STEVFNs training

Global Mitigation Potential Atlas - Pilot Phase

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Set-up and useful links

1. Download Python if using Windows https://www.python.org/downloads/release/python-3917/

2. Git setup

    1. Check if you have git installed through terminal or command line and running the line git --version

    2. If not installed, download git:

    3. macOS https://git-scm.com/download/mac

    4. Windows https://git-scm.com/download/win

3. STEVFNs repository*: https://github.com/OmNomNomzzz/STEVFNs

* The repository includes links to YouTube tutorials of the model, as well as a README file with steps on how to run the model, change or create your own case study. These are further detailed in this document

Download Anaconda

To set up a virtual environment and run with a Python IDE

1. https://www.anaconda.com/download#downloads

2. Find your required installer at the bottom of the page

Setting up virtual environment with dependencies

1. Create new environment in Anaconda:
   ```
   conda create --name STEVFNs python=3.9
   conda activate STEVFNs
   ```
2. cvxpy https://www.cvxpy.org/install/index.html
   ```
   conda install -c conda-forge cvxpy
   ```
3. pandas https://pandas.pydata.org/docs/getting_started/install.html
   ```
   conda install pandas
   ```
4. Matplotlib https://matplotlib.org/stable/users/installing/index.html
   ```
   conda install matplotlib
   ```

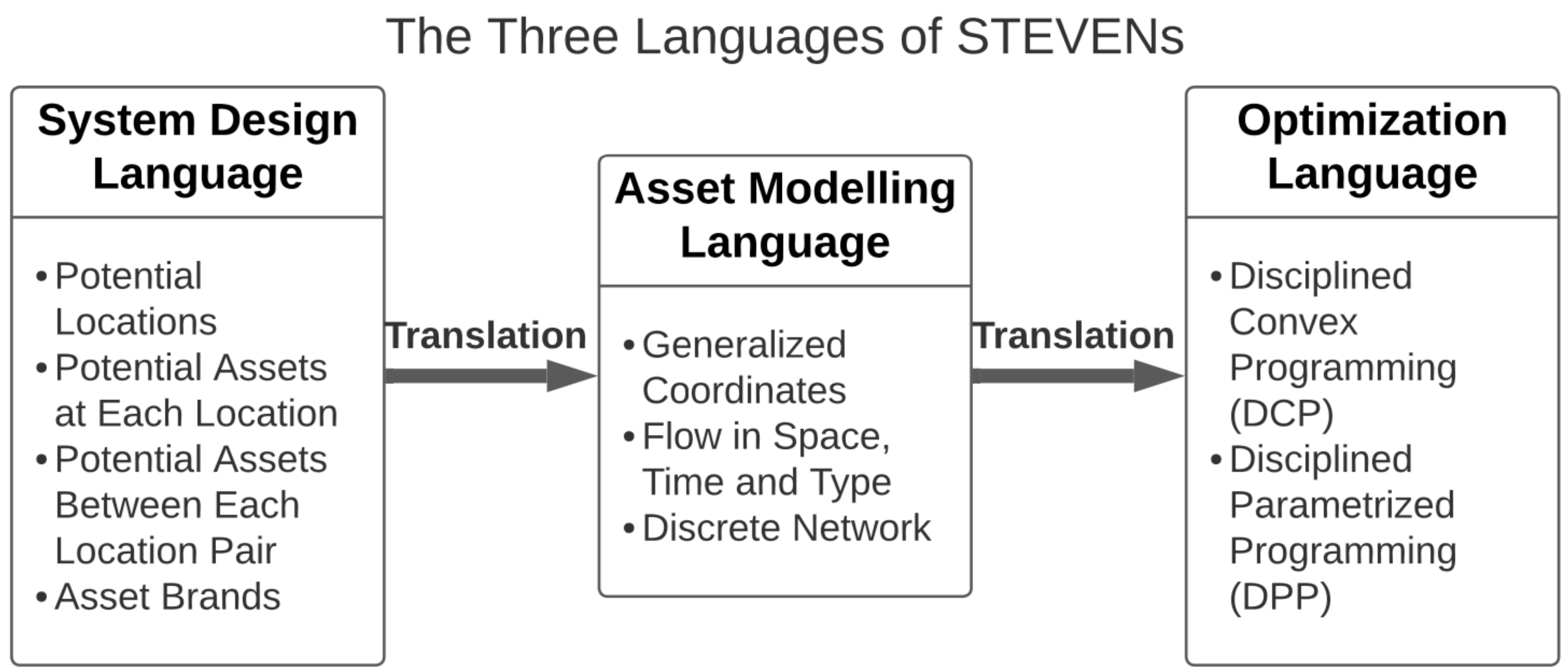
STEVFNs model and examples

STEVFNs model

Space Time Energy Vector Flow Networks

1. Co-optimization of: sizing, operation and location of assets using a generalized spatio-temporal asset model

2. Consists of three models (or languages) and translates between them



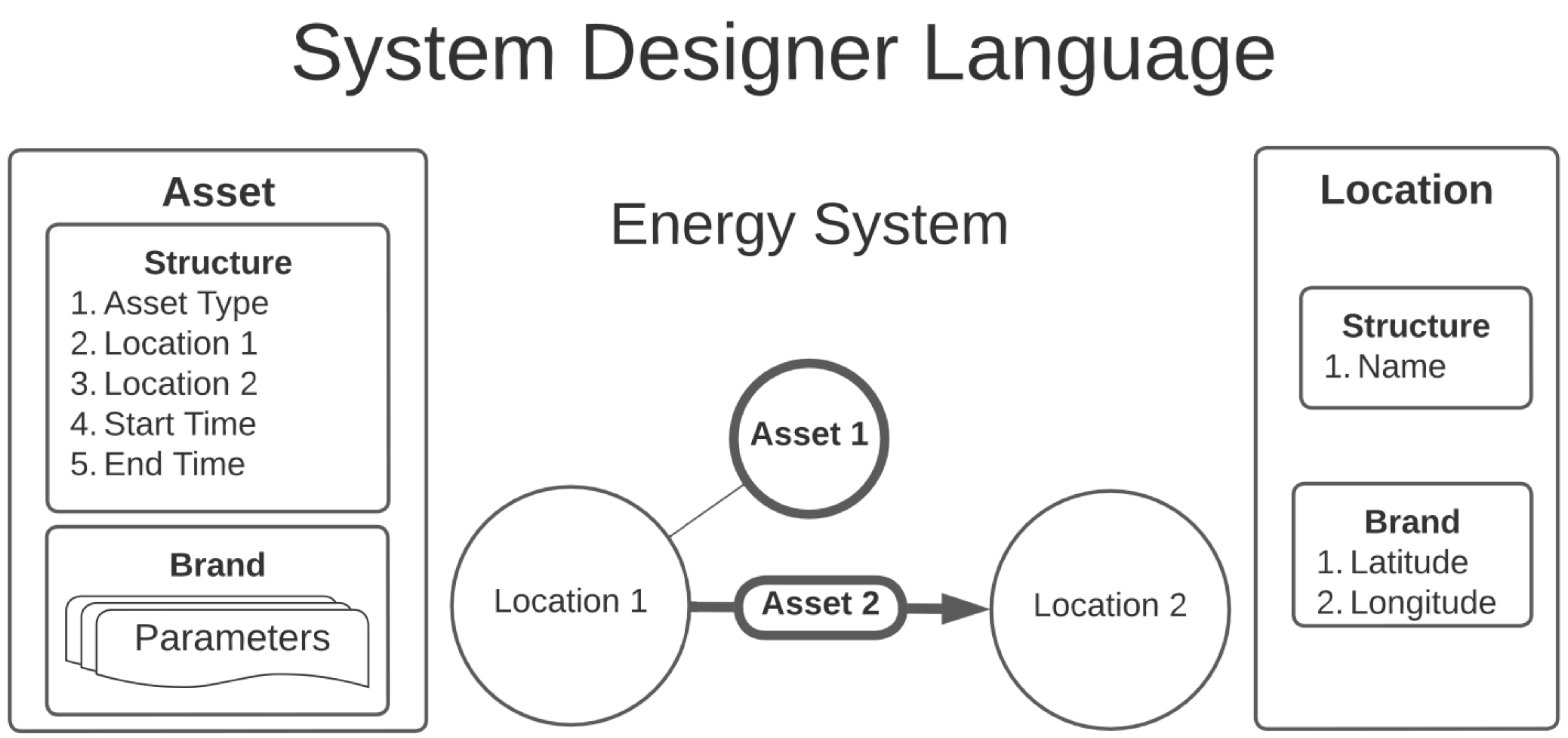
3. The following examples in this tutorial are focused from a System Designer perspective

STEVFNs model

Space Time Energy Vector Flow Networks

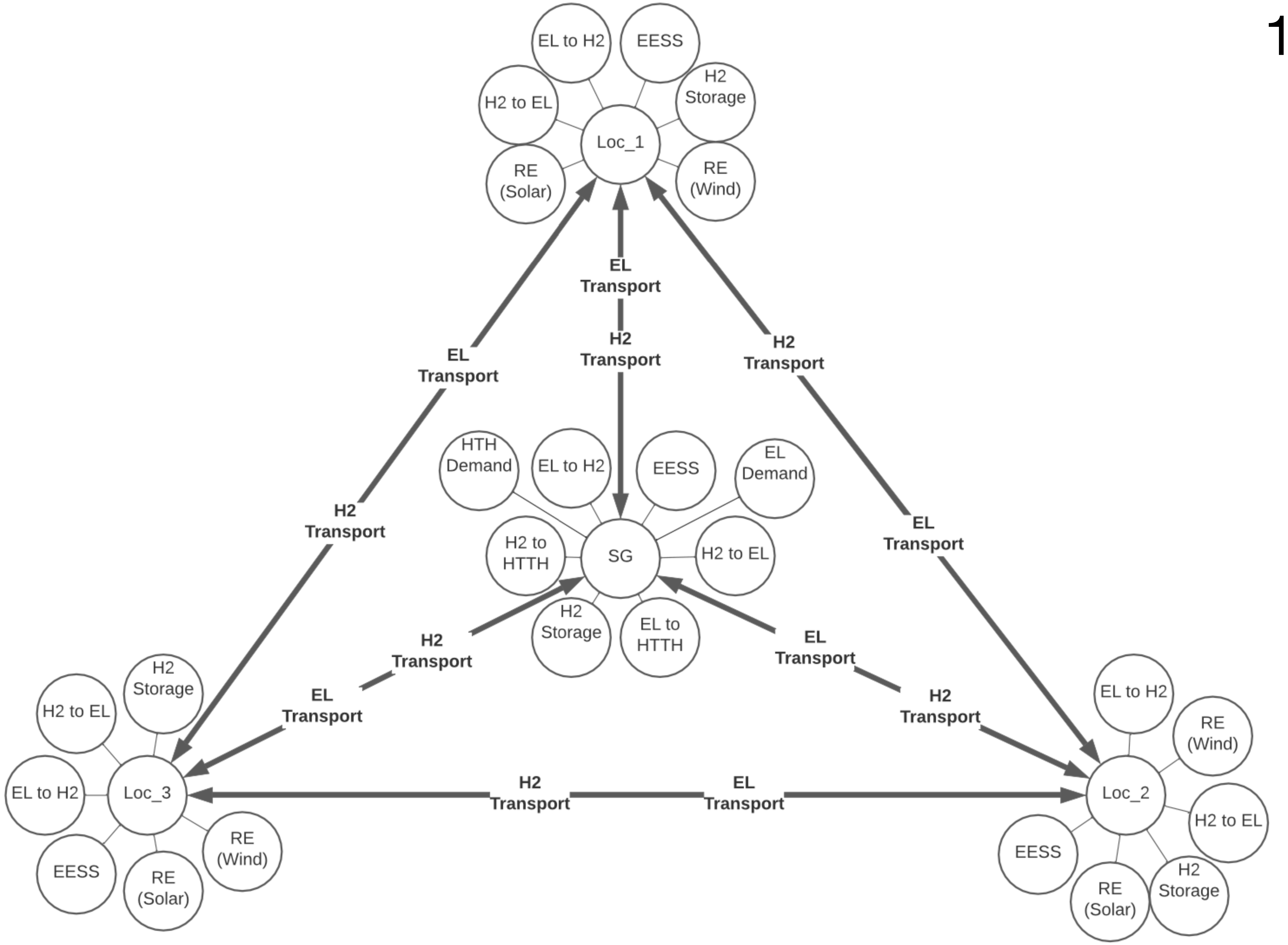
1. The energy system is designed with knowledge of the locations and their structure (which type of energy transport(s) links them, and which energy assets are located in each location), the types or “brands” of said assets. This defines the **Case Study**

2. The parameters input into the “brands” and locations will define the **scenarios** to be run within the same case study.



Network Structure

Example from SG_Case_Study in repository

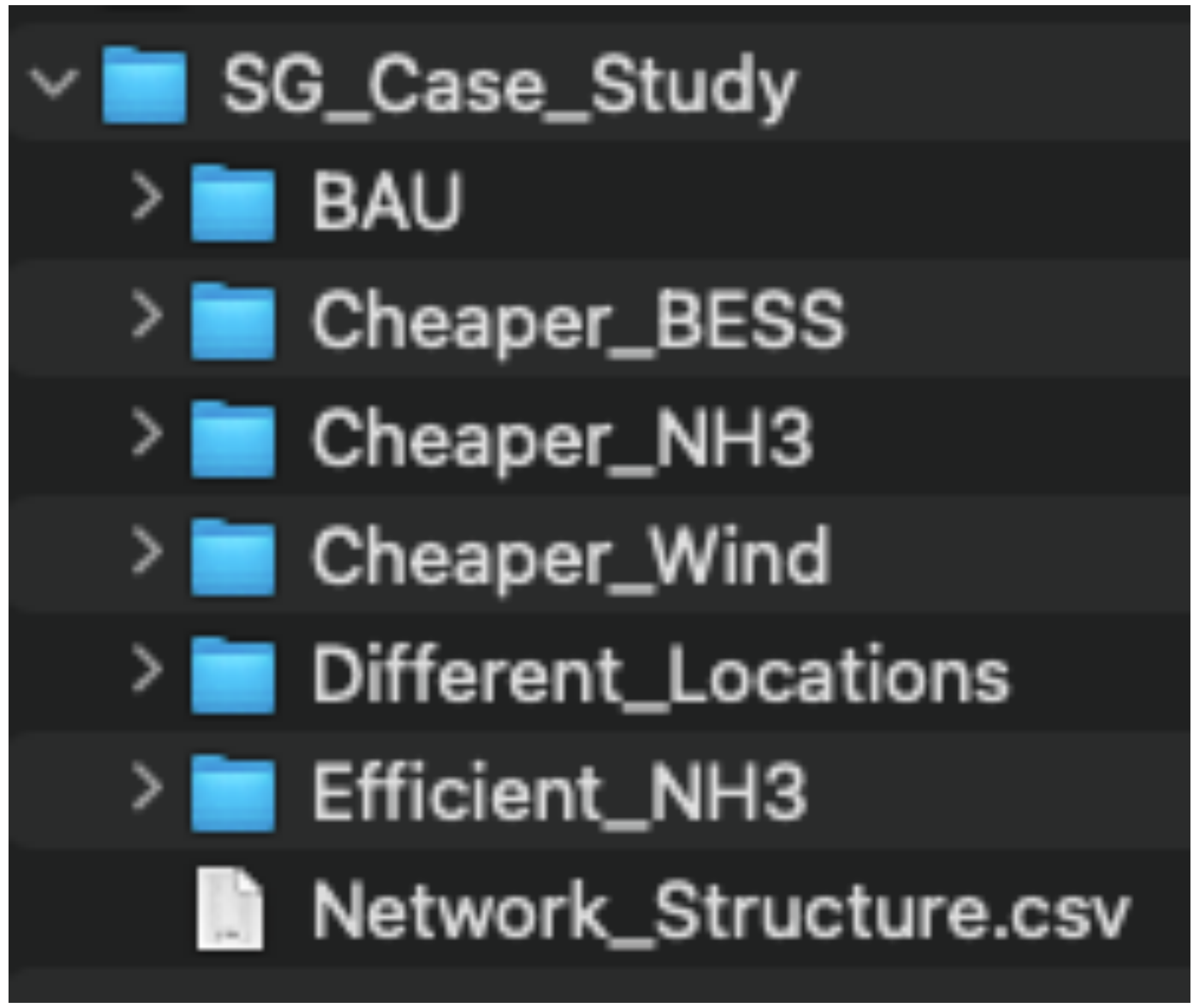


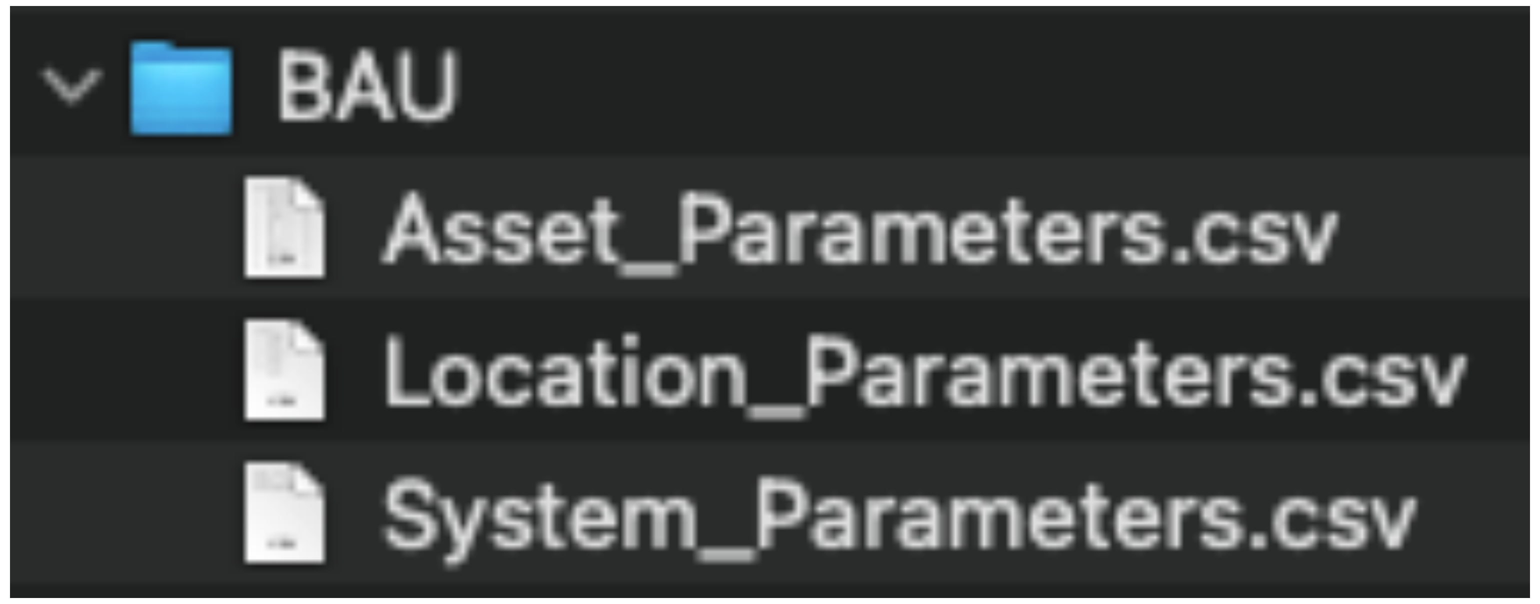
1. The case study which has this network structure can have any number of scenarios with different parameters for asset brands or locations

Note:

Case Study and Scenarios

1. Each folder at STEVFNs -> Data -> Case_Study contains folders for the **same network structure**, each of which can have several scenarios, which can run different asset "brands", locations, or input profiles (renewable energy, or demand for example) to observe sensitivities.

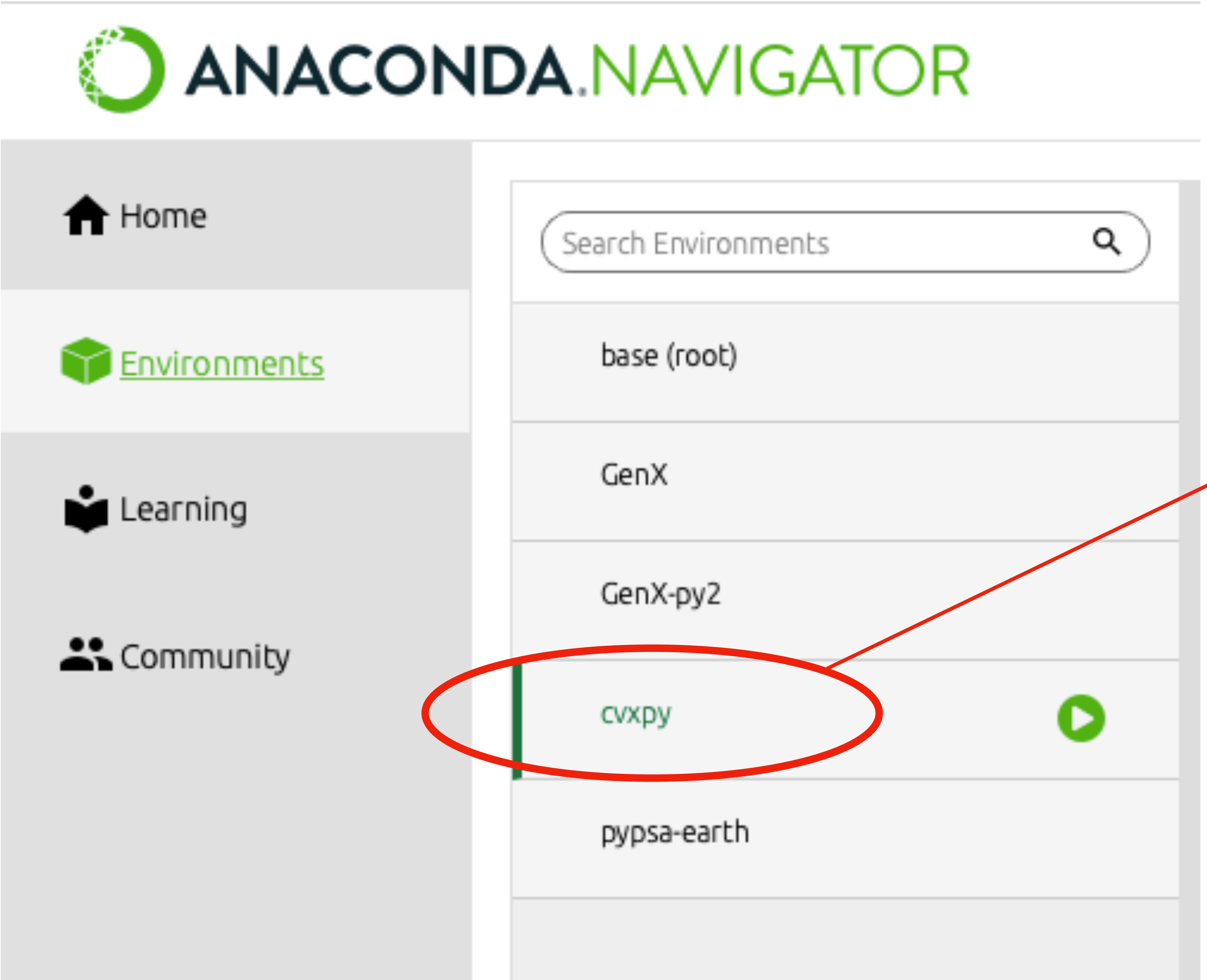


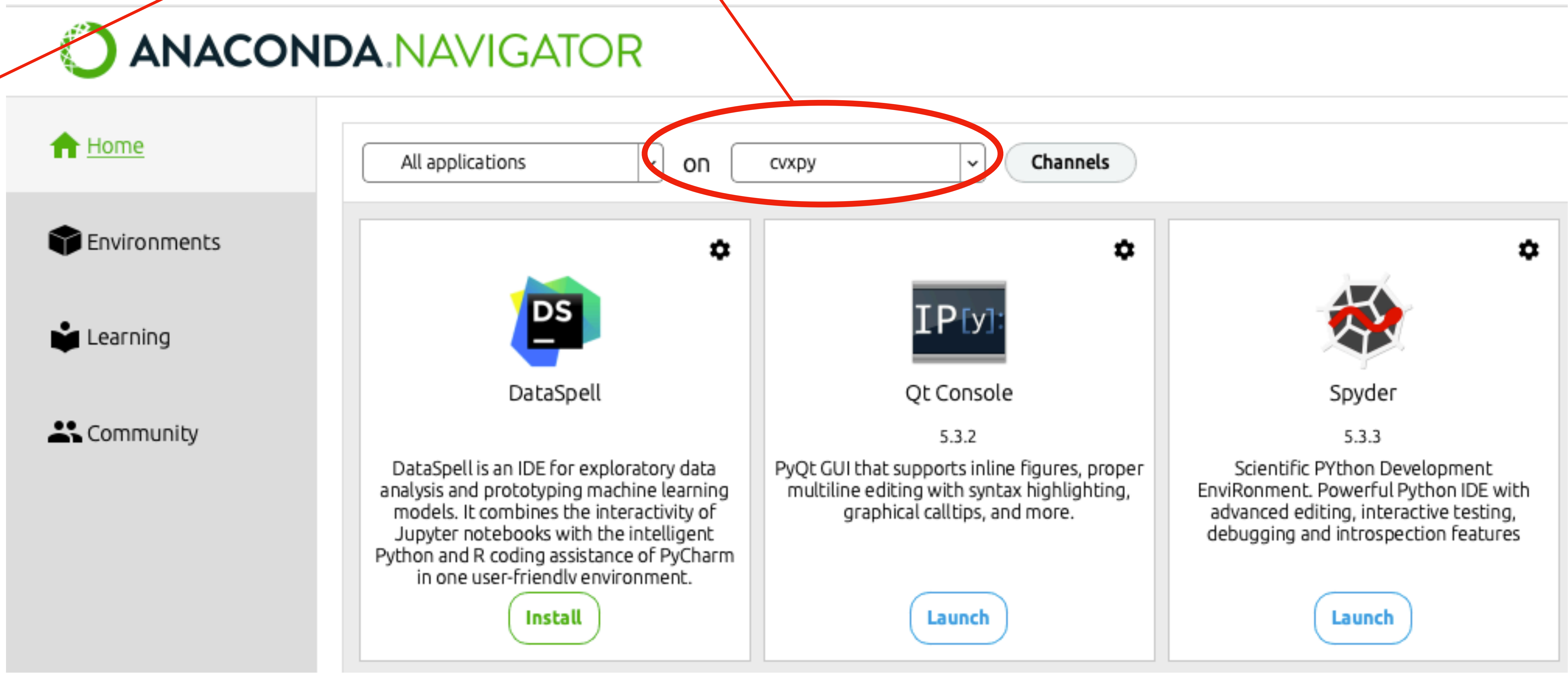


Test: Run SG_Case_Study

1. Activate STEVFNs environment in Anaconda Navigator, launch Spyder

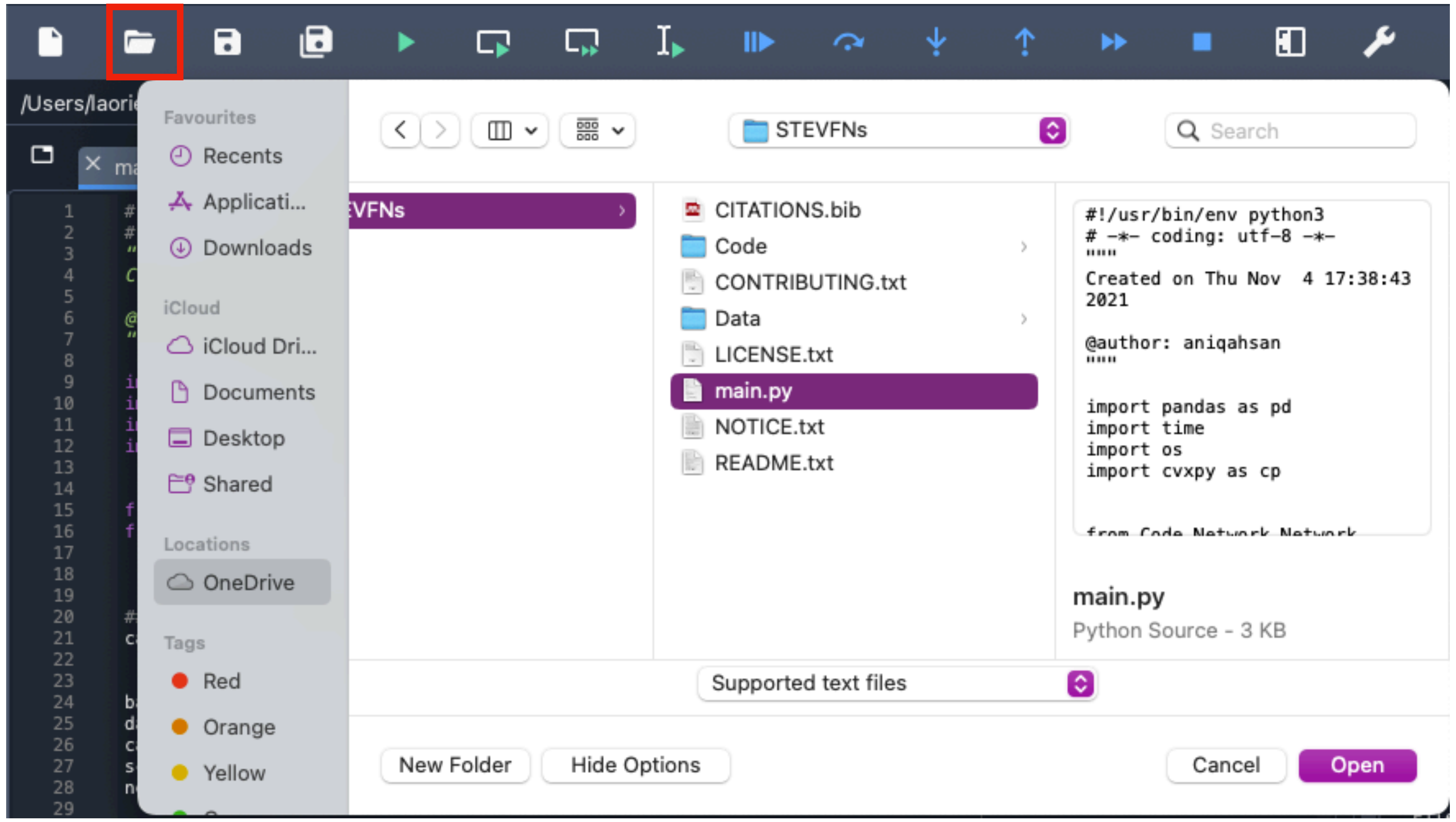
These should be the STEVFNs environment you created in the session





Test: Run SG_Case_Study

1. Open File -> STEVFNs -> main.py



Test: Run SG_Case_Study

1. If lines 51 and 52 are commented as:

```
49
50
51     # for counter1 in range(len(scenario_folders_list)):
52     for counter1 in range(1):
53         ### Read Input Files ###
54         scenario_folder = scenario_folders_list[counter1]
55         asset_parameters_filename = os.path.join(scenario_folder, "Asset_Parameters.csv")
56         location_parameters_filename = os.path.join(scenario_folder, "Location_Parameters.csv")
57         system_parameters_filename = os.path.join(scenario_folder, "System_Parameters.csv")
58
```

The model will run only one scenario folder in a few seconds

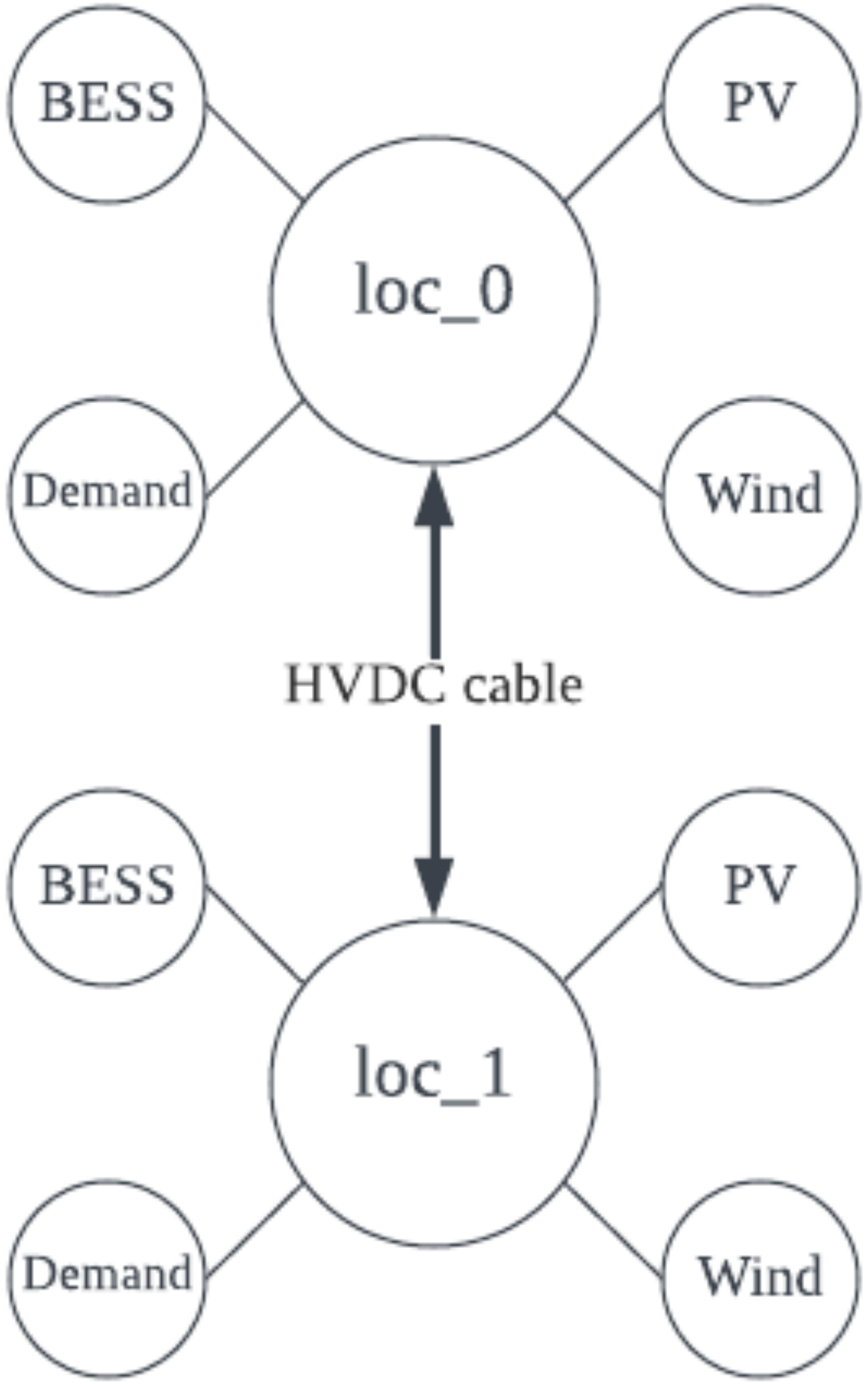
To run all the scenario folders, uncomment line 51 and comment line 52. This should also take about a minute, as once the network is built, optimising with different parameters is faster

Creating your own case study

Creating a new case study

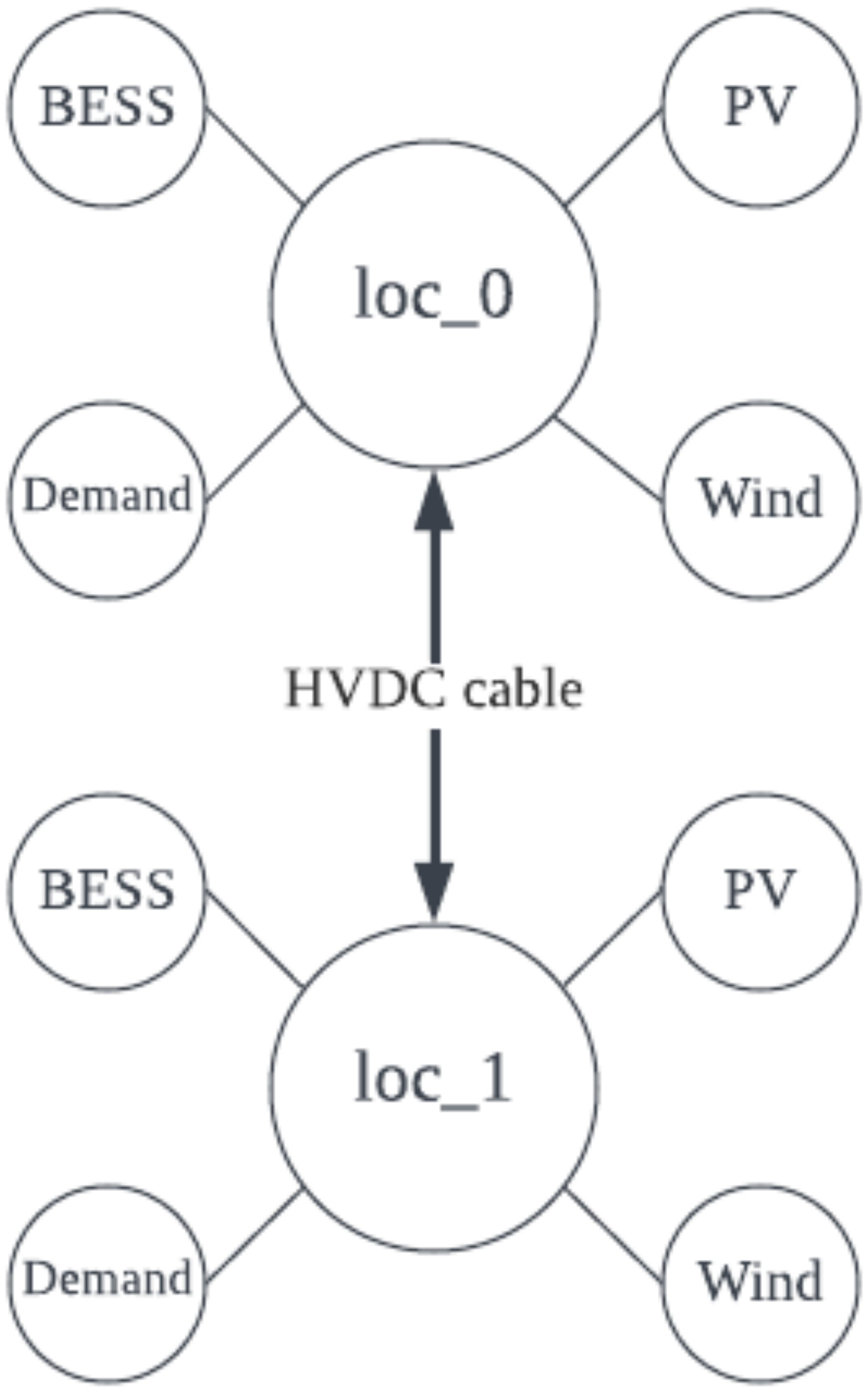
1. STEVFNs -> Data -> Case_Study -> Create Case Study folder named demo
2. Copy Network_Structure.csv file and the BAU scenario folder from SG_Case_Study into your new demo case study folder
3. Draw desired network in pen and paper (see next slide)
4. Input into Network_Structure.csv (delete all the data from the copied file, keep column names)

Creating a new case study



1. Build this network into Network_Structure.csv
2. We will use data from the locations already in SG_Case_Study so this is just practice for moving around in between the input files

Creating a new case study



1. Using data in the repository, build this network into Network_Structure.csv

2. It should look something like this

Asset_Numb	Asset_Class	Location_1	Location_2	Start_Time	End_Time	Period	Transport_Time
0	RE_PV	0	0	0	8760	1	0
1	RE_WIND	0	0	0	8760	1	0
2	BESS	0	0	0	8760	1	0
3	EL_Demand	0	0	0	8760	1	0
4	RE_PV	1	1	0	8760	1	0
5	RE_WIND	1	1	0	8760	1	0
6	BESS	1	1	0	8760	1	0
7	EL_Demand	1	1	0	8760	1	0
8	EL_Transport	0	1	0	8760	1	0

Asset names must correspond to the folder names in STEVFNs->Code->Assets

When an asset is in one location, the same value should be input in Location_1 and Location_2. When some kind of transport is needed, enter values as in asset number 8: There is EL_Transport from location 0 to location 1, and this is automatically modelled bidirectionally

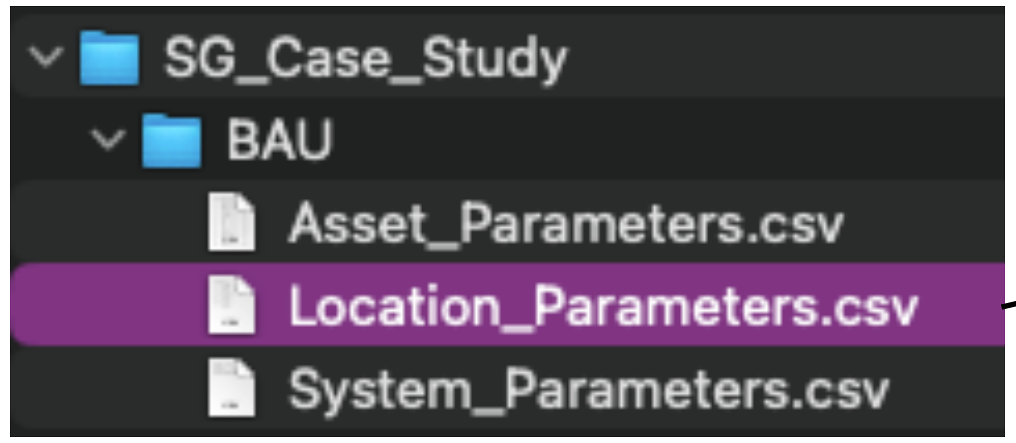
Time periods (hours) in our time series that we want to run the model for. This is for an entire year, input 168 to run for one week of the year*

Assuming instantaneous transport, leave all Transport_Time as 0

* In which case the model will grab equally distributed “blocks” of 168 consecutive hours (or the defined End_Time) of data, which is useful to reduce modelling times and roughly approximate a full year

Input of locations

1. Assume loc_0 and loc_1 are the same as some locations in SG_Case_Study -> BAU
2. Their coordinates are found in Location_Parameters.csv, let's use the following values for demo:



Location	lat	lon
0	10	77.5
1	30.5	84.375

In your demo case study -> BAU folder we copied, open Location_Parameters.csv, remove the data there, input the data in the table above, and save

*Note: Make sure all edits are saved into the **same .csv files**, and not create an .xlsx or pages file, for example.

Asset Parameters

1. STEVFNs -> Code -> Assets

2. For each type of asset, different **types**, or “brands” are available, e.g.

3. PV and wind:

Type	sizing_consta	sizing_consta	lifespan	lifespan_unit	RE_type	set_size	set_number
0	0.6	G$/GWp	175200	h	PVOUT	24	0
1	0.858	G$/GWp	175200	h	WINDOUT	24	0
2	0.3	G$/GWp	175200	h	PVOUT	24	0
3	0.429	G$/GWp	175200	h	WINDOUT	24	0

4. Batteries:

Type	storage_sizir	storage_sizir	storage_usag	storage_usag	storage_conv	charging_siz	charging_siz	charging_usa	charging_usa	charging_cor	discharging_	discharging_	discharging_	discharging_	discharging_	lifespan	lifespan_units
0	0.271	G$/GWh	0	G$/GWh	1.00E+00	0.542	G$/GW	2.71E-05	G$/GWh	0.975	2.71E-01	G$/GW	2.71E-05	G$/GWh	9.75E-01	87600	h
1	0.136	G$/GWh	0	G$/GWh	1.00E+00	0.271	G$/GW	1.36E-05	G$/GWh	0.975	1.36E-01	G$/GW	1.36E-05	G$/GWh	9.75E-01	87600	h

5. The Type column will let us know which Asset_Type to input into our Asset_Parameters.csv file, see next slide

Asset Parameters

1. STEVFNs -> Case_Study -> demo -> BAU -> Asset_Parameters.csv

2. Open Network_Structure.csv file from the demo case study folder, and copy the first four columns into Asset_Parameters.csv

3. Delete the rest of the information from the copied file, it should look like this for the network we created in slide 13:

Asset_Numb	Asset_Class	Location_1	Location_2	Asset_Type
0	RE_PV	0	0	0
1	RE_WIND	0	0	0
2	BESS	0	0	0
3	EL_Demand_	0	0	0
4	RE_PV	1	1	0
5	RE_WIND	1	1	0
6	BESS	1	1	0
7	EL_Demand_	1	1	0
8	EL_Transport	0	1	0

We can leave all the assets as brand 0 for the first run, feel free to play around with these, though. Make sure that the Asset_Type number you assign here has available parameters in its corresponding asset folder parameters.csv file, for example 2 for RE_PV assets and 3 for RE_WIND assets

Type	sizing_const	sizing_const	lifespan	lifespan_unit	RE_type	set_size	set_number
0	0.6	G$/GWp	175200	h	PVOUT	24	0
1	0.858	G$/GWp	175200	h	WINDOUT	24	0
2	0.3	G$/GWp	175200	h	PVOUT	24	0
3	0.429	G$/GWp	175200	h	WINDOUT	24	0

Running that case study

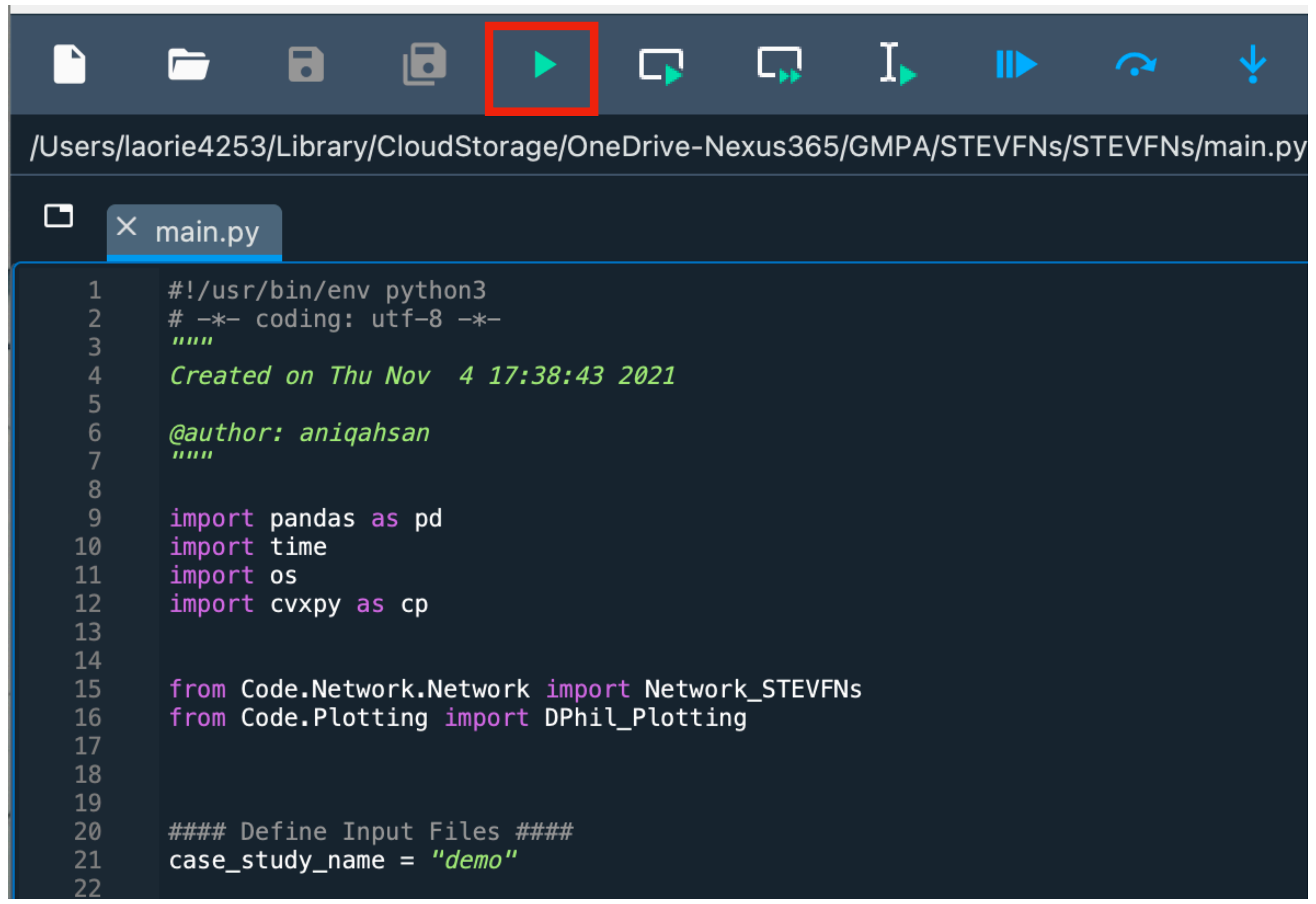
1. For now, leave System_Parameters.csv file as is

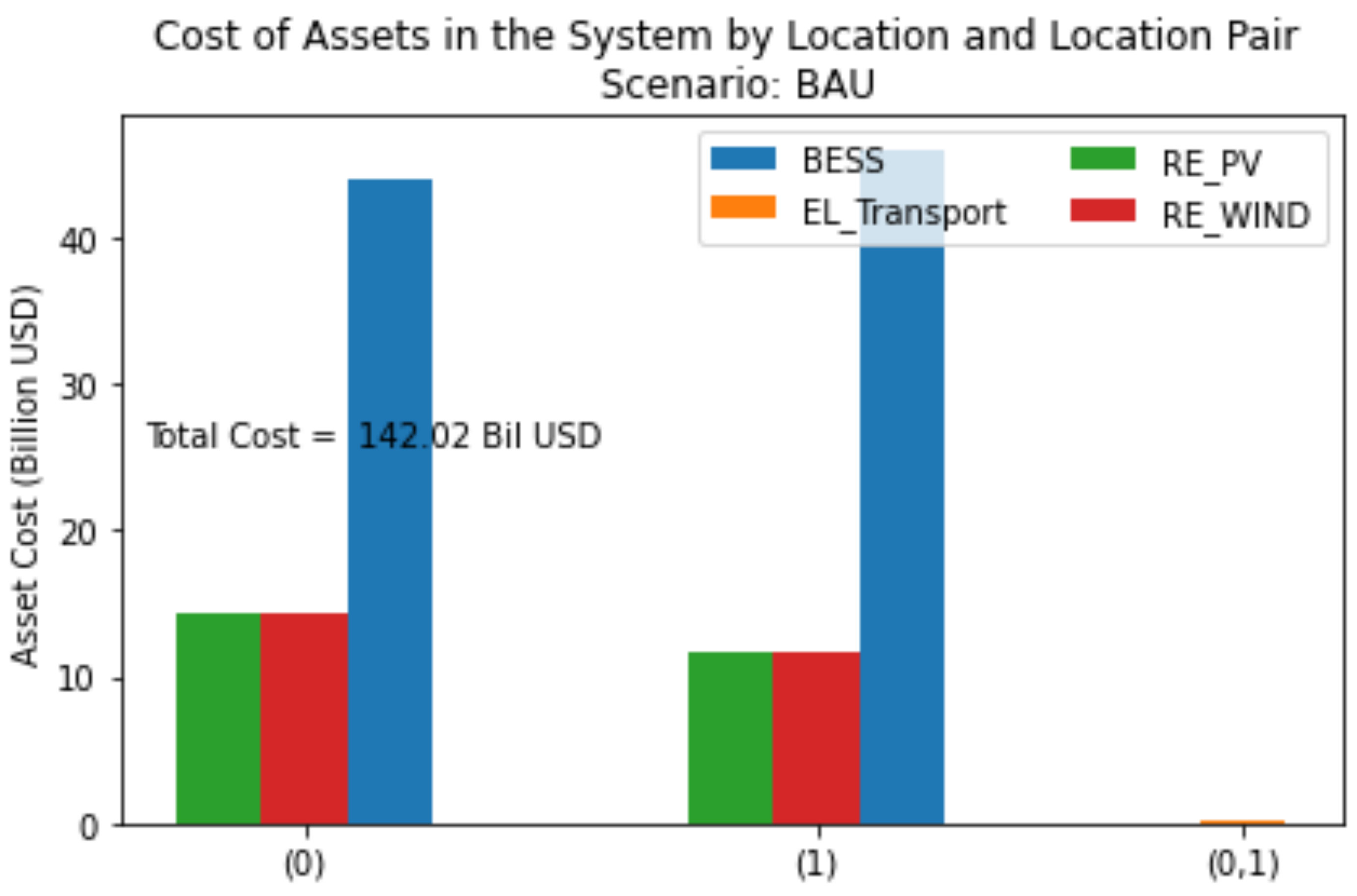
2. If you have already activated STEVFNs environment and opened Spyder in Anaconda Navigator, go to Spyder and open main.py from STEVFNs folder

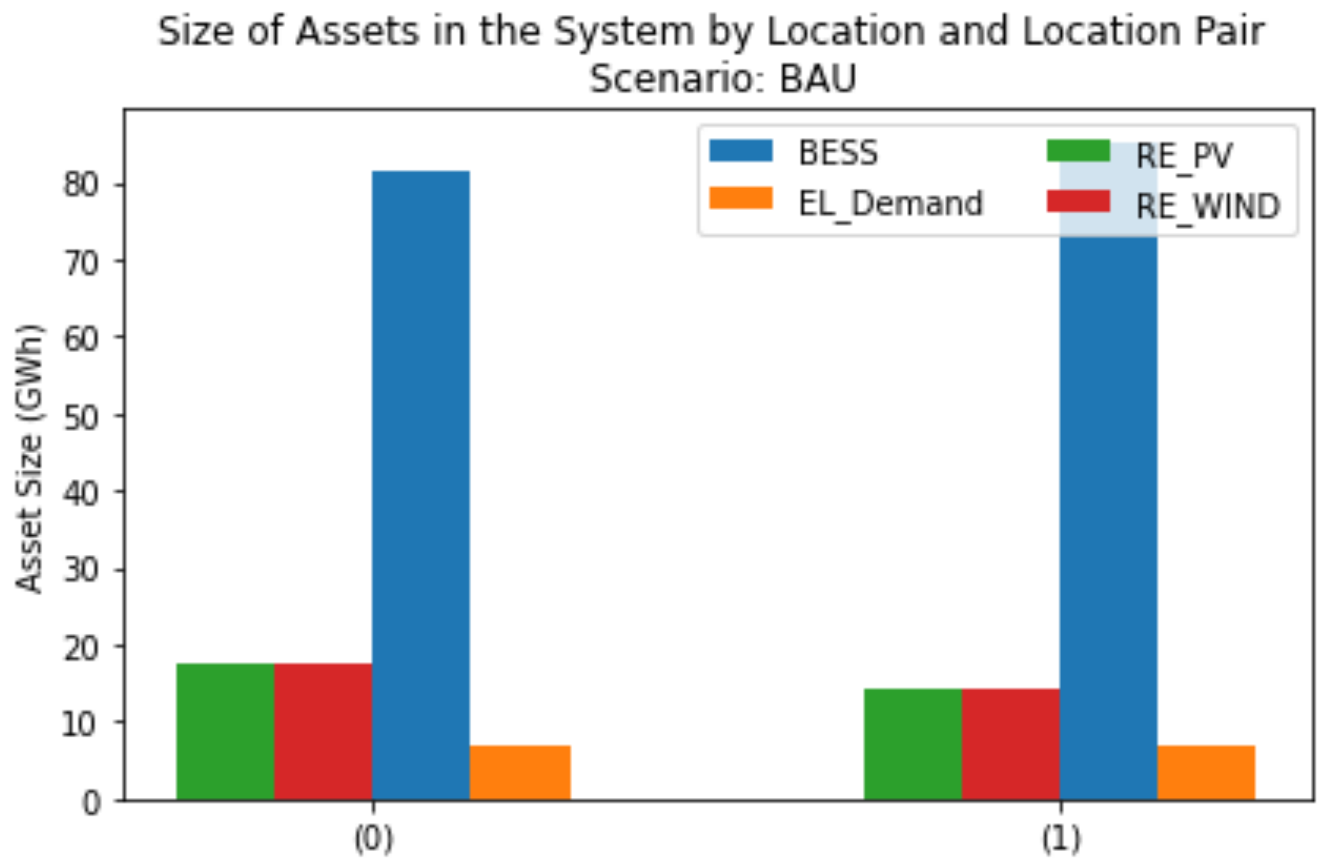
3. The only change you need to do is the case_study_name line, to read the name of your case study folder between quotes, in our case: “demo”

```
import pandas as pd
import time
import os
import cvxpy as cp


from Code.Network.Network import Network_STEVFNs
from Code.Plotting import DPhil_Plotting



#### Define Input Files ####
case_study_name = "demo"

```

Run the case study







1. Once you run this system, the output is plotted like this
2. Other results from the model, e.g. energy flows, may be extracted as well. Details on this will be in a separate file

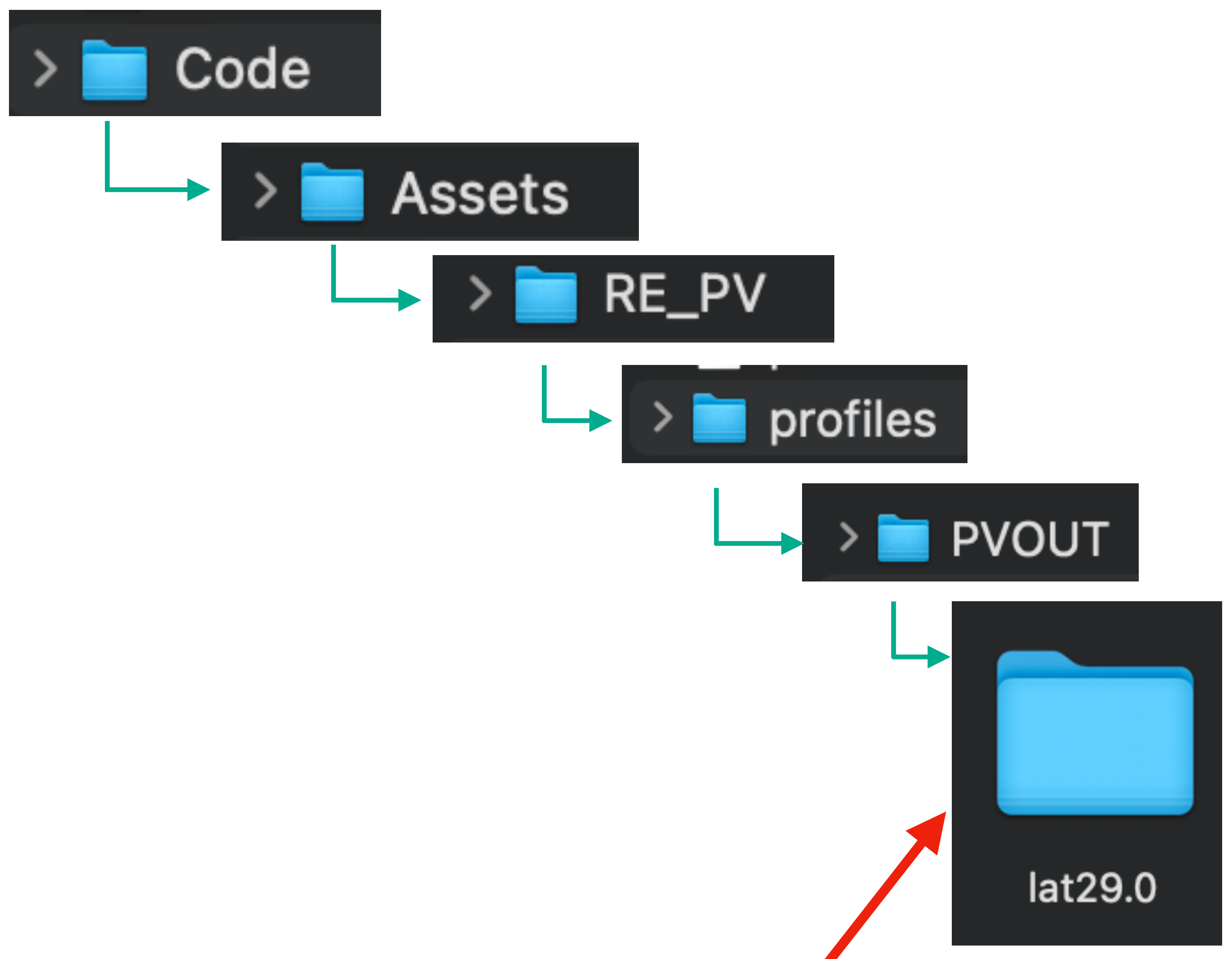
Data inputs

Examples for Renewable Energy and Demand profiles, and reminder of how files link between each other

Renewable Energy Profiles

1. Hourly capacity factor profiles from MERRA-2
2. From exact lat-lon of each location,
    1. $lat_{new} = (round(\frac{lat_{exact}}{0.5}) * 0.5)$
    2. $lon_{new} = (round(\frac{lon_{exact}}{0.625}) * 0.625)$
3. Name folder with rounded latitude value,

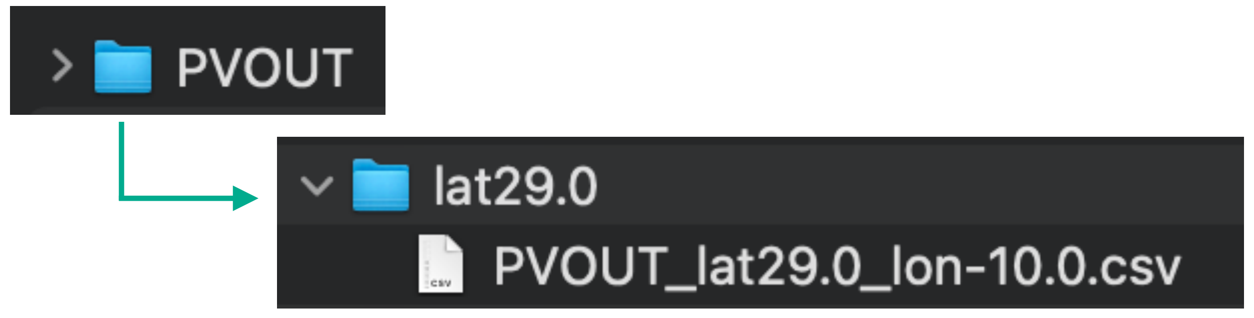
   e.g., location with lat = 29.16, lon = -10.29): $lat_{new} = (round(29.16/0.5) * 0.5) = 29.0$



4. Name csv file with the following format:

   PVOUT_lat29.0_lon-10.0.csv

   $$lon_{new} = (round(-10.29/0.625) * 0.625) = -10.0$$



Renewable Energy Profiles

1. The input should be the hourly capacity factor profiles for the RE technology, for one year (8760 hours)

2. These can be easily obtained from https://www.renewables.ninja/, which automatically converts weather profiles to specific electricity output for PV and wind through methods in [1, 2]

3. Or, if another data source is better suited, hourly profiles in GW/GWp are to be input with no additional formatting (see existing files in repository)

Example:

	A	B	C
1	0		
2	0		
3	0		
4	0		
5	0		
6	0		
7	0		
8	0.0246		
9	0.3294		
10	0.5436		
11	0.6788		
12	0.7577		
13	0.7974		
14	0.7704		
15	0.6826		
16	0.5397		
17	0.3268		
18	0.0408		
19	0		
20	0		
21	0		
22	0		
23	0		
24	0		
25	0		
26	0		
27	0		
28	0		
29	0		
30	0		
31	0		
32	0.0223		
33	0.3214		
34	0.5453		
35	0.6899		
36	0.7705		
37	0.7991		

PVOUT_lat29.0_lon-10.0

[1] Pfenninger, S., Staffell, I. *Energy*, **114**, 1251–1265 (2016). https://doi.org/10.1016/J.ENERGY.2016.08.060

[2] Staffell, I., Pfenninger, S. *Energy*, **114**, 1224–1239 (2016). https://doi.org/10.1016/J.ENERGY.2016.08.068

Renewable Energy Profiles

1. Naming the RE profile folders and .csv files as such creates the link between the data input and the network structure

2. For example, in our *demo* case study, BAU scenario (slides 13-20):

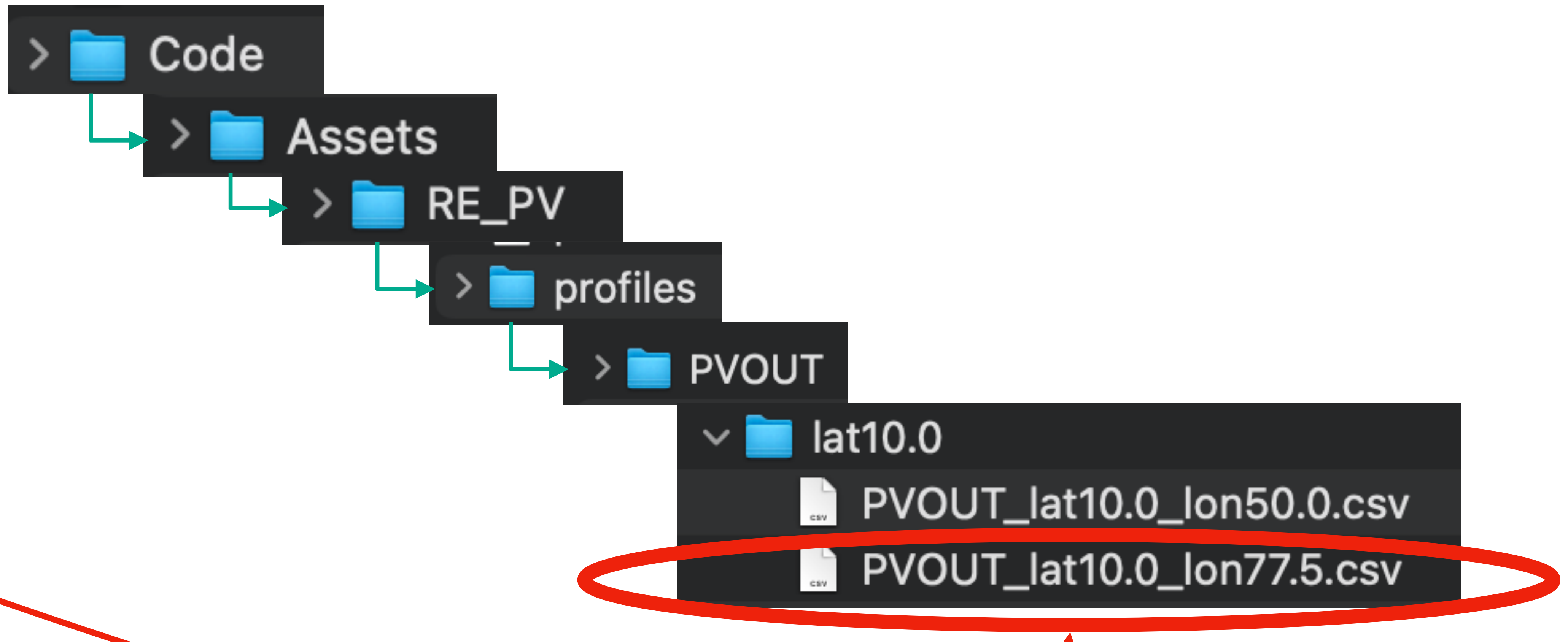
Network_Structure.csv

	A	B	C	D	E	F	G	H
1	Asset_Numb	Asset_Class	Location_1	Location_2	Start_Time	End_Time	Period	Transport_Time
2	0	RE_PV	0	0	0	168	1	0
3	1	RE_WIND	0	0	0	168	1	0
4	2	BESS	0	0	0	168	1	0
5	3	EL_Demand	0	0	0	168	1	0
6	4	RE_PV	1	1	0	168	1	0
7	5	RE_WIND	1	1	0	168	1	0
8	6	BESS	1	1	0	168	1	0
9	7	EL_Demand	1	1	0	168	1	0
10	8	EL_Transport	0	1	0	168	1	0
11								

Location_Parameters.csv

	A	B	C
1	Location	lat	lon
2	0	10	77.5
3	1	30.5	84.375

Location 0 in the Network Structure is in coordinates (10, 77.5). Therefore the RE_PV asset located here must access its capacity factor profile



Renewable Energy cont. - Asset brands link

Reminder: The generalised coordinates which calculate costs of assets, link the Asset_Parameters of each scenario:

Network_Structure.csv

	Asset_Numb	Asset_Class	Location_1	Location_2	Start_Time	End_Time	Period	Transport_Time
2	0	RE_PV	0	0	0	168	1	0
3	1	RE_WIND	0	0	0	168	1	0
4	2	BESS	0	0	0	168	1	0
5	3	EL_Demand	0	0	0	168	1	0
6	4	RE_PV	1	1	0	168	1	0
7	5	RE_WIND	1	1	0	168	1	0
8	6	BESS	1	1	0	168	1	0
9	7	EL_Demand	1	1	0	168	1	0
10	8	EL_Transport	0	1	0	168	1	0

Asset_Parameters.csv

	Asset_Number	Asset_Class	Location_1	Location_2	Asset_Type
2	0	RE_PV	0	0	0
3	1	RE_WIND	0	0	0
4	2	BESS	0	0	0
5	3	EL_Demand	0	0	0
6	4	RE_PV	1	1	0
7	5	RE_WIND	1	1	0
8	6	BESS	1	1	0
9	7	EL_Demand	1	1	0
10	8	EL_Transport	0	1	0

For this scenario, the PV plant in location 0, coords (10, 77.5) will cost 0.6 Billion USD per GWp installed, and this will be optimised through the available solar resource in the capacity factor profile for this location

Location_Parameters.csv

	Location	lat	lon
2	0	10	77.5
3	1	30.5	84.375

- Code
  - Assets
    - RE_PV
      - __init__.py
      - __pycache__
      - parameters.csv
      - profiles
        - PVOUT
          - lat10.0
            - PVOUT_lat10.0_lon50.0.csv
            - PVOUT_lat10.0_lon77.5.csv

parameters.csv

	Type	sizing_consta	sizing_consta	lifespan	lifespan_unit	RE_type	set_size	set_number
2	0	0.6	G$/GWp	175200	h	PVOUT	24	0
3	1	0.858	G$/GWp	175200	h	WINDOUT	24	0
4	2	0.3	G$/GWp	175200	h	PVOUT	24	0
5	3	0.429	G$/GWp	175200	h	WINDOUT	24	0

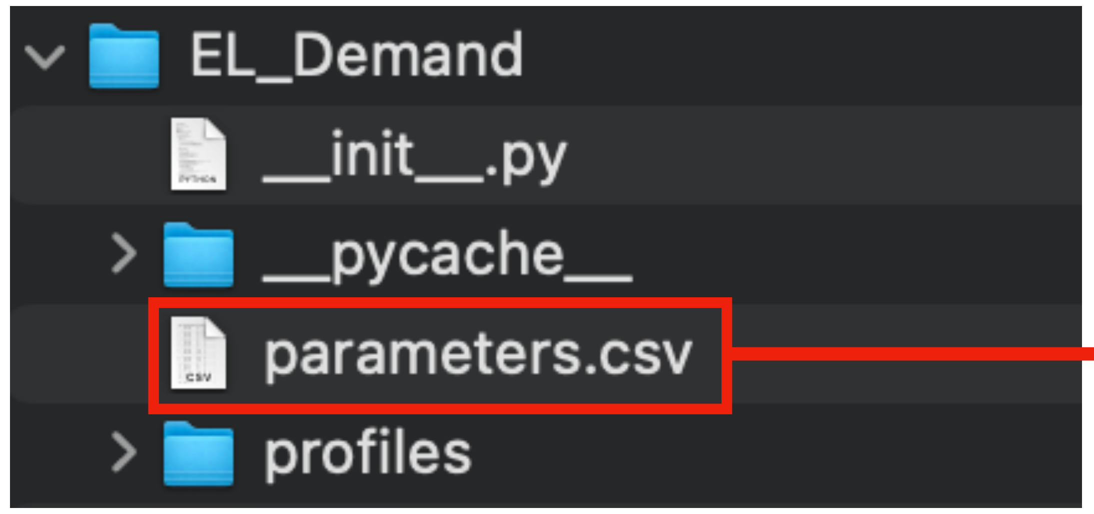
Demand data

1. EL_Demand profiles should include hourly demand in GW for the location(s) of the network which have a demand asset

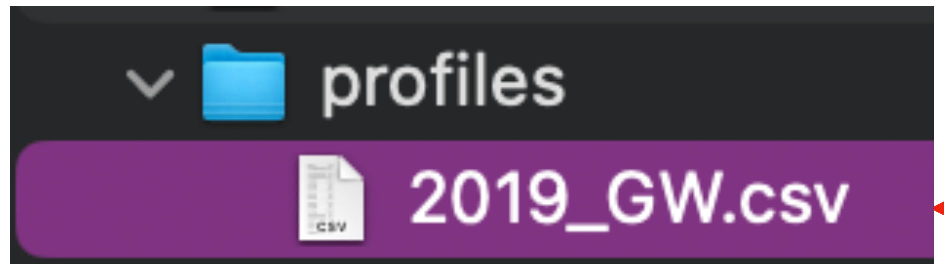
Demand	Unit
5.1812925	GW
5.380152	GW
5.5193615	GW
5.5495245	GW
5.5377875	GW
5.537142	GW
5.577153	GW
5.581966	GW
5.598156	GW
5.6702955	GW
5.707148	GW
5.8269325	GW
5.8182075	GW
5.799185	GW
5.615506	GW
5.4350925	GW
5.2260445	GW
5.017342	GW
4.9159815	GW
4.8547755	GW
4.850867	GW
5.01094	GW
5.356994	GW
5.748379	GW
6.20835	GW
6.4811605	GW
6.6155445	GW
6.6027865	GW
6.5521	GW
6.6514255	GW
6.6604685	GW
6.671236	GW
6.6705425	GW
6.545475	GW
6.4230465	GW
6.4184715	GW

2019_GW

2. The name of the .csv file does not require a particular format, but the selected name must be typed into the parameters file for this asset:



Type	profile_filena	set_size	set_number
0	2019_GW	24	0



Demand Data

1. To link demand data to its location(s) in the modelled network, the **Type** value in the parameters.csv file in Demand asset folder should match the **Asset_Type** cell in Asset_Parameters.csv in the corresponding scenario folder