Hands-on exercise 4: Adding a service demand

In this section, we detail how to add a service demand to MUSE. In the residential sector, a service demand could be cooking. Houses require energy to cook food and a technology to service this demand, such as an electric stove. This process consists of setting a demand, either through inputs derived from the user or correlations of GDP and population which reflect the socioeconomic development of a region or country. In addition, a technology must be added to service this new demand.

This tutorial will build off the default model that comes with MUSE. To copy the files for this model, run:

```
python -m muse --model default --copy PATH/TO/COPY/THE/MODEL/TO
```

Addition of cooking demand

In this example, we will add a cooking preset demand. To achieve this, we will first edit the `Residential2020Consumption.csv` and `Residential2050Consumption.csv` files, found within the `technodata/preset/` directory.

The `Residential2020Consumption.csv` file allows us to specify the demand in 2020 for each region and technology per timeslice. The `Residential2050Consumption.csv` file does the same, but for the year 2050. The datapoints between these years are interpolated.

Firstly, we must add the new service demand, `cook`, to these two files, with values specifying the demand. For simplicity, we will copy over the values from the `heat` column:

RegionName	Timeslice	electricity	gas	heat	CO2f	wind	cook
R1	1	0	0	1.0	0	0	**1.0**
R1	2	0	0	1.5	0	0	**1.5**
R1	3	0	0	1.0	0	0	**1.0**
R1	4	0	0	1.5	0	0	**1.5**
R1	5	0	0	3.0	0	0	**3.0**
R1	6	0	0	2.0	0	0	**2.0**

The process is very similar for the `Residential2050Consumption.csv` file: again we copy the values over from the `heat` column. For the complete file see the link here (https://github.com/EnergySystemsModellingLab/MUSE_OS/blob/v1.3.3/docs/tutorial-code/5-add-service-demand/1-exogenous-demand/technodata/preset/Residential2050Consumption.csv).

Next, we must edit the `GlobalCommodities.csv` file (in the `input` folder). This is where we define the new commodity `cook`. It tells MUSE the commodity type, name, emissions factor of CO2 and heat rate, amongst other things:

Commodity	CommodityType	CommodityName	CommodityEmissionFactor_CO2	HeatRate	Unit
Electricity	Energy	electricity	0	1	PJ
Gas	Energy	gas	56.1	1	PJ
Heat	Energy	heat	0	1	PJ
Wind	Energy	wind	0	1	PJ
CO2fuelcomsbustion	Environmental	CO2f	0	1	kt
Cook	**Energy**	**cook**	**0**	**1**	**PJ**

Finally, the `Projections.csv` file must be changed. This is a large file which details the expected cost of the commodities across the timeframe of the simulation. Due to its size, we will only show two rows of the new column `cook`:

RegionName	Attribute	Time	…	cook
Unit	-	Year	…	**MUS$2010/PJ**
R1	CommodityPrice	2010	…	**100**
…	…	…	…	**…**
R1	CommodityPrice	2100	…	**100**

We set every price of cook to be `100MUS$2010/PJ`

Addition of cooking technology

Next, we must add a technology to service this new demand. This is similar to how we added the solarPV technology in a previous tutorial. However, we must be careful to specify the end-use of the technology as `cook`.

For this example, we will add two competing technologies to service the cooking demand (`electric_stove` and `gas_stove`) to the `Technodata.csv` file in `/technodata/residential`.

Again, in the interests of space, we have omitted the existing `gasboiler` and `heatpump` technologies. For the new `electric_stove` technology, we will copy and paste the data from the `heatpump` row. For `gas_stove`, we copy and paste the data for `gasboiler`. Importantly, however, we must specify the end-use for these new technologies to be `cook` and not `heat`:

ProcessName	RegionName	Time	cap_par	...	Fuel	EndUse	Agent1
Unit	-	Year	MUS$2010/PJ_a	...	-	-	New
...	...	...	...	...	...	...	...
electric_stove	**R1**	**2020**	**8.8667**	**...**	**electricity**	**cook**	**1**
gas_stove	**R1**	**2020**	**3.8**	**...**	**gas**	**cook**	**1**

As can be seen, we have added two technologies with different `cap_par` costs. We specified their respective fuels, and the enduse for both is `cook`. For the full file please see here (https://github.com/EnergySystemsModellingLab/MUSE_OS/blob/v1.3.3/docs/tutorial-code/5-add-service-demand/1-exogenous-demand/technodata/residential/Technodata.csv).

We must also add the data for these new technologies to the following files:

- `CommIn.csv`
- `CommOut.csv`
- `ExistingCapacity.csv`

This is largely a similar process to the previous tutorial. We must add the input to each of the technologies (gas and electricity for `gas_stove` and `electric_stove` respectively), outputs of `cook` for both and the existing capacity for each technology in each region.

To prevent repetition of the previous tutorial, we will leave the full files here (https://github.com/EnergySystemsModellingLab/MUSE_OS/tree/main/docs/tutorial-code/5-add-service-demand/1-exogenous-demand).

Again, we run the simulation with our modified input files using the following command, in the relevant directory:

```
python -m muse settings.toml
```

Once this has run we are ready to visualise our results.

In [1]:

```
import matplotlib.pyplot as plt
import pandas as pd
```

In [2]:

```
mca_capacity = pd.read_csv(
    "../tutorial-code/add-service-demand/1-exogenous-demand/Results/MCACapacity.csv"
)
mca_capacity.head()
```

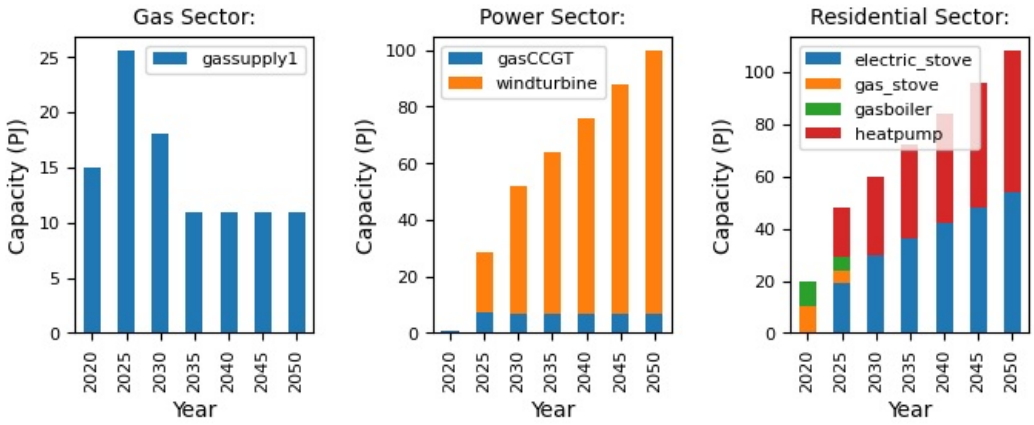
Out[2]:

	agent	capacity	dst_region	installed	region	sector	technology	type	year
0	A1	10.0	R1	2020	R1	residential	gas_stove	newcapa	2020
1	A1	10.0	R1	2020	R1	residential	gasboiler	newcapa	2020
2	A1	1.0	R1	2020	R1	power	gasCCGT	newcapa	2020
3	A1	15.0	R1	2020	R1	gas	gassupply1	newcapa	2020
4	A1	19.0	R1	2025	R1	residential	electric_stove	newcapa	2025

In [3]:

```
fig, axes = plt.subplots(1, 3)
all_years = mca_capacity["year"].unique()
for ax, (sector_name, sector_data) in zip(axes, mca_capacity.groupby("sector")):
    sector_capacity = sector_data.groupby(["year", "technology"]).sum().reset_index()
    sector_capacity.pivot(
        index="year", columns="technology", values="capacity"
    ).reindex(all_years).plot(kind="bar", stacked=True, ax=ax)
    ax.set_ylabel("Capacity (PJ)")
    ax.set_xlabel("Year")
    ax.set_title(f"{sector_name.capitalize()} Sector:", fontsize=10)
    ax.legend(title=None, prop={"size": 8})
    ax.tick_params(axis="both", labelsize=8)

fig.set_size_inches(8, 2.5)
fig.subplots_adjust(wspace=0.5)
```



We can see that `electric_stove` is heavily used in the residential sector, and `gas_stove` is barely used at all. Therefore, compared to the default model, there is a larger increase in capacity in the `power` sector to accommodate this increase in demand for electricity, which is largely driven by `windturbine`.

Summary

In this tutorial we have shown how to add a service demand to MUSE, and how to add technologies to meet this demand. Try changing the demand profile for `cook` to see how this influences investment decisions.