

# Energy and Flexibility Modelling

## Hands-on 13: Free investment run

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## Learning outcomes

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

- 1) Run DemoModel-2.
- 2) Explore results of DemoModel-2.
- 3) Remove maximum investment limits.
- 4) Create your own scenario.

## Activity 1

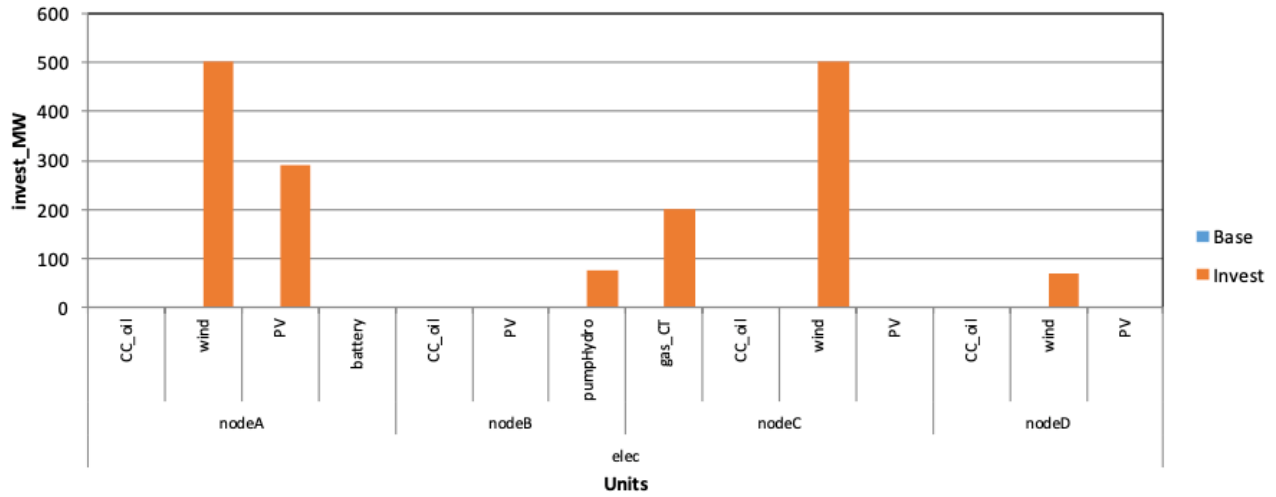
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In the final slide of the previous lecture, we ran the base and invest scenarios of DemoModel-2. In this hands-on exercise, we will further explore the results of some DemoModel-2 scenarios. These are scenarios, as we are making assumptions about what the future will look like in 2030.

For example, the prices are estimated 2030 prices, which mean lower wind, photovoltaics (PV), and battery prices than currently. These kinds of checks are useful when we want to know how the model will solve some flexibility issues, as well as discussing long-term planning.

To begin the exercise, run the following scenarios:

### Invested capacity



Next, check the **unit\_type**, **capacity (MW)** and **Transfer, capacity (MW)** from the **Summary\_D** for capacity comparison between base and invest.

|    | A             | B                | C                |
|----|---------------|------------------|------------------|
| 1  | Update sheets | demoModel-2-2030 | demoModel-2-2030 |
| 2  |               | Base             | Invest           |
| 65 |               |                  |                  |
| 66 | Unit type     | Capacity (MW)    | Capacity (MW)    |
| 67 | ST_coal       | 600              | 600              |
| 68 | gas_CC        | 300              | 300              |
| 69 | gas_CT        | 100              | 300              |
| 70 | CC_oil        | 1580             | 1580             |
| 71 | wind          | 250              | 1319.89          |
| 72 | PV            | 300              | 591.362          |
| 73 | battery       | 5                | 5                |
| 74 | pumpHydro     | 10               | 87.992           |

|     | A             | B                | C                |
|-----|---------------|------------------|------------------|
| 1   | Update sheets | demoModel-2-2030 | demoModel-2-2030 |
| 2   |               | Base             | Invest           |
| 75  |               |                  |                  |
| 96  | Transfer      | Capacity (MW)    | Capacity (MW)    |
| 97  | nodeA - nodeB | 250              | 398.49           |
| 98  | nodeB - nodeA | 250              | 398.49           |
| 99  | nodeB - nodeC | 200              | 616.891          |
| 100 | nodeC - nodeB | 200              | 616.891          |

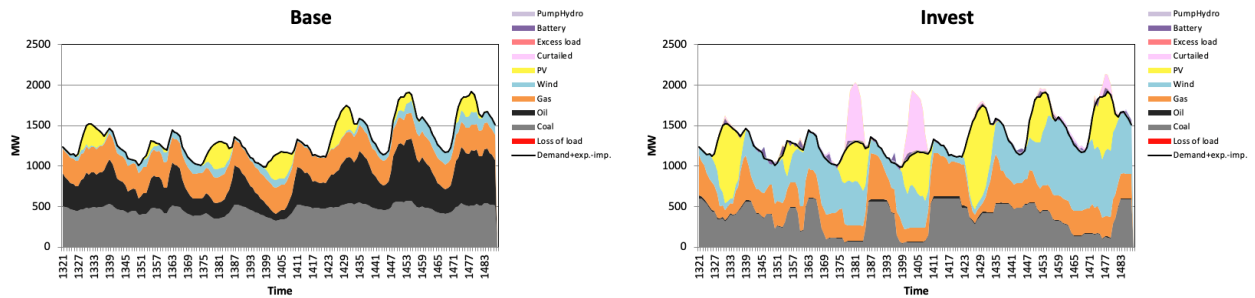
Then check the **units\_invest\_plot** to see the specific nodes where units are invested.

We see that wind power is invested in, in all allowed nodes. We also see that pumped hydro is invested in in NodeB, as well as additional PV to nodeA.

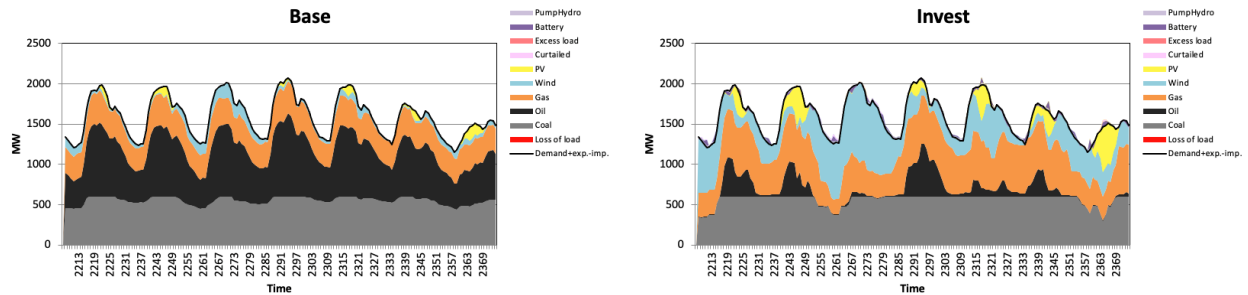
# Activity 2

Next, we will check the results of these scenarios. Navigate to the “**genUnitGroup\_elec\_plot**” sheet. This will show dispatch figures for each week.

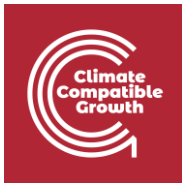
Below are the dispatch figures for the first week, and the two scenarios “Base” and “Invest.”



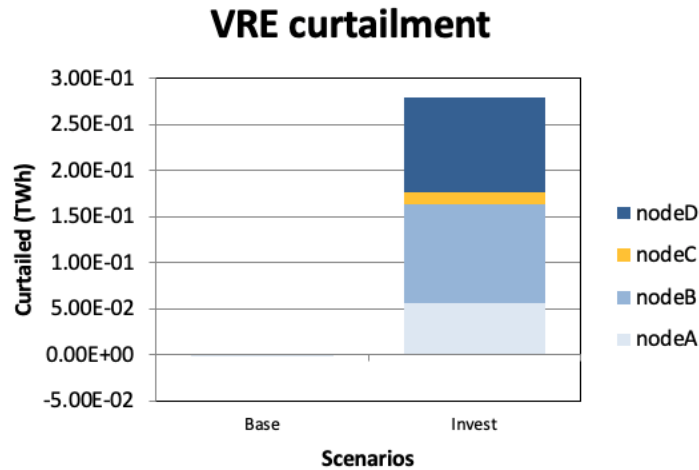
The dispatch figures below are for the third week. Again, we display the “Base” and “Invest” scenarios. This week has high demand, whereas the first week has a lower demand.



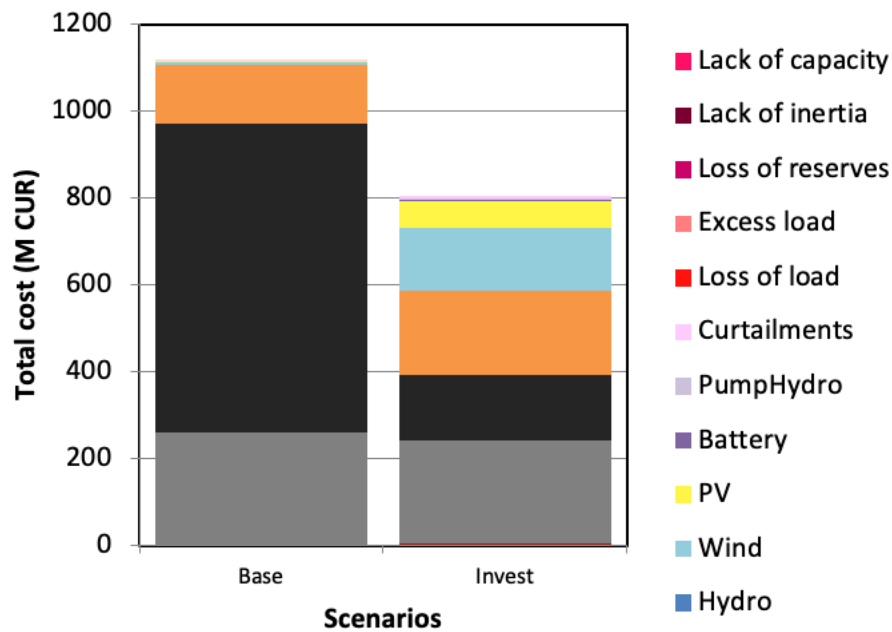
Next, we can check “**summary\_D**” for flexibility issues in general, and **node\_plot** for a graphical version.



We see that the VRE share for the base scenario is much lower than the invest scenario (8.988% compared to 39.29%). This leads to a larger amount of curtailment, but considerably lower costs. See the plot below for the VRE curtailment.

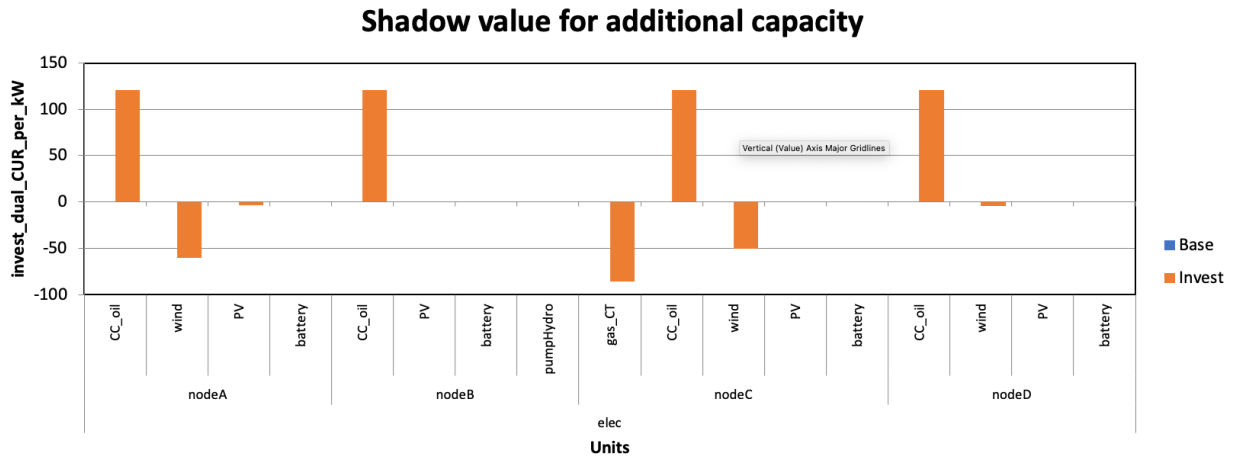


The investment scenario can have higher curtailment costs than the base scenario, due to savings in fuel costs are larger than (annualized) investment costs + curtailment penalties. This can be seen in the plot below found in the “costs\_unitGroup\_plot” sheet:



Next, check the “units\_invest\_plot” to see the specific nodes where the units are invested.

The investment shadow values detail how additional investments to each capacity type would affect the total costs. In this example, gas and wind have negative shadow values, which means that additional investments in these technologies would lower the total costs of the system. These investments are limited by investment constraints in the input data.



## Removing max investment limits in wind and gas

In this next activity, select and run the following 3 scenarios:

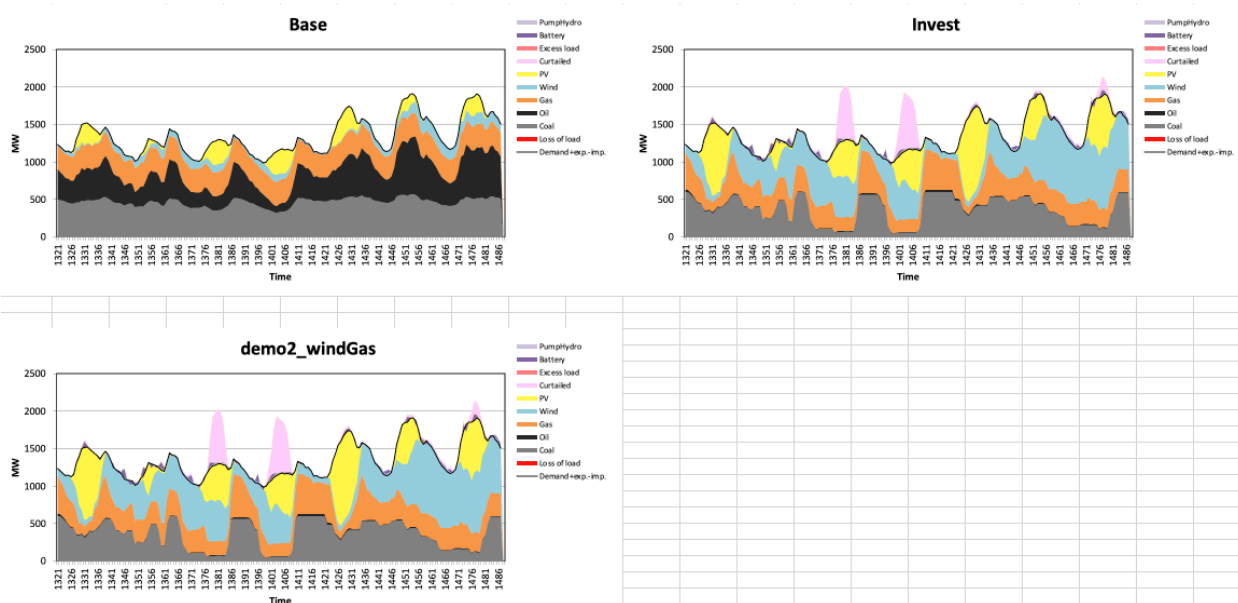
| Active input files: | Inactive input files:     | Active scenarios: | Inactive scenarios:      |
|---------------------|---------------------------|-------------------|--------------------------|
|                     | <> template.xlsm          | Base              | <>                       |
|                     | <> demoModel-1.xlsm       | Invest            | <>                       |
|                     | <> demoModel-2-2017.xlsm  |                   | <> demo1_invest_transCap |
|                     | <> demoModel-2-2030.xlsm  |                   | <> demo1_invest_genCap   |
|                     | <> template-EVs.xlsm      |                   | <> demo1_invest_storages |
|                     | <> template-Storages.xlsm |                   | <> demo1_invest_all      |
|                     | <>                        |                   | <> demo2_storages        |
|                     | <>                        |                   | <> demo2_PV              |
|                     | <>                        | demo2_windGas     | <>                       |

The windGas scenario removes max\_investment limits to wind power and gas turbines.

For these scenarios, check the **unit\_type**, **capacity (MW)** and **Transfer, capacity (MW)** from **Summary\_D** to compare invest capacity in scenarios.

Also check the **units\_invest\_plot** to see the specific nodes where units are invested in.

Below we check the **“genUnitGroup\_elec\_plot”** sheet to see the electricity mix. Feel free to go further and compare weeks with different demand profiles.



The conclusions from these exercises seem to be:

- A higher VRE share is cost-effective. It allows the power system to be flexible to operate with a higher VRE.
- If possible, it would be better to position VRE capacity near the demand.
- However, this is an example, therefore further modelling is needed to assess large VRE shares.
- Additional natural gas capacity would also decrease the total costs by replacing oil power.
- In this topic, additional modelling is needed about:
  - The acceptable minimum loads and annual running hours of the thermal capacity.



- Possible required additional investments to natural gas grid (locations, if operating at full capacity or not, etc).

## Create your own scenario

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As a final exercise, create your own scenario for demo model 2 and check how it affects the investment run.

1. Open flexTool.xlsm and sensitivity scenario sheet
  - a. Add new scenario names to list of inactive scenarios.
2. Open sensitivity definition sheet
  - a. Add data to some input scenario definition table.
  - b. This example increases the annual demand of nodeA by 20%
  - c. If you want to study a scenario in the invest mode, you have to add this also to the first scenario definition table. Do not add this if creating a dispatch scenario.

| Active input files:   | Inactive input files:     | Active scenarios: | Inactive scenarios:      |
|-----------------------|---------------------------|-------------------|--------------------------|
|                       | <> template.xlsm          | Base              | <>                       |
|                       | <> demoModel-1.xlsm       |                   | <> Invest                |
|                       | <> demoModel-2-2017.xlsm  |                   | <> demo1_invest_transCap |
| demoModel-2-2030.xlsm | <> demoModel-2-2030.xlsm  |                   | <> demo1_invest_genCap   |
|                       | <> template-EVs.xlsm      |                   | <> demo1_invest_storages |
|                       | <> template-Storages.xlsm |                   | <> demo1_invest_all      |
|                       | <>                        |                   | <> demo2_storages        |
|                       | <>                        |                   | <> demo2_PV              |
|                       | <>                        |                   | <> demo2_windGas         |
|                       | <>                        |                   | <> new_scen              |

1a

|    | A                            | B      | C         | D                    | E                        | F                       | G                   | H                        | I             | J                    | K                | L                   | M          | N         | O                   | P                 | Q           | R             | S              | T                  | U                  |
|----|------------------------------|--------|-----------|----------------------|--------------------------|-------------------------|---------------------|--------------------------|---------------|----------------------|------------------|---------------------|------------|-----------|---------------------|-------------------|-------------|---------------|----------------|--------------------|--------------------|
|    | Add empty row                |        |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   |             |               |                |                    |                    |
| 1  | Scenario definitions master: | Sheet  | cost_root | loss_of_load_penalty | loss_of_reserves_penalty | loss_of_inertia_penalty | containment_penalty | loss_of_capacity_penalty | time_in_years | time_period_duration | reserve_duration | use_capacity_margin | use_online | use_ramps | use_non_synchronous | use_inertia_limit | mode_invest | mode_dispatch | print_duration | print_durationRamp | print_unit_results |
| 2  | Invest                       | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   | 1           |               |                |                    |                    |
| 3  | Invest_extra                 | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   | 1           |               |                |                    |                    |
| 4  | Invest_only                  | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   | 1           | 0             |                |                    |                    |
| 5  | NoLimits                     | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           | 0                   | 0                 |             |               |                |                    |                    |
| 6  | demo1_invest_transCap        | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   | 1           |               |                |                    |                    |
| 7  | demo1_invest_genCap          | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   | 1           |               |                |                    |                    |
| 8  | demo1_invest_storages        | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   | 1           |               |                |                    |                    |
| 9  | demo1_invest_all             | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   | 1           |               |                |                    |                    |
| 10 | deactivate_ramp              | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           | 0                   |                   |             |               |                |                    |                    |
| 11 | invest_cheap_pumpH           | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   |             | 1             |                |                    |                    |
| 12 | demo2_windGas                | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   |             | 1             |                |                    |                    |
| 13 | new_scen                     | master |           |                      |                          |                         |                     |                          |               |                      |                  |                     |            |           |                     |                   |             |               | 1              |                    |                    |

2c

|    | A                              | B        | C    | D     | E         | F          | G            | H            | I                    | J                     | K                   | L              | M                   | N             | O | P | Q | R | S | T | U |
|----|--------------------------------|----------|------|-------|-----------|------------|--------------|--------------|----------------------|-----------------------|---------------------|----------------|---------------------|---------------|---|---|---|---|---|---|---|
|    | Add empty row                  |          |      |       |           |            |              |              |                      |                       |                     |                |                     |               |   |   |   |   |   |   |   |
| 27 | Scenario definitions gridnode: | Sheet    | grid | node  | nodeGroup | nodeGroup2 | demand (MWh) | import (MWh) | capacity margin (MW) | non synchronous share | inertia limit (MWs) | use ts_reserve | use dynamic reserve | print results |   |   |   |   |   |   |   |
| 28 | template_changeDemand          | gridNode | elec | CO_AC | sync1     | reserve1   | 12219000     |              |                      |                       |                     |                |                     |               |   |   |   |   |   |   |   |
| 29 | Res_NG_only                    | gridnode | elec | nodeA | sync1     | reserve1   |              |              |                      |                       |                     |                |                     |               |   |   |   | 0 | 0 |   |   |
| 30 | Res_No                         | gridnode | elec | nodeA | sync1     | reserve1   |              |              |                      |                       |                     |                |                     |               |   |   |   | 0 | 0 |   |   |
| 31 | new_scen                       | gridNode | elec | nodeA | mainLand  |            | 8409600      |              |                      |                       |                     |                |                     |               |   |   |   |   |   |   |   |

2b