Data formats

This chapter presents the conventions deployed to name the files, the format of datasets, and the main transformations.

All the input files are given as CSV files.

1. One row containing column labels
2. Serie of Rows containing the data (consistent with column labels)
3. Each row contains a name, a region and various values of variables

Columns that are not used may be skipped.

Description of geography

Each dataset is linked to a geographical area that may be partitioned. Different partitions may be used for dealing with different levels of constraints or computations.

Those partitions are described in files or sheets named ZP_ZonePartition, that follow the same rules:

The first column ‘Level1’ lists the lowest level partition. The partition ‘level2’ is a higher level partition, meaning that the regions in Level2 are larger than the regions in level1, and each region in level2 is composed of a list of regions in level1. Level3 partitions again are bigger than level2. At each level we may have different partitions obtained by regrouping regions differently (here we have 2 different ways of grouping the regions of level2: level3part1 and level3part2).

- Level1 = identifier of the first level zone (e.g., datazone) - string
- Level2= identifier of the second level zone (e.g., cluster) - string
- Level3Part1 = identifier of the third level zone (e.g., region), in a first partition – string
- Level3Part2 = identifier of the third level zone (e.g., region), in a second partition – string
- Etc.

A row with values L1, L2, L31, L32 … means that zone L1 belongs to second level zone L2, and this zone belongs to third level zones L31 and L32, …; Each L1 belongs to a unique L2; Each L2 belongs to a unique L3 for the first partition, and to a unique L3 – that can be different- for the second partition, etc…

The Figure 1 below illustrates this. In Blue: Level1; in Green: level2, in red and orange: level3 (partition1 and partition2), and in black level4. Here there are 7 zones in level1, that are aggregated in 4 level 2 clusters: BE, FR1, FR2 and ES. Each level1 zone belongs to a unique level2 cluster. At level3 there are 2 partitions: Level3part1 partitions the 4 clusters as North=BE+FR1, South=FR2+ES while Level3part2 partitions the same 4 clusters as BE=BE, FR=FR1+FR2 and ES=ES.

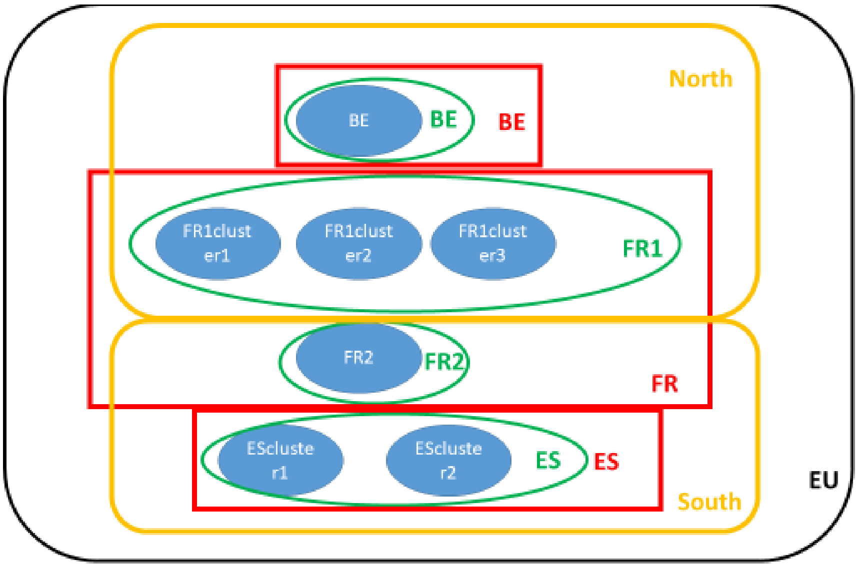

Figure 1: partitions

Coupling Constraints

The coupling constraints, ie the constraints linking different assets together, can be of the following categories:

- ActivePowerDemand: this is related to the equilibrium constraint Active power = Active Power demand at each node of the network. The Active Power Demand is computed as the sum of different components that are listed in the 'SumOf' row of settingsCreateInputPlan4res.yml corresponding line (this means that the power demand is computed as the sum of the electric heating demand, the electric cooling demands….). Each component is computed as the product of an energy and a timeseries. For the case with only one component, ActivePowerDemand= Final Energy|Electricity * TimeSerie (with a Timeserie with the characteristic that the average on all scenarios of the sum on one year of its values is equal to 1). ActivePowerDemand may also be the sum of:
    - ElecHeating = Final Energy|Electricity|Heat * ElecHeating Timeserie
    - AirCondition= Final Energy|Electricity|Cooling * AirCondition Timeserie
    - ElecVehicle= Final Energy|Electricity|Transportation * ElecVehicle Timeserie
    - Nonthermo= Final Energy|Electricity|Other (excl. Heat, Cooling, Transport) * Nonthermo Timeserie
- PrimaryDemand: this is related to the primary reserve, in each "zone" (can be a country….)

  Equivalent to Network|Electricity|Reserve|Requirement|Frequency Containment
- SecondaryDemand: this is related to the secondary reserve.

Equivalent to Network|Electricity|Reserve|Requirement| Automatic Frequency Restoration

- InertiaDemand: this is related to the inertia requirement.

  Equivalent to Network|Electricity|Reserve|Requirement|Inertia

- PollutantBudget: this constraint is related to the maximum amount of polluting emissions, for a specific pollutant.

Each coupling constraint is applying to a region. Different categories of coupling constraints may apply to different region partitions, as described above (eg. ActivePowerDemand may apply to Countries and InertiaDemand to a group of countries)

1 Input Data

This section describes the format of data used to feed the models used in Capacity Expansion Model, Seasonal Storage Valuation Model and European Unit Commitment model.

The dataset is organized as follows:

- A set of csv files representing the ‘fixed’ data :
  - ZP_ZonePartition: contains the description of the different geographical partitions (follows common format for patitions)
  - ZV_ZoneValues : contains data linked to zones (follows common format for data depending on zones)
  - IN_Interconnections: contains the description of the network (follows common format on interconnections)
  - TU_ThermalUnits: contains the description of the thermal power plants (follows common format for data depending on zones)
  - SS_SeasonalStorage: contains the description of the hydrovalleys and other long term storages (follows common format for data depending on zones)
  - STS_ShortTermStorage: contains the description of other storages: batteries but also demand-response. (follows common format for data depending on zones)
  - RES_RenewableUnits: contains the description of PV, WindPower and RunofRiver (follows common format for data depending on zones)
- A set of CSV files containing scenarised time series: those files follow the common format on time series, ie 1 line of heading; The first column contains the UCT timestamp (in any format readable by pandas) and the following columns are different scenarios of the current timeserie=> one CSV file contains one scenarized timeserie. Scenarios are stamped by the value in the line2 (usually past years, eg 1970, 1971, 1972…); Deterministic timeseries can either be aggregated in a single csv file or be given each in a different csv file.

1.1 ZP_ZonePartition.csv

	A	B
1	**Level1**	**Level2**
2	France	Europe
3	Germany	Europe
4	Italy	Europe
5	Switzerlan	Europe
6	EasternEu	Europe
7	Benelux	Europe
8	Iberia	Europe
9	Britain	Europe
10	Balkans	Europe
11	Baltics	Europe
12	Denmark	Europe
13	Finland	Europe
14	Sweden	Europe
15	Norway	Europe
16		

Figure 2: 'ZP_ZonePartition.csv'

The file ZP_ZonePartition.csv describes the different partitions that are used for dealing with different coupling constraints.

The mapping between the coupling constraints and the partitions is defined in the first block of the sheet parameter: In our example, ActivePowerDemand is using level1. This means that level1 is the level to be used to generate the nodes of the model. In the example we have 14 nodes. In practice the model will receive the constraint at each node ActivePower in the current node=ActivePowerDemand of the current node ; InertiaDemand uses usually level2 (which in the example is Europe). This means that there is only one InertiaDemand constraint ; In practice the model will receive the constraint Total inertia (ie sum of the inertia in all nodes)=inertiademand

1.2 file ZV_ZoneValues.csv

Type	Zone	value	Profile_Timeserie
AirCondition	Balkans	4297011.38	EDF__HourlyCoef-AirCondition-PresentClimate-HR__20062019__28062019__v1.csv
CostActivePowerDemand	Balkans	10000	
CostPrimaryDemand	Balkans	15000	
CostSecondaryDemand	Balkans	15000	
ElecHeating	Balkans	162425696.5	EDF__HourlyCoef-Heating-PresentClimate-HR__20062019__28062019__v1.csv
ElecVehicle	Balkans	41565561.78	EDF__HourlyCoef-ElecVehicle__20062019__28062019__v1.csv
MaxActivePowerDemand	Balkans	500000	
MaxPrimaryDemand	Balkans	1000	
MaxSecondaryDemand	Balkans	1000	
nonthermo	Balkans	201269335.9	EDF__HourlyCoef-non-thermo-PresentClimate-HR__20062019__28062019__v1
Total	Balkans	409557605.6	
AirCondition	Baltics	408.9409178	EDF__HourlyCoef-AirCondition-PresentClimate-LV__20062019__28062019__v1.csv
CostActivePowerDemand	Baltics	10000	
CostPrimaryDemand	Baltics	15000	
CostSecondaryDemand	Baltics	15000	
ElecHeating	Baltics	25818341.05	EDF__HourlyCoef-Heating-PresentClimate-LV__20062019__28062019__v1.csv
ElecVehicle	Baltics	9429033.308	EDF__HourlyCoef-ElecVehicle__20062019__28062019__v1.csv

Figure 3: ZV_ZoneValue.csv

This file contains the values of all coupling constraints, and may also (optional) contain the costs associated (imbalance costs).

1.3 file IN_Interconnections.csv

2	Name	Type	Direction	StartLine	EndLine	axPowerFl	inPowerFl	mpedance
3	Denmark>Germany	AC	Bidirectior	Denmark	Germany	1091.25	-2075	0
4	Denmark>Norway	AC	Bidirectior	Denmark	Norway	1000	-950	0
5	Denmark>Sweden	AC	Bidirectior	Denmark	Sweden	1393.458	-1980	0
6	Finland>Sweden	AC	Bidirectior	Finland	Sweden	1950	-2250	0
7	France>Germany	AC	Bidirectior	France	Germany	1800	-1675	0
8	France>Italy	AC	Bidirectior	France	Italy	866	-1160	0
9	France>Switzerland	AC	Bidirectior	France	Switzerlan	3200	-1100	0
10	Germany>Sweden	AC	Bidirectior	Germany	Sweden	353.9583	-610	0
11	Germany>Switzerland	AC	Bidirectior	Germany	Switzerlan	3500	-3500	0
12	Italy>Switzerland	AC	Bidirectior	Italy	Switzerlan	1910	-1336	0
13	Norway>Sweden	AC	Bidirectior	Norway	Sweden	3145	-2926	0
14	France>Benelux	AC	Bidirectior	France	Benelux	2600	-1500	0
15	France>Iberia	AC	Bidirectior	France	Iberia	1241.667	-1070	0
16	France>Britain	AC	Bidirectior	France	Britain	2000	-2000	0
17	Germany>EasternEurope	AC	Bidirectior	Germany	EasternEu	3400	-4000	0
18	Germany>Benelux	AC	Bidirectior	Germany	Benelux	3830	-3380	0
19	Italy>EasternEurope	AC	Bidirectior	Italy	EasternEu	100	-71	0
20	Italy>Balkans	AC	Bidirectior	Italy	Balkans	680	-703	0
21	Switzerland>EasternEurope	AC	Bidirectior	Switzerlan	EasternEu	1200	-434	0
22	EasternEurope>Balkans	AC	Bidirectior	EasternEu	Balkans	3250.083	-3350	0
23	EasternEurope>Sweden	AC	Bidirectior	EasternEu	Sweden	265.9167	-341	0
24	Benelux>Britain	AC	Bidirectior	Benelux	Britain	1016	-1016	0
25	Benelux>Norway	AC	Bidirectior	Benelux	Norway	700	-700	0
26	Baltics>Finland	AC	Bidirectior	Baltics	Finland	365	-365	0

Figure 4: IN_Interconnections.csv

This file describes the characteristics of the lines that are linking the nodes of the network, where the nodes are those described in the partition linked to the ActivePowerDemand variable:

- Name: name of the line (used for processing results)
- (optional) Type: type of the line (not used)
- (optional) Direction : unused, all lines are bidirectional. To include not bidirectionnal lines, Min or MaxPower =0
- StartLine and EndLine must be nodes defined in the partition linked to the ActivePowerDemand
- MaxPowerFlow and MinPowerFlow are the bounds on the flows for this line
- Impedance (used in the version with AC)

1.4 file TU_ThermalUnits.csv

Zone	Name	umberUnit	MaxPower	MinPower	ariableCos	FixedCost	tartUpCos	MinUpTime	inDownTin	CO2	Inertia	PrimaryRho
Balkans	Biomass|w/o CCS	1	250	150	197.0484	0	6000	3	3	0	0	0.1
Balkans	Coal|w/o CCS	13	800	320	86.79424	0	36000	24	24	0	5	0.1
Balkans	Gas|CCGT|w/o CCS	6	500	150	115.0671	0	3600	3	3	0	4.5	0.1
Balkans	Geothermal	12	100	0	0.304	0	0	1	1	0	0	0
Balkans	Nuclear	6	1600	800	15.83083	0	33500	168	168	0	5.5	0.1
Balkans	Oil|w/o CCS	1	200	100	138.1965	0	0	3	3	0	5	0.1
Baltics	Biomass|w/o CCS	1	250	150	197.0484	0	6000	3	3	0	0	0.1
Baltics	Biomass|w/ CCS	2	250	150	197.0484	0	6000	3	3	0	0	0.1
Baltics	Gas|CCGT|w/o CCS	2	500	150	115.0671	0	3600	3	3	0	4.5	0.1

Figure 5: TU_ThermalUnits.csv

This sheets gives the characteristics of all thermal power plants.

It contains the following data:

- Name
- Zone
- NumberUnits : number of units of the same type at the same location
- MaxPower
- MinPower (optional, 0 by default)
- Pauxiliary: Power taken from the system when off. Optional (0 by default)
- FixedCost: Optional (0 by default) ;
- VariableCost: proportional cost; Optional (0 by default).
- Quadterm: quadratic cost; Optional (0 by default)
- StartUpCost: Optional (0 by default)
- MinUpTime: minimum duration when the plant is on; Optional (1 by default)
- MinDownTime: minimum duration when the plant is off; Optional (1 by default)
- Inertia: max inertia that can be provided by a unit; Optional (0 by default)
- PrimaryRho: this parameter, multiplied by Maxpower, gives the maximum primary reserve that can be provided by a unit; Optional (0 by default)
- SecondaryRho: this parameter, multiplied by Maxpower, gives the maximum secondary reserve that can be provided by a unit; Optional (0 by default)
- DeltaRampDown: maximum gradient when the power is decreased from one time step to the other. Optional (MaxPower by default)
- DeltaRampUp: maximum gradient when the power is increased from one time step to the other. Optional (MaxPower by default)
- CO2 : emissions per MWh (optional, default 0)

1.5 Excel sheet SS_SeasonalStorage

HydroSystem	NumberUnits	MaxPower	MinPower	MaxVolume	MinVolume	Inflows	InitialVolume	TurbineEfficiency	PumpingEfficiency	Inertia	PrimaryRho	SecondaryRho	WaterValues	InflowsProfile
0	1	27177.9	0	2E+07	0	7.9E+07	5568181.382	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-Iberia__18
0	1	10390	0	7887467	0	3E+07	1498618.64	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-CH__18092
0	1	23400	0	9.1E+07	0	6.8E+07	48457476	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-NO__18092
0	1	13422.5	0	2986771	0	3.9E+07	1194708.4	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-FR__18092
0	1	4095	0	5414400	0	1.2E+07	2274048	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-FI__18092
0	1	9578.4	0	5382043	0	2.8E+07	2206637.712	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-IT__18092
0	1	12637.7	0	2298865	0	3.7E+07	850580.1728	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-EasternEur
0	1	14586	0	3.7E+07	0	4.2E+07	19889712	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-SE__18092
0	1	23939.7	0	6096617	0	6.9E+07	2255748.216	1	0	4.5	0.1	0.1		EDF__Inflow-HourlyCoefficient-PresentClimate-Balkans__1

Figure 6: SS_SeasonalStorage.csv

This sheets gives the characteristics of all seasonal storages.

It contains the following:

- Name
- Zone
- NumberUnits : number of units of the same type at the same location
- MaxPower (MW)
- MinPower (MW, optional, 0 by default)
- DeltaRampDown: maximum gradient when the power is decreased from one time step to the other. Optional (MaxPower by default)
- DeltaRampUp: maximum gradient when the power is increased from one time step to the other. Optional (MaxPower by default)
- MaxVolume (MWh)
- MinVolume (MWh, optional, 0 by default)
- TurbineEfficiency: (optional, 1 by default). This value, multiplied by the flow, gives the generated power.
- PumpingEfficiency: (optional, 1 by default). This value, multiplied by the flow, gives the generated power.
- Inflows: (MWh ; optional, 0 by default). Inflows to the upstream reservoir (energy per year).
- Inflows profile: (optional): time serie profile for Inflows. Multiplied by the Inflows in energy, gives the inflows time serie.
- InitialVolume: (MWh, optional, 0 by default). Initial Volume of the upstream reservoir
- Inertia: max inertia that can be provided by a unit; Optional (0 by default)
- PrimaryRho: (%) this parameter, multiplied by Maxpower, gives the maximum primary reserve that can be provided by a unit; Optional (0 by default)
- SecondaryRho: (%) this parameter, multiplied by Maxpower, gives the maximum secondary reserve that can be provided by a unit; Optional (0 by default)
- WaterValues: Optional; Used if external water values are used in the current run. Contains the name of the file/sheet where the water values are stored. When using the simulation mode with 1 BV file for all units, this file is only given in the first line ; when using the simulation mode with 1 BV per unit, this file is given at each line ; in optimisation mode, this is not required (output of the model)

1.6 sheet STS_ShortTermStorage.csv

This file is used for :

- Pumped storage
- Batteries
- Other flexibilities such as residential flexibilities or EV, which are modelled as short term storages

Name	Zone	NumberUnits	MaxPower	MinPower	MaxVolume	MinVolume	TurbineEfficiency	Pumping Efficiency	Inertia	MaxPrimary Power	MaxSecondary Power	VolumeLevelTarget	InitialVolume
Pumped Storage	Balkans	1	3107.58612	-3107.5861	310758.6119	0	1	0.866	4.5	310.758612	310.7586119		310758.6119
Compressed Air	Balkans	1	11431.7403	-11431.74	182907.8447	0	1	0.837	0	10288.5663	10288.56627		182907.8447
Lithium-Ion	Balkans	1	2182.2611	-2182.2611	43645.22209	0	1	0.95	0	1964.03499	1964.034994		43645.22209
Electric Vehicle	Balkans	1	DR__Electric	DR__Electric	51766.21236	DR__Electric	1	1	0	0	0		51766.21236
Dryer	Balkans	1	DR__Dryer_	DR__Dryer_	21892.72859	DR__Dryer__	1	1	0	0	0		21892.72859
Washing Machin	Balkans	1	DR__Washin	DR__Washin	25326.37738	DR__Washing	1	1	0	0	0		25326.37738
Dish Washer	Balkans	1	DR__Dish W	DR__Dish W	19225.49652	DR__Dish Wa	1	1	0	0	0		19225.49652

Figure 7: STS_ShortTermStorage.csv

It contains the following data:

- Name
- Zone
- NumberUnits : number of units of the same type at the same location
- WindowsSize (hours, optional): size of the windows where load shifting is allowed
- MaxPower (MW) ; can be a (deterministic) timeserie, in this case : name of the time serie
- MinPower (MW, optional, 0 by default) ; can be a (deterministic) timeserie, in this case : name of the time serie
- Cost: proportional cost. (€/MWh, optional, 0 by default)
- MaxVolume (MWh) ; can be a (deterministic) timeserie, in this case : name of the time serie
- MinVolume (MWh, optional, 0 by default) ; can be a (deterministic) timeserie, in this case : name of the time serie
- TurbineEfficiency: (optional, 1 by default). This value, multiplied by the flow, gives the generated power.
- PumpingEfficiency: (optional, 1 by default). This value, multiplied by the flow, gives the generated power.
- Inflows: (optional, 0 by default). Inflows to the upstream reservoir.
- InitialVolume: (MWh, optional, 0 by default)
- VolumeLevelTarget: (MWh, optional) used to force the optimisation to reach this volume at the end of each time set. If there is a VolumeLevelTarget filled, then the minimum volume constraint is replaced by this value at first and last timesteps of each time set.
- MaxPrimaryPower: (MW) maximum primary reserve that can be provided by a unit; Optional (0 by default)
- MaxSecondaryPower: (MW) maximum secondary reserve that can be provided by a unit; Optional (0 by default)

1.7 file RES_RenewableUnits.csv

<table>
<tr><th>Name</th><th>Zone</th><th>NumberUnits</th><th>MaxPower</th><th>MinPower</th><th>MaxPowerProfile</th><th>Inertia</th><th>Gamma</th><th>Kappa</th></tr>
<tr><td>Hydro|Run of River</td><td>France</td><td>1</td><td>90447000</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-FR__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Germany</td><td>1</td><td>62500848</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-DE__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Italy</td><td>1</td><td>64543680</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-IT__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Switzerland</td><td>1</td><td>33761040</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-CH__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>EasternEuro</td><td>1</td><td>74446768.95</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-AT__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Benelux</td><td>1</td><td>1474823.176</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-FR__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Iberia</td><td>1</td><td>172010846</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-ES__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Britain</td><td>1</td><td>6325538.508</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-FR__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Balkans</td><td>1</td><td>132556645.5</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-RO__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Baltics</td><td>1</td><td>14615398.94</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-NO__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Hydro|Run of River</td><td>Scandinavia</td><td>1</td><td>173188685.1</td><td>0</td><td>EDF__RunOfRiver-HourlyCoefficient-PresentClimate-NO__18092019__18092019__v1.csv</td><td>4.5</td><td>0.2</td><td>1</td></tr>
<tr><td>Solar|PV</td><td>France</td><td>1</td><td>148447.2285</td><td>0</td><td>EDF__PV-LoadFactor-PresentClimate-FR_C8__13082019__13082019__v1.csv</td><td>0</td><td>0.3</td><td>1</td></tr>
<tr><td>Solar|PV</td><td>Germany</td><td>1</td><td>242816.9394</td><td>0</td><td>EDF__PV-LoadFactor-PresentClimate-DE_C1__13082019__13082019__v1.csv</td><td>0</td><td>0.3</td><td>1</td></tr>
<tr><td>Solar|PV</td><td>Italy</td><td>1</td><td>130262.0482</td><td>0</td><td>EDF__PV-LoadFactor-PresentClimate-IT__13082019__13082019__v1.csv</td><td>0</td><td>0.3</td><td>1</td></tr>
</table>

Figure 8: RES_renewableUnits.csv

This sheets gives the characteristics of all renewable units: windpower, PV power and run-of-river.

It contains the following data:

- Name
- Zone
- NumberUnits: number of units of the same type at the same location
- MaxPower (MW for PV and WindPower ; for RunOfRiver MWh/year)
- MinPower (MW, optional, 0 by default)
- Inertia: max inertia that can be provided by a unit; Optional (0 by default)
- Gamma (optional, 1 by default): this parameter is used by the model to determine the maximum available primary and secondary reserve. It is used to take into account the fact that

some renewable units, due to the uncertainty in their maximum capacity, may not be able to provide reserve at full capacity.

- Kappa (optional, 1 by default) ; this parameter is used to determine the maximum capacity to be invested.

1.8 Additional columns for Investments (CEM)

For running the capacity expansion model, 3 clumns need to be added to the sheets corresponding to assets for which investment is possible :

- MaxAddedCapacity (MW) : this is the maximum capacity that may be added
- MaxRetCapacity (MW) : this is the maximum capacity that may be taken out
- InvestmentCost (€/MW) : this is the cost for investing into 1MW of the given capacity in the given region
- DecommissionCost (€/MW) : this is the cost for taking out 1MW of the given capacity in the given region

These columns may be added to the files :

- IN_Interconnections.csv
- TU_ThermalUnits.csv
- STS_ShortTermStorage.csv
- RES_RenewableUnits.csv

2 Plan4res outputs : results of SMS++

The results of SMS++ are detailed in the following subsections.

2.1 Results of SSV

The SSV (sddp_solver ran in optimization mode) computes BellmanValues for the seasonal storages, which can be given in different files:

- When the convergence criteria of the SDDP algorithm is met : BellmanValuesOUT.csv, and BellmanValuesAllOUT.csv (the later containsn all cuts of the algorithm while in the first, redundant cuts have been eliminated)
- In any case, ie even without convergence : cuts.txt, which contains all the cuts already found by the SDDP algorithm.

2.2 Results of SIM

The simulation produces for each scenario the following results

- ActiveDemandOUT.csv : 1 column per zone with the demand of the region
- ActivePowerOUT.csv : Generation schedules. 1 column per unit (apart from the Seasonal Storage units which are duplicated in 2 columns: one for the generation part, and the other one for the pumping part)
- PrimaryOUT.csv : Primary reserve schedules. 1 column per unit (apart from the Seasonal Storage units which are duplicated in 2 columns: one for the generation part, and the other one for the pumping part)
- SecondaryOUT.csv : Secondary reserve schedules. 1 column per unit (apart from the Seasonal Storage units which are duplicated in 2 columns: one for the generation part, and the other one for the pumping part)
- InertiaOUT.csv : Inertia provided by each unit. 1 column per unit (apart from the Seasonal Storage units which are duplicated in 2 columns: one for the generation part, and the other one for the pumping part)
- VolumeOUT.csv : Volumes of each storages (seasonal storages and short term storages)
- FlowsOUT.csv : flows between regions. 1 column per line
- MarginalCostActivePowerDemandOUT.csv : Marginal costs of the demand constraint. 1 columns per region.
- MarginalCostPrimaryOUT.csv : Marginal costs of the primary reserve constraint. 1 column per region.
- MarginalCostSecondaryOUT.csv : Marginal costs of the secondary reserve constraint. 1 columns per region.
- MarginalCostInertiaOUT.csv : Marginal costs of the Inertia constraint. 1 column per region.
- MarginalCostFlowsOUT.csv : Marginal costs of the lines. 1 column per line.
- MaxPowerOUT.csv: maximum available power. 1 column per technology, 1 row per timestep.
- DemandOUT.csv: Demand. 1 column per region, 1 row per timestep.

All file share the same format: a header containing the names of the series, an index with the timesteps indexes.

2.3 Plan4res outputs : results of PostTreatPlan4res.py

2.3.1 Installed Capacity

InstalledCapacity.csv and AggrInstalledCapacity.csv: installed capacities (aggregated installed capacity, with aggregations such as defined in settingsPostTreatPlan4res.py) in different available technologies per region. 1 column/technology, 1 row per timestep

<table>
<tr><th></th><th>Geothermal</th><th>Hydro|Run c</th><th>Nuclear</th><th>Coal|w/o CC</th><th>Wind|Offsh</th><th>Wind|Onsh</th><th>Solar|PV</th><th>Biomass|w/</th><th>Biomass|w/</th><th>Hydrogen|O</th><th>Gas|CCGT|w</th><th>Gas|CCGT|w</th><th>Oil|w/o CCS</th><th>Reservoir</th><th>Pumped Storage</th></tr>
<tr><td>France</td><td>0</td><td>10325</td><td>47037.0434</td><td>0</td><td>50840.0435</td><td>82643.272</td><td>148447.229</td><td>0</td><td>660</td><td>0</td><td>0</td><td>1879.16385</td><td>68.50722</td><td>13422.5</td><td>4512</td></tr>
<tr><td>Germany</td><td>0</td><td>7134.8</td><td>0</td><td>9586.78646</td><td>83829.4524</td><td>114867.893</td><td>242816.939</td><td>16812.0883</td><td>6327</td><td>4527.18441</td><td>0</td><td>1977.76184</td><td>83.8</td><td>9275.24</td><td>5831.1</td></tr>
<tr><td>Italy</td><td>0</td><td>7368</td><td>0</td><td>1705.22558</td><td>0</td><td>47754.235</td><td>130262.048</td><td>0</td><td>691.650085</td><td>7280.68425</td><td>0</td><td>2415.9806</td><td>1.947536</td><td>9578.4</td><td>14922.2681</td></tr>
<tr><td>Switzerland</td><td>0</td><td>3854</td><td>0</td><td>0</td><td>0</td><td>4559.2662</td><td>25284.0346</td><td>0</td><td>102.619516</td><td>867.435571</td><td>0</td><td>0</td><td>0</td><td>10390</td><td>0</td></tr>
<tr><td>EasternEuro</td><td>0</td><td>8498.48961</td><td>19012.6324</td><td>4298.16565</td><td>0</td><td>77796.9701</td><td>135757.304</td><td>7964.83126</td><td>1380.00558</td><td>17989.9229</td><td>16711.6989</td><td>1938.1211</td><td>79.036044</td><td>12637.665</td><td>11923.6886</td></tr>
<tr><td>Benelux</td><td>0</td><td>168.35881</td><td>0</td><td>930.53843</td><td>27571.9364</td><td>23477.9272</td><td>81047.1945</td><td>6969.43405</td><td>762.342245</td><td>4340.58573</td><td>4442.92019</td><td>4966.5955</td><td>0</td><td>256.316667</td><td>3281.02129</td></tr>
<tr><td>Iberia</td><td>0</td><td>19635.9413</td><td>0</td><td>0</td><td>0</td><td>194148.393</td><td>250872.819</td><td>4621.81626</td><td>459.347161</td><td>0</td><td>0</td><td>2679.72441</td><td>0</td><td>27177.9465</td><td>5977.99842</td></tr>
<tr><td>Britain</td><td>0</td><td>722.093437</td><td>0</td><td>1551.42732</td><td>176460.491</td><td>100047.174</td><td>132642.325</td><td>7489.93595</td><td>1634.17446</td><td>0</td><td>0</td><td>4493.21799</td><td>19.362935</td><td>1768</td><td>4869.42198</td></tr>
<tr><td>Balkans</td><td>1170</td><td>15132.0372</td><td>8521.38833</td><td>9601.51157</td><td>23195.6116</td><td>34057.5587</td><td>139547.493</td><td>0</td><td>177.837147</td><td>0</td><td>0</td><td>2572.64982</td><td>198</td><td>23939.6956</td><td>3107.58612</td></tr>
<tr><td>Baltics</td><td>0</td><td>1668.42454</td><td>0</td><td>0</td><td>6576.11002</td><td>1346.91798</td><td>12531.0172</td><td>320.721047</td><td>186.756955</td><td>0</td><td>0</td><td>621.434573</td><td>0</td><td>2240.16</td><td>900</td></tr>
<tr><td>Scandinavia</td><td>0</td><td>19770.3978</td><td>43.808304</td><td>0</td><td>11570.9374</td><td>95189.9336</td><td>70921.2225</td><td>1969.84435</td><td>1057.51349</td><td>0</td><td>0</td><td>79.615644</td><td>270.154414</td><td>42081</td><td>1730</td></tr>
</table>

Figure 9: InstalledCapacity.csv

2.3.2 Generation

Generation.csv and AggrGeneration.csv : Total generation (aggregated generation, with aggregations such as defined in settingsPostTreatPlan4res.py) from the different available technologies per region. 1 column/technology, 1 row per region

	Hydro	Geothermal	WindPower	PV	Biomass	Nuclear	Hydrogen	Coal	Gaz	Battery	Oil	Non Served
France	120568847	0	287617484	150482515	0	287384845	0	0	0	-1648018.88	0	0
Germany	47197794.3	0	466410144	138020686	206915191	0	5320505.4	0	217304.966	-16356865.6	0	0
Italy	73743874.7	0	34957015	133427172	8102071.33	0	91583830.4	0	32279.2293	-16598953.3	0	0
Switzerland	50951022.6	0	1477770.7	21123258.1	714789.719	0	2148116.69	0	0	0	0	0
EasternEuro	84145229.2	0	217061316	91833905.7	243336.745	216962878	76422.7969	0	0	-267710.937	0	0
Benelux	189920.775	0	141644805	55295622.3	13518823	0	64173543.4	0	13955643.8	-2140883.88	0	0
Iberia	180805663	0	198896982	143119773	43827319.7	0	0	0	20815442.6	-204619.364	0	712620.033
Britain	2740891.89	0	549537627	62271837.7	16549265.3	0	0	0	14795329.1	-6222047.55	0	0
Balkans	134984520	77272563.4	83200528.5	81900461.8	28365.2631	54020159.3	0	130371.037	714882.155	-3359441.48	2311.37379	0
Baltics	12107630.1	0	17486942.2	6238427.46	3387217	0	0	0	5528985.5	0	0	5542697.36
Scandinavia	248290300	0	230230093	39702643.5	7150297.67	1649279.83	0	0	138974.023	-748834.085	34420.6142	325752.246

Figure 10: AggrGeneration.csv

Generation-ZONE.csv and AggrGeneration-ZONE.csv : Average generation (aggregated generation, with aggregations such as defined in settingsPostTreatPlan4res.py) from the different available technologies per region. 1 file per region 1 column/technology, 1 row per timestep

	Hydro	Geothermal	WindPower	PV	Biomass	Nuclear	Hydrogen	Coal	Gaz	Battery	Oil	Non Served
2050-07-02 0	24195.4862	0	24951.7027	0	0	29436.9746	0	0	0	0	0	0
2050-07-02 0	24211.1757	0	24268.5717	0	0	23382.5813	0	0	0	0	0	0
2050-07-02 0	23917.7569	0	23099.7627	0	0	17123.7441	0	0	0	0	0	0
2050-07-02 0	23600.885	0	22407.0559	0	0	15345.5185	0	0	0	0	0	0
2050-07-02 0	23544.0451	0	21705.4391	0	0	14254.2005	0	0	0	-1.12768727	0	0
2050-07-02 0	23171.4812	0	20999.688	481.450471	0	11387.2616	0	0	0	-114.980598	0	0
2050-07-02 0	22158.059	0	20037.9383	5789.44191	0	6963.85983	0	0	0	-216.559966	0	0
2050-07-02 0	16354.4361	0	18850.0071	16734.4159	0	1038.06033	0	0	0	-1330.34312	0	0
2050-07-02 0	10361.1615	0	17358.2596	31534.7191	0	445.81691	0	0	0	-2785.74124	0	0
2050-07-02 0	5225.88184	0	14859.6548	46283.144	0	214.116341	0	0	0	-6615.77903	0	0
2050-07-02 1	3804.58107	0	13583.7764	49298.4458	0	128.142529	0	0	0	-6967.88798	0	0
2050-07-02 1	3382.15089	0	9909.77199	55267.6422	0	100.977214	0	0	0	-7598.57274	0	0
2050-07-02 1	1845.99949	0	7674.4139	61184.5746	0	100.977214	0	0	0	-9811.47378	0	0
2050-07-02 1	3245.04012	0	5391.96823	58391.0602	0	100.977214	0	0	0	-9924.06661	0	0

Figure 11: AggrGeneration-France.csv

Generation-ZONE-$i.csv : generation from the different available technologies in the region for scenario $i. 1 file per region and scenario, 1 column/technology, 1 row per timestep

Slack-ZONE.csv : Electricity non served per region. 1 file per region. 1 columns per scenario, 1 row per timestep.

France-0	France-1	France-2	France-3	France-4	France-5	France-6	France-7	France-8	France-9	F
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	

Figure 12: Slack-France.csv

nbHoursSlack.csv : number of hours with non served electricity per region and scenario

2.3.3 Costs

meanVariableCost.csv : Average variable costs. 1 column per region, 1 row per technology. Same format as meanStartUpCost.csv.

	Iberia	France
Geothermal	18937.575	22276.8
Hydro|Run o	0	0
Nuclear	269478485	5306254349
Coal|Hard co	478527714	73416112
Coal|Hard co	0	0
Coal|Lignite|	27731252.1	0

Figure 13: MeanVariableCost.csv

VariableCostPerScenario.csv : Variable costs. 1 column per scenario and region , 1 row per technoCoûts proportionnels en €. 1 colonne par scenario/zone (identifiée Zone-i), 1 ligne par technologie ; même format que StartUpCostPerScenario.csv

	Iberia-0	Iberia-1	France-0	France-1
Geothermal	19499.85	18375.3	22276.8	22276.8
Hydro|Run o	0	0	0	0
Nuclear	271282977	267673993	5391918134	5220590564
Coal|Hard cc	488554056	468501371	73503237.8	73328986.1
Coal|Hard cc	0	0	0	0
Coal|Lignite|	27957680.4	27504823.7	0	0
Wind|Offshc	0	0	0	0

Figure 14: VariableCostPerScenario.csv

2.3.4 Marginal Costs

meanScenCmar.csv : Average over all scenarios of the marginal Costs. 1 column par region, 1 row per timestep,

	Iberia	France
02/07/2030 00:00	31.2407507	12.4154082
02/07/2030 01:00	31.2406682	12.4153796
02/07/2030 02:00	31.2406682	12.4153796
02/07/2030 03:00	31.2406682	12.4153256
02/07/2030 04:00	31.2406682	12.4153256
02/07/2030 05:00	31.2406682	12.4153256
02/07/2030 06:00	31.2406682	12.4152986
02/07/2030 07:00	23.2569	12.4153526
02/07/2030 08:00	20.1404809	12.4153256

Figure 15: meanScenCmar.csv

meanTimeCmar.csv :Average over all timesteps of the marginal costs. 1 column per region, 1 row per scenario.

	France	Germany	Italy	Switzerland	EasternEuro|	Benelux	Iberia	Britain	Balkans	Baltics	Scandinavia
0	10.0017916	12.627596	42.490835	31.7141263	7.66411584	40.0294435	42.6613128	12.8529953	4.55587547	2060.97874	12.2201652
1	9.69227039	8.52444049	43.0467851	38.7308398	6.53666704	36.7040107	223.171869	10.2837684	4.6981039	2033.43619	4.74404652
2	10.3288737	9.37353669	42.117134	31.952233	7.53592615	41.0401734	42.5633024	18.501651	4.45614196	2698.81407	112.051093
3	9.55761209	15.9528174	44.105486	939.943149	7.14025279	47.4428936	194.728893	22.6292927	17.1144993	3377.18889	322.078168
4	9.82969121	12.1518885	42.7560408	369.574226	7.49095538	41.2517987	82.2259141	10.5424854	5.21314862	2594.29045	148.974584
5	10.1909432	15.7723012	41.8901917	464.109506	8.20773537	46.6836205	89.8033024	28.683413	7.81741969	3017.58513	148.236302
6	8.86570825	7.29514207	41.9248344	31.631455	6.85554654	35.4527305	38.7852692	8.29644509	4.16811995	2696.23831	7.39171049
7	9.53233609	7.45645671	38.6234038	46.8661374	6.43878895	34.1042506	66.9689116	12.6328536	3.64768332	982.615293	23.1759666
8	9.50194492	5.67742224	36.1771126	610.968409	5.74191136	25.2614037	112.640293	6.5424717	3.1135563	1088.85861	3.93019885
9	10.2479143	11.0077585	43.095968	157.16267	7.73642026	39.8542586	95.9500739	19.7408548	7.92131013	1941.32043	36.1178868
10	9.22268466	9.28545367	39.5594783	128.144848	7.30263483	36.8149199	160.460943	14.01241	4.59688779	1690.70131	2.45393333

Figure 16: meanTimeCmar.csv

MonotoneCmar.csv : Average of the marginal costs histogram. 1 column par region, 1 row per sorted timestep index

	Iberia	France
0	10000	10000
1	10000	10000
2	10000	10000
3	10000	10000
4	10000	10000
5	10000	10000
6	10000	10000
7	10000	5039.46006
8	10000	5039.45993
9	10000	5032.01263
10	10000	5032.01263

Figure 17: MonotoneCmar.csv

MarginalCostActivePowerDemand-ZONE.csv : Marginal costs of the region. 1 column par scenario, 1 row per timestep

HistCmar-ZONE.csv : Histogram of the Marginal costs of the region. 1 column par scenario, 1 row per sorted timestep index

2.3.5 Flows

MeanImportExport-ZONE.csv : Average Import and exports to/from the region. 1 column for Import, 1 column for export, 1 row per timestep

	Export	Import
02/07/2030 00:00	5000	0
02/07/2030 01:00	5000	0
02/07/2030 02:00	5000	0
02/07/2030 03:00	5000	0
02/07/2030 04:00	5000	0
02/07/2030 05:00	5000	0

Figure 18: meanImportExport-ZONE.csv

ImportExport-ZONE-$i.csv : Import and exports to/from the region for scenario $i. 1 column for Import, 1 column for export, 1 row per timestep

MeanImportExport: Average flows. 1 column for Import, 1 column for line, 1 row per timestep

	Iberia>Franc
02/07/2030 00:00	-5000
02/07/2030 01:00	-5000
02/07/2030 02:00	-5000
02/07/2030 03:00	-5000
02/07/2030 04:00	-5000

Figure 19: MeanImportExport.csv

Model	Scenario	Region	Variable	Unit	2015	2020	2025	2030	2035	2040	2045	2050
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity	GW	28.28	26.45	41.64	65.24	69.58	73.64	73.8	72.08
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Biomass	GW	1.758	1.654	0.69	0.536	0.389	0.373	0.353	0.333
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Biomass|w/o CCS	GW	1.758	1.654	0.69	0.536	0.389	0.373	0.353	0.333
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Coal	GW	0.814	0.066	0.011	0.011	0.011	0.011	0.011	0.011
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Coal|w/o CCS	GW	0.814	0.066	0.011	0.011	0.011	0.011	0.011	0.011
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Gas	GW	5.119	4.221	4.147	4.031	3.53	3.033	1.868	0.015
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Gas|CCGT	GW	5.119	4.221	4.147	4.031	3.53	3.033	1.868	0.015
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Gas|CCGT|w/o CCS	GW	5.119	4.221	4.147	4.031	3.53	3.033	1.868	0.015
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Hydro	GW	17.04	17.01	17.01	17.01	17.01	17.01	17.01	17.01
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Hydro|Pumped Storage	GW	3.175	3.175	3.175	3.175	3.175	3.175	3.175	3.175
GENeSYS-MOD 2.9	Directed Transition 1.0	Austria	Capacity|Electricity|Hydro|Reservoir	GW	7.846	7.818	7.818	7.818	7.818	7.818	7.818	7.818

Figure 20: IAMC format without subannual data

model	scenario	region	variable	unit	subannual	2018	2019	2020	2021	2022	2023	2024
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 00:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 01:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 02:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 03:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 04:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 05:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 06:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 07:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 08:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263
Flexibilities	TF_CS1_BE1-Full	AT	Demand Response|Maximum Dispatch|Load Shifting|Electricity|Residential|Air Conditioning	MW	01-01 09:00+01:00	184.305729	183.618245	182.132632	180.207717	239.320287	238.354546	235.74263

Figure 21: IAMC format with subannual data