulation required?** | **Actions needed.** |
|---|---|---|---|
| SpecifiedAnnualDemand<br><br>Cell Z41983 (INDELC);<br>Cell Z41984 (COMELC);<br>Cell Z41985 (RESELC) | Demand (MWh); F2 | Yes | **sum** the values of the SpecifiedAnnualDemand in 2030 of INDELC, COMELC and RESELC.<br><br>Transform from PJ to MWh (for an approximate result, multiply the energy value in PJ by 277778).<br><br>[72.1 PJ = **20027794 MWh**] |
| Reserve Margin | Capacity Margin (MW); H2 | Yes | In the previous exercises we assumed that the capacity margin was 15% of the actual demand. Therefore, we need to multiply the summed demand [72.1 PJ = **20027794 MWh**] by 0.15. Then we need to divide by 8760 (the number of hours in one year) as the capacity margin in FlexTool is expressed in MW and not in MWh.<br><br>(0.15*sumSpecifiedAnnualDemand(INDELC, COMELC, RESELC))<br><br>/8760 = **343 MW** |

## 2. Unit_typeTab

We will include only generation technologies (PWRCOA, PWROHC, PWRNGS001, PWRNGS002, PWRBIO, PWRHYD, PWRGEO, PWRNUC, PWRSOL, PWRWND) so the one that produce ELC001 (no T&D, no primary supply tecs, no energy sector appliances).

**2.1. Efficiency**: you need to divide the OutputActivityRatio by the InputActivityRatio of each technology in 2030. To do this, here is a table that could help:

| **YEAR 2030** | | | | | |
|---|---|---|---|---|---|
| Technology (SAND) | Output Fuel (SAND) | Output Activity Ratio (SAND) | Input Fuel (SAND) | InputActivity Ratio (SAND) | Efficiency in FlexTool; Column B |
| PWRCOA | ELC001 | 1 | COA | 2.56 | **0.39** |
| PWROHC | ELC001 | 1 | OIL | 2.86 | **0.35** |
| PWRNGS001 | ELC001 | 1 | NGS | 1.69 | **0.59** |
| PWRNGS002 | ELC001 | 1 | NGS | 2.56 | **0.39** |
| PWRBIO | ELC001 | 1 | BIO | 2.86 | **0.35** |
| PWRHYD | ELC001 | 1 | HYD | 1 | **1** |
| PWRGEO | ELC001 | 1 | GEO | 1.25 | **0.8** |
| PWRNUC | ELC001 | 1 | NUC | 3.03 | **0.33** |
| PWRSOL | ELC001 | 1 | SOL | 1 | **1** |
| PWRWND | ELC001 | 1 | WND | 1 | **1** |

2.2. In this **unit_type Tab** we need to input other data to define the technologies.

| **OSeMOSYS name and location** | **FlexTool Name and location** | **Manipulation required?** | **Actions needed.** |
|---|---|---|---|
| Variable Cost ($/GJ) | O&M Cost ($/MWh), Column G | Yes | Convert the cost from ($/GJ) to ($/MWh). |

| | | | |
|---|---|---|---|
| Z48470; Z48471; Z48472; Z48473; Z48477; Z48479; Z48481; Z48483; Z48485; Z48487 | | | 0.0001 ($/GJ) * 3.6 = 0.00036 ($/MWh) |
| Availability Factor<br><br>Z69; Z70; Z71; Z72; Z76; Z78; Z80; Z82; Z84; Z86 | Availability, Column H | No | Copy-paste from SAND to Flex tool. |
| ReTagTechnology<br><br>Z41580; Z41581; Z41582; Z41583; Z41587; Z41591; Z41593; Z41595; Z41597 | Max Reserve, Column I | No | Copy-paste from SAND to Flex tool. |
| FixedCost<br><br>Z20971; Z20972; Z20973; Z20974; Z20978; Z20980; Z20982; Z20984; Z20986; Z20988 | Fixed cost [$/kW/year], Column K | No | Copy-paste from SAND to Flex tool. |
| Capital Cost<br><br>Z19770; Z19771; Z19772; Z19773; Z19777; Z19779; Z19781; Z19783; Z19785; Z19787 | Inversion cost [$/kW], Column L | No | Copy-paste from SAND to Flex tool. |
| OperationalLife<br><br>Z31130; Z31131; Z31132; Z31133; Z31137; Z31139; Z31141; Z31143; Z31145; Z31147 | Lifetime [years], Column U | No | Copy-paste from SAND to Flex tool. |

| | | | |
|---|---|---|---|
| DiscountRate J19963 | Interest [%], Column V | No | Copy-paste from SAND to Flex tool. |

## 3. Fuel Tab

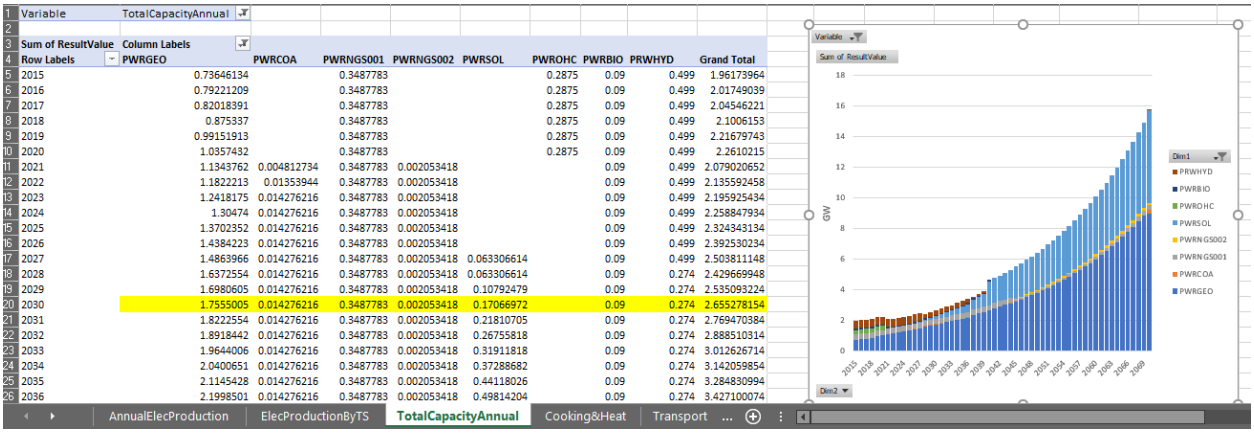
In this tab we need to add fuel prices for the commodities used and the CO2 content. We will not differentiate between imported or locally produced commodities; therefore, you need to calculate the average price.

| **OSeMOSYS name and location** | **FlexTool**<br><br>**Name and location** | **Manipulation required?** | **Actions needed.** |
|---|---|---|---|
| Variable Cost<br><br>($/GJ)<br><br>Z48464; Z48465; Z48466; Z48467; Z48468; Z48469; Z48476 | Fuel ($/MWh); Column B | Yes | Make the average cost for MINCOA and IMPCOA; MINOIL and IMPOIL; MINNGS and IMPNGS. We didn't include an IMPBIO tech so you can take directly the value there for MINBIO.<br><br>**Convert the cost from ($/GJ) to ($/MWh).**<br><br>BIO: 1.6 ($/GJ) * 3.6 = 5.76 ($/MWh)<br><br>COA: 4.8 ($/GJ) * 3.6 = 17.3 ($/MWh)<br><br>NGS: 12.03 ($/GJ) * 3.6 = 43.2 ($/MWh)<br><br>OIL: 13.6 ($/GJ) * 3.6 = 49.0 ($/MWh) |
| EmissionActivityRatio<br><br>Z19969; Z19974; Z19979; Z19984; Z19989; Z19994; Z20029 | CO2 content (t/MWh); Column C | Yes | Make the average cost for MINCOA and IMPCOA; MINOIL and IMPOIL; MINNGS and IMPNGS. We didn't include an IMPBIO tech so you can take directly the value there for MINBIO.<br><br>**Convert the cost from (kg/GJ) to (t/MWh)**. |

| | | | |
|---|---|---|---|
| | | | BIO: 100 (kg/GJ)/1000 * 3.6 = 0.36 (t/MWh)<br><br>COA: 94.6 (kg/GJ)/1000 * 3.6 = 0.34 (t/MWh)<br><br>NGS: 56.1 (kg/GJ)/1000 * 3.6 = 0.20 (t/MWh)<br><br>OIL: 73.3 (kg/GJ)/1000 * 3.6 = 0.26 (t/MWh) |

## 4. UnitsTab

We need to specify the installed capacity and maximum investment allowed for each technology. Also add the input fuel and cf profile data.



| Variable | TotalCapacityAnnual | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sum of ResultValue | Column Labels | | | | | | | | |
| Row Labels | PWRGEO | PWRCOA | PWRNGS001 | PWRNGS002 | PWRSOL | PWROHC | PWRBIO | PRWHYD | Grand Total |
| 2015 | 0.73646134 | | 0.3487783 | | | 0.2875 | 0.09 | 0.499 | 1.96173964 |
| 2016 | 0.79221209 | | 0.3487783 | | | 0.2875 | 0.09 | 0.499 | 2.01749039 |
| 2017 | 0.82018391 | | 0.3487783 | | | 0.2875 | 0.09 | 0.499 | 2.04546221 |
| 2018 | 0.875337 | | 0.3487783 | | | 0.2875 | 0.09 | 0.499 | 2.1006153 |
| 2019 | 0.99151913 | | 0.3487783 | | | 0.2875 | 0.09 | 0.499 | 2.21679743 |
| 2020 | 1.0357432 | | 0.3487783 | | | 0.2875 | 0.09 | 0.499 | 2.2610215 |
| 2021 | 1.1343762 | 0.004812734 | 0.3487783 | 0.002053418 | | | 0.09 | 0.499 | 2.079020652 |
| 2022 | 1.1822213 | 0.01353944 | 0.3487783 | 0.002053418 | | | 0.09 | 0.499 | 2.135592458 |
| 2023 | 1.2418175 | 0.014276216 | 0.3487783 | 0.002053418 | | | 0.09 | 0.499 | 2.195925434 |
| 2024 | 1.30474 | 0.014276216 | 0.3487783 | 0.002053418 | | | 0.09 | 0.499 | 2.258847934 |
| 2025 | 1.3702352 | 0.014276216 | 0.3487783 | 0.002053418 | | | 0.09 | 0.499 | 2.324343134 |
| 2026 | 1.4384223 | 0.014276216 | 0.3487783 | 0.002053418 | | | 0.09 | 0.499 | 2.392530234 |
| 2027 | 1.4863966 | 0.014276216 | 0.3487783 | 0.002053418 | 0.063306614 | | 0.09 | 0.499 | 2.503811148 |
| 2028 | 1.6372554 | 0.014276216 | 0.3487783 | 0.002053418 | 0.063306614 | | 0.09 | 0.274 | 2.429669948 |
| 2029 | 1.6980605 | 0.014276216 | 0.3487783 | 0.002053418 | 0.10792479 | | 0.09 | 0.274 | 2.535093224 |
| 2030 | 1.7555005 | 0.014276216 | 0.3487783 | 0.002053418 | 0.17066972 | | 0.09 | 0.274 | 2.655278154 |
| 2031 | 1.8222554 | 0.014276216 | 0.3487783 | 0.002053418 | 0.21810705 | | 0.09 | 0.274 | 2.769470384 |
| 2032 | 1.8918442 | 0.014276216 | 0.3487783 | 0.002053418 | 0.26755818 | | 0.09 | 0.274 | 2.888510314 |
| 2033 | 1.9644006 | 0.014276216 | 0.3487783 | 0.002053418 | 0.31911818 | | 0.09 | 0.274 | 3.012626714 |
| 2034 | 2.0400651 | 0.014276216 | 0.3487783 | 0.002053418 | 0.37288682 | | 0.09 | 0.274 | 3.142059854 |
| 2035 | 2.1145428 | 0.014276216 | 0.3487783 | 0.002053418 | 0.44118026 | | 0.09 | 0.274 | 3.284830994 |
| 2036 | 2.1998501 | 0.014276216 | 0.3487783 | 0.002053418 | 0.49814204 | | 0.09 | 0.274 | 3.427100074 |



| **OSeMOSYS name and location** | **FlexTool**<br><br>**Name and location** | **Manipulation required?** | **Actions needed.** |
|---|---|---|---|
| In the Results_Template_HO), TotalCapacityAnnual (GW) Tab, Year 2030, Row 20 | Capacity (MW); Column J | Yes | **Convert the capacities from (GW) to (MW).**<br><br>PWRGEO: 1.756 (GW) *1000 = **1756 MW** |

| | | | |
|---|---|---|---|
| | | | PWRCOA: 0.014 (GW) * 1000 = **14 MW**<br>PWRNGS001: 0.349 (GW) * 1000 = **349 MW**<br>PWRNGS002: 0.002 (GW) * 1000 = **2 MW**<br>PWRSOL: 0.170 (GW) * 1000 = **170 MW**<br>PWROHC: 0<br>PWRBIO: 0.09 (GW) * 1000 = **90 MW**<br>PWRHYD: 0.274 (GW) * 1000 = **274 MW** |
| Resource potential<br>(not added in the exercises yet) | Max invest (MW); Column L | No | Add a constraint on PWRHYD and PWRGEO.<br>The Maximum investment in MW will be respectively 9000 MW and 10000 MW. |

## 5. Ts_cf Tab

We need to add the HOURLY capacity factor profile for wind, pv, hydro and geothermal technologies. These data were the raw data used to calculate the capacity factors used in SAND (for 96 time slices). The source for them is a database called PLEXOS. You will find the data needed in the Data_Prep_HO15.

## 6. Ts_energy Tab

In this Tab we need to add the hourly demand profile for the entire year, so for 8760 hours. Again, these were the raw data used to calculate the SpecifiedDemandProfile used in SAND (for 96 time slices) and were taken from PLEXOS. You will find the data needed in the Data_Prep_HO15.