Demand documentation

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1 Introduction

This document describes the various inputs that need to be provided to set up a model instance that can help estimate energy demand. Energy demand arises from a set of 'demand sectors'. Each demand sector is characterized by a set of 'consumer types' or 'consumer categories' – the types/categories of entities in that sector who demand 'energy services'. Energy (or energy service) demand is specified for each consumer type who demands an energy service in a demand sector. This demand can be specified in multiple ways as described in this document. Broadly, Rumi allows for four kinds of demand specification, namely:

1. Bottom-up (discussed in section 3)
2. GDP-Elasticity based (discussed in section 4)
3. Exogenous (discussed in section 4)
4. Residual (discussed in section 4)

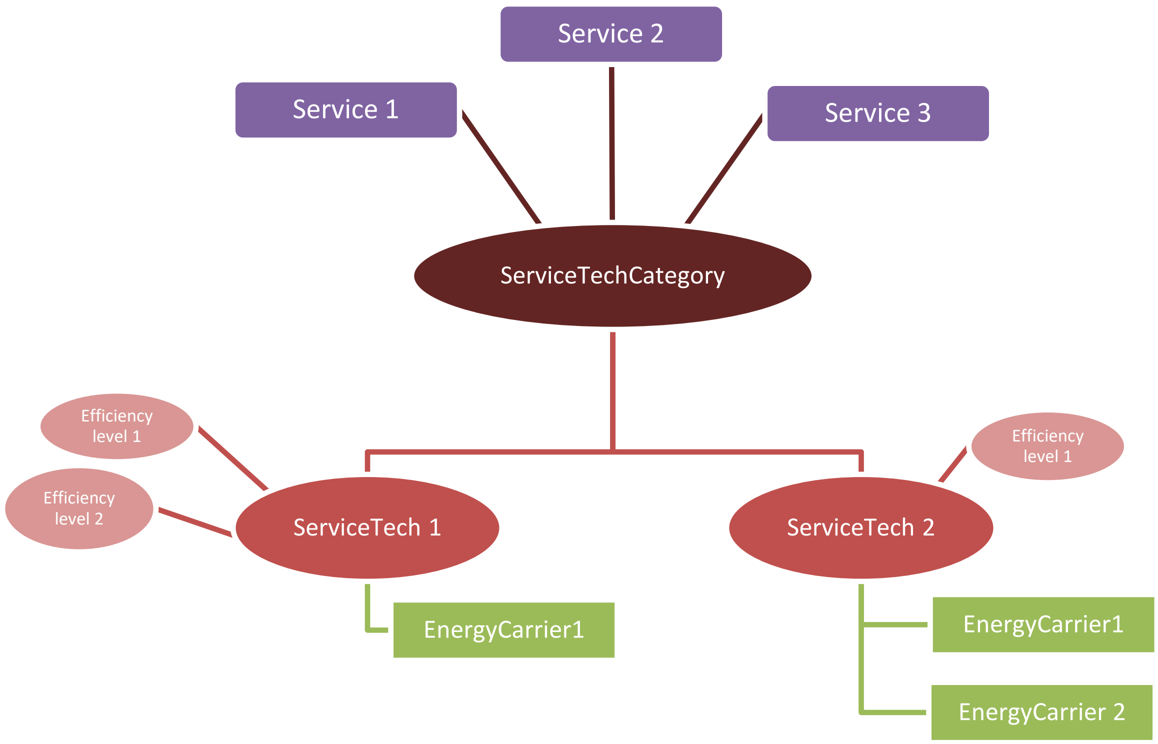
The most detailed way of specifying energy demand is by describing it bottom-up, as briefly explained below. More details follow in section 3.

Energy services are requirements / needs of consumers in a demand sector, which are typically met through 'energy service technologies'. The same energy service may be demanded in multiple demand sectors (e.g. lighting or cooling in both residential and commercial sectors). Energy service technologies provide one or more energy services through the use of one or more energy carriers.

To allow conceptually cleaner modelling of energy service technologies, two 'levels' of service technologies are supported in Rumi. The top level consists of service technology "categories", which describe categories or types of service technologies, with each such category providing a defined set of energy services. Each service technology category can have multiple "service technology realizations" (the bottom level), which are referred to as just "service technologies"[1]. All such "realizations" of a "category" provide the same set of energy services as defined by the category.

Energy carriers are associated at the level of service technologies; thus each of the service technologies in a given service technology category could perhaps use different sets of energy carriers. Note that different energy service technology categories can provide one or more common energy services. In addition, each energy service technology can have multiple 'efficiency levels' – i.e. different amounts of input energy required to provide the same unit of energy service.

[1] In cases where a service technology category is realized by just one service technology, the two levels can be merged. This is described later in the document.



This feature allows the modeller to club service technologies into sets most relevant to their modelling contexts. For example, cars and buses may both be defined as energy service technology categories that provide the "passenger mobility" energy service. The car category may be realized by service technologies such as "petrol car", "diesel car" and "electric car" each of which also provides passenger mobility but uses a different energy carrier to do so. Similarly, buses may be realized by service technologies such as "diesel bus", "CNG bus" and "electric bus". Further, petrol cars may have multiple efficiency levels corresponding to, say, "compact petrol cars", "petrol sedans" and "petrol SUVs". Rumi allows such specifications from which energy demand is computed. Note that modellers are free to choose any names for the various energy services, service technology categories, and so on.

The demand inputs are intended to capture the above set of information from the modeller at the level of detail of interest to the modeller. All inputs to Rumi are in the form of comma-separated value (csv) files with a certain structure. Many input files have header rows with defined column names, but some do not. For any input file that has a header row with named column headers, the order of the columns is immaterial. But if there is no header row, then the order of columns is important and should be exactly as documented. The Rumi platform will then compute the total energy demand (by energy carrier, by energy service, by demand sector, by consumer category etc.) for each time and geographic granularity of interest, so that the demand can be satisfied through suitable supply options.

All demand side inputs are provided through files under the `Demand/Parameters` top-level directory (referred to as the `Root` directory henceforth) under the scenario root directory (or, alternatively, Default Data/Demand/Parameters if the information is common across many scenarios). Depending on the inputs provided, there is a further directory structure under Demand/Parameters, which is explained further in this document. Broadly, the Root directory consists of input files which are cross-cutting in nature, such as the definition of demand sectors, energy services and service technologies, and other inputs that apply across various demand sectors, energy services, etc. At the root level, there will also be one directory per demand sector. Inputs specific to a demand sector are provided in the corresponding directory. Each demand sector directory may have further sub-directories – one corresponding to each energy service. These have files with information specific to that combination of demand sector and energy service.

2 High level inputs

These inputs define the various demand sectors, energy consumers, energy services, and technologies providing energy services along with their characteristics. In addition, these inputs also define the relationships across these entities and the geographic and temporal granularity at which demand inputs are provided for them.

2.1 DS_List.csv

Directory: Root

This file provides information about the various demand sectors that have been modelled.

This file does not have a header row. It consists of a single row, wherein the name of each demand sector used in the model is listed in this row, with a comma between any two successive names. Each demand sector name specified in the row should be unique. At least one demand sector name should be specified.

Example:

- D_RES, D_TRANS, D_IND, D_AGRI

The above example indicates that four demand sectors have been modelled, with the names as listed above.

Note that the use of space (after each comma) in the above example is only for improving the readability of this documentation. In the actual parameter file, no spaces should be used. This also holds true for all examples used in the sections that follow.

2.2 DS_ES_Map.csv

Directory: Root/<DemandSector>

Columns: DemandSector, EnergyService, InputType

Note that this file has to be placed inside the sub-folder for each demand sector.

Each row in this file provides a combination of a demand sector (DS) and an energy service (ES) required in that demand sector. The demand sector name specified in the first column of each row should be identical to that of the demand sector sub-folder, in which the file is placed. In addition, in the last column, each row also provides information about how the demand for this energy service as used in this demand sector is specified. This value can be one of EXOGENOUS, GDPELASTICITY, BOTTOMUP or RESIDUAL. Briefly, these mean the following:

- EXOGENOUS means the energy demand for this DS-ES combination is provided exogenously
- GDPELASTICITY means the energy demand for this DS-ES is to be estimated based on a supplied GDP elasticity of demand
- BOTTOMUP means that energy demand is to be estimated based on energy service demands, and details of energy service technologies that are provided
- RESIDUAL means that the energy demand for this DS-ES is a residual demand over and above all other demand that has been estimated. For any given DS, at most one ES can be residual.

Further details of these are given later in this document. Note that this file implicitly defines all the energy services that are being modelled in the given demand sector. Any service that is not listed in this file cannot appear later in subsequent inputs for that demand sector.

Example[2]:

- D_RES, LIGHTING, BOTTOMUP: The residential demand sector (D_RES) needs the lighting energy service which is defined in a bottom-up manner
- D_AGRI, IRRIGATION, GDPELASTICITY: The agricultural demand sector (D_AGRI) needs the irrigation energy service, the energy demand for which is defined using GDP elasticity.

2.3 DS_Cons1_Map.csv

Directory: Root/<DemandSector>

Note that this file has to be placed inside the sub-folder for each demand sector.

Consumer types (CT) in Rumi can be specified as a two-level hierarchy to allow structured definition of different types of consumers. Every demand sector (DS) can map to one or more (first level) CTs. This file maps a DS to a set of first level consumer types for that DS. In addition, it also specifies the time and

[2] All examples provided in these documentation files are intended to be purely for illustrative purposes and do not necessarily present 'realistic' values.

geographic granularities at which the input regarding number of consumers is given (see `NumConsumers` below).

This file has no header row. It consists of a single row with a variable number of columns, thus the following column order should be adhered to. The first column specifies the name of the DS for which the number of consumer details are being given. The demand sector name specified here should be identical to that of the demand sector sub-folder, in which the file is placed. The second column mentions the geographic granularity at which the `NumConsumers` input is given for this sector (for example, see Section 2.10) and it can be one of the keywords `MODELGEOGRAPHY`, `SUBGEOGRAPHY1`, `SUBGEOGRAPHY2`, or `SUBGEOGRAPHY3` corresponding to the level at which this information regarding number of consumers is provided. Similarly, the third column indicates the temporal granularity at which `NumConsumers` is specified and it can be one of the keywords `YEAR`, `SEASON`, `DAYTYPE`, `DAYSLICE`. Each column from the fourth column onwards gives the name of a first level CT for this DS. If this file is supplied for any DS, then at least one first level CT should be specified for that DS.

The geographic granularity must be finer than or equal to the granularity at which any bottom-up energy service demand input is given for this DS (see `DS_ES_STC_DemandGranularityMap` below). The time granularity must be coarser than or equal to the time granularity at which any bottom-up energy service demand input is given for this DS. These restrictions allow the number of consumers for the right time-geographic granularity to be estimated consistent with the requirement of any of the bottom-up energy service demand inputs, as the number of consumers can be aggregated over the finer geographies and the value for the coarser time granularity can be used for each finer granularity[3].

As mentioned above, the geographic and temporal granularity provided in this file for a given DS are actually applicable to the `NumConsumers` input. This `NumConsumers` input though is relevant only for those DS-ES combinations that are specified as bottom-up input type in `DS_ES_Map`; in other words, this input is not used for DS-ES combinations whose input types are non-bottom-up. However, even if all energy services in a particular DS happen to be of non-bottom-up input type (and thereby the `NumConsumers` input need not be given for such a DS), the geographic and time granularities for that DS must nevertheless still be specified (for technical reasons) in this file (i.e. `DS_Cons1_Map`) – in case one or more consumer types are specified for that DS in this file.

Each element of this first level CT can optionally further map to a set of second level consumer types. However, for a given DS, either there is no second level CT at all, or every element of the first level CT maps to at least one second level CT.

[3] Typically, throughout Rumi, inputs that can be aggregated up along a dimension can be provided at finer granularities than required for that dimension, and inputs that can be identically applied to finer granularities can be provided at coarser granularities.

Note that it is not mandatory to specify first level CTs for every DS. If some DS does not require any first level CTs, then this file should not be supplied for that DS.

In other words, this is an optional parameter. It is required only if the given demand sector requires one or more first level CTs.

Example:

- `D_RES, SUBGEOGRAPHY2, YEAR, RES_URBAN, RES_RURAL`: to indicate that the residential sector has two first level CTs corresponding to urban and rural residences, whose number of consumers details are given at the mentioned geographic and temporal granularity.
- `D_TRANS, SUBGEOGRAPHY1, YEAR, TRANS_LOCAL, TRANS_NONLOCAL`: to indicate that the transport sector has two first level CTs corresponding to local and non-local transport.
- `D_IND, MODELGEOGRAPHY, YEAR, IND_STEEL, IND_CEMENT, IND_PAPERPULP, IND_OTHERS`: to indicate that the industry sector has four first level CTs corresponding to the steel, cement, paper & pulp and other industries.

Note that in the above example, each bullet point corresponds to a single row in separate parameter files, with one file each for the concerned demand sector.

2.4 Cons1_Cons2_Map.csv

Directory: `Root/<DemandSector>`

This file lists the second level consumer types for each first level consumer type specified for the given demand sector. It is also without a header row, hence the order of the columns matters. The first column indicates the first level consumer type while the subsequent columns indicate the further split of the first level consumer type into finer consumer types. As stated above, either there is no second level CT at all for a DS, or every element of the first level CT of a DS maps to at least one second level CT. If the given DS does not have any second-level CTs, then this file may be skipped altogether.

Example:

- `RES_URBAN, UQ1, UQ2, UQ3, UQ4, UQ5`: Indicates that urban residential consumers are split into five sub-categories corresponding to five expenditure quintiles.
- `RES_RURAL, RQ1, RQ2, RQ3, RQ4, RQ5`: Indicates that rural residential consumers are split into five sub-categories corresponding to five expenditure quintiles.
- `TRANS_LOCAL, L_PASS, L_FREIGHT`: Indicates that local transport consumers are split into local passenger and local freight consumers.
- `TRANS_NONLOCAL, N_PASS, N_FREIGHT`: Indicates that non-local transport consumers are split into non-local passenger and non-local freight consumers.
- `IND_STEEL, LARGE_STEEL, SMALL_STEEL`: Indicates that steel industry is split into large and small steel manufacturers.

- IND_CEMENT, ALL_CEMENT: Does not split the cement industry into finer categories, but this input is required because the steel industry (a first level consumer type of the industry demand sector) has been mapped to second level consumer types.

2.5 DS_ES_EC_Map.csv

Directory: Root/<DemandSector>

Columns: DemandSector, EnergyService, EnergyCarrier, ConsumerGranularity, GeographicGranularity, TimeGranularity

This file has to be placed inside the sub-folder for each demand sector.

This file is relevant only for those DemandSector and EnergyService (DS-ES) combinations that are not specified as bottom-up input type in the DS_ES_Map parameter for the given demand sector.

The demand sector name specified in the DemandSector column in each row should be identical to that of the demand sector sub-folder, in which the file is placed. The EnergyService column in each row is the name of an ES relevant to this DS and whose input type for that DS is not BOTTOMUP.

For each such DS-ES combination, this file specifies the following pieces of information:

- EnergyCarrier specifies an energy carrier (EC) that provides the given ES in the given DS. If multiple energy carriers provide that ES in that DS, each such EC should be listed in a separate row for the same DS-ES combination.
- ConsumerGranularity, GeographicGranularity, TimeGranularity specify the consumer, geographic and time granularity respectively at which the demand input(s) will be given for the specified DS-ES-EC combination.

The EC must be one of the carriers specified in the common inputs, but it cannot be a non-physical primary energy carrier.

If the DS_ES_Map.csv file for a given DS defines the input-type for some specific DS-ES combination as RESIDUAL, then for each EC given in this file for such a DS-ES combination, there must be at least one other ES for that DS that is provided with the use of the same EC (either directly or through the means of a service technology), whose input type in DS_ES_Map.csv is not RESIDUAL. This ensures the presence of a base value whose residual can be computed.

The consumer granularity must be one of the following keywords: CONSUMERALL, CONSUMERTYPE1, CONSUMERTYPE2. The CONSUMERTYPE1 keyword signifies that the demand input(s) would be given at the first consumer level granularity, while the CONSUMERTYPE2 keyword signifies that the demand input(s) would be given at second consumer level granularity. On the other hand, the CONSUMERALL keyword signifies that the demand input(s) would be given at the demand sector level i.e. for the entire demand sector, without any consumer granularity. The consumer granularity specified must be coarser or equal to the actual number of consumer levels for this demand sector. If no first level consumer type has been specified for some DS, then the consumer granularity will obviously have to be CONSUMERALL.

The geographic and time granularities must be one of the respective keyword values mentioned in Section 2.3.

The consumer, time and geographic granularities of a RESIDUAL energy service must be respectively coarser than or equal to the corresponding granularities of all the other ES (whether non-bottom-up or bottom-up) for that DS using this EC (directly or through the means of a service technology). This allows the demand from the other ES for this DS-EC combination to be aggregated up to the level required for the RESIDUAL energy service, allowing the calculation of the residual value.

Example:

The following two rows indicate that both electricity and diesel are energy carriers that provide the irrigation energy service in the agricultural demand sector. The demand input(s) for this irrigation service in this sector provided by electricity would be given at the first consumer type, sub-geography2 and day-slice granularities – whereas the corresponding demand inputs provided by diesel would be given at the first consumer type, sub-geography1 and annual granularities.

- D_AGRI, IRRIGN, ELECTRICITY, CONSUMERTYPE1, SUBGEOGRAPHY2, DAYSLICE
- D_AGRI, IRRIGN, HSD, CONSUMERTYPE1, SUBGEOGRAPHY1, YEAR

2.6 DS_ES_STC_DemandGranularityMap.csv

Directory: Root/<DemandSector>

Columns: DemandSector, EnergyService, ServiceTechCategory, ConsumerGranularity, GeographicGranularity, TimeGranularity

This file has to be placed inside the sub-folder for each demand sector.

This file is relevant only for those DemandSector and EnergyService (DS-ES) combinations that are specified as bottom-up input type in the DS_ES_Map parameter for the given demand sector.

The demand sector name specified in the DemandSector column in each row should be identical to that of the demand sector sub-folder, in which the file is placed. The EnergyService column in each row is the name of an ES relevant to this DS and whose input type for that DS is BOTTOMUP.

For each such DS-ES combination, this file specifies the following pieces of information:

- `ServiceTechCategory` specifies the name of a service technology (ST) category[4] that provides the given ES in the given DS. If multiple service technology categories provide that ES in that DS, each such ST category should be listed in a separate row for the same DS-ES combination.
- `ConsumerGranularity, GeographicGranularity, TimeGranularity` specify the consumer, geographic and time granularity respectively at which the energy service demand input will be given for the specified DS-ES-STC combination.

Note that a given ST category may in general be capable of providing multiple ES; in a given DS though, such an ST category may conceivably be used to provide only some of those energy services.

The consumer granularity must be one of the following keywords: `CONSUMERALL, CONSUMERTYPE1, CONSUMERTYPE2`. The meaning signified by these keywords is already explained in Section 2.5. The consumer granularity specified must be coarser or equal to the actual number of consumer levels for this demand sector.

The geographic and time granularities must be one of the respective keyword values mentioned in Section 2.3.

Examples:

The following three rows indicate that the cooling service in the residential sector is provided by three service technology categories, namely fans, coolers and ACs; the demand inputs for the cooling energy service provided by each of these three ST categories in this sector would be given at the second consumer type, sub-geography2 and day-slice granularities.

- `D_RES, COOL, CL_FAN, CONSUMERTYPE2, SUBGEOGRAPHY2, DAYSLICE`
- `D_RES, COOL, CL_COOLER, CONSUMERTYPE2, SUBGEOGRAPHY2, DAYSLICE`
- `D_RES, COOL, CL_AC, CONSUMERTYPE2, SUBGEOGRAPHY2, DAYSLICE`

The following two rows indicate that in the transport demand sector, car is a service technology category that provides both short distance travel and long distance travel as energy services. The demand input for the short distance travel energy service provided by a car in this sector would be given at the second consumer type, sub-geography1 and seasonal granularities – while the corresponding demand input for the long distance energy service would be given at the first consumer type, sub-geography1 and annual granularities.

- `D_TRANS, SHORT_DIST, CAR, CONSUMERTYPE2, SUBGEOGRAPHY1, SEASON`
- `D_TRANS, LONG_DIST, CAR, CONSUMERTYPE1, SUBGEOGRAPHY1, YEAR`

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[4] Note that the name of the ST category cannot contain a plus (+).

The following row indicates that the cooking service in the residential sector is provided by a service technology category, namely cooking stoves; the demand inputs for the cooking energy service provided by a stove in this sector would be given at the second consumer type, sub-geography2 and daytype granularities.

- `D_RES, COOK, CK_STOVE, CONSUMERTYPE2, SUBGEOGRAPHY2, DAYTYPE`

2.7 STC_ES_Map.csv

Directory: `Root`

This file provides information about the various service technology categories that provide energy services. Specifically, it maps each ST category to all the energy services (ES) provided by that ST category and the corresponding energy service units.

This file does not have a header row, and can have a variable number of columns. Hence, the order of the columns as described below should be adhered to.

The first column in each row mentions the name of the service technology category for which information is being provided. The plus (+) character is not allowed in an ST category name.

This is then followed by pairs of columns as follows. The first column of each pair is the name of an energy service provided by this service technology category, and the second column of the pair has the name of the unit used for measuring that corresponding energy service. Each row must have at least one such pair of energy service name and energy service unit name. If an ST category provides multiple energy services, as many such pairs of names should be provided as the number of energy services provided by the ST category. The names of the multiple energy services, provided by a given ST category, must be all distinct. This information should be consistent with the information provided in the `DS_ES_STC_DemandGranularityMap.csv` file.

Example:

- `CL_FAN, COOL, CH`: Indicates that fans provide cooling as the only energy service with ch (cooling hours) as the energy service unit.
- `CL_AC, COOL, CDH`: Indicates that ACs provide cooling as the only energy service with cdh (cooling degree hours) as the energy service unit.
- `CK_STOVE, COOK, USEFULMJ`: Indicates that cookstoves provide cooking as the only energy service whose energy service unit is the amount of useful energy required (in MJ)
- `CAR, SHORT_DIST, PKM, LONG_DIST, PKM`: Here we specify a car that provides two energy services viz. short distance travel and long distance travel – with passenger kilometres as the energy service unit for both.

2.8 STC_ST_Map.csv

Directory: `Root`

This file provides further information about each service technology category. Specifically, it maps each ST category to all its underlying service technologies (STs).

This file does not have a header row, and can have a variable number of columns. Hence, the order of the columns as described below should be adhered to.

The first column in each row mentions the name of the service technology category for which information is being provided.

This is then followed by the names of all the underlying service technologies in that ST category, provided one per column. The plus (+) character is not allowed in an ST name. The names of the various STs, across all the various ST categories, must be all distinct. In other words, the same ST name cannot be used in different ST categories. As many ST names must be provided as the number of underlying STs in that ST category.

If there happens to be only one underlying ST in a given ST category, the entry for that ST category in this map file can be skipped. In that case, the name of the ST category itself would also represent the name of the single underlying ST.

By definition, all the underlying STs in a given ST category provide the exact same set of energy services as defined for that ST category (in `STC_ES_Map`).

Example:

- `CK_STOVE, CK_LPG, CK_BIOGAS, CK_ELEC`: Indicates that the cooking stove ST category is realized by the following three STs – LPG stoves, biogas stoves and electric stoves
- `CAR, MS_CAR, HSD_CAR`: Here we specify that the car ST category is realized by two STs viz. petrol cars and diesel cars

2.9 ST_EC_Map.csv

Directory: `Root`

This file provides information about the various service technologies (STs); specifically, it maps each ST to all the energy carriers (EC) used by that ST.

This file does not have a header row, and can have a variable number of columns. Hence, the order of the columns as described below should be adhered to.

The first column in each row mentions the name of the service technology for which information is being provided.

This is then followed by the names of all the energy carriers used by the service technology, provided one per column; as many names must be provided as the number of ECs used by that ST. These ECs (used by a given ST) must all be distinct and each should be one of the energy carriers specified in the common inputs. Each row should specify at least one energy carrier.

Example:

- `CL_FAN, ELECTRICITY`: Indicates that fans use electricity as the only energy carrier.
- `CL_AC, ELECTRICITY`: Indicates that use electricity as the only energy carrier.
- `CK_LPG, LPG`: Indicates that LPG cookstoves use LPG as the only energy carrier.
- `MS_CAR, MS, ETHANOL`: Here we specify a car that uses a blend of petrol and ethanol (i.e. two energy carriers).

2.10 NumConsumers.csv

Directory: `Root/<DemandSector>`

Columns: `C*, G*, T*, NumConsumers`

This input is only relevant for DS-ES combinations whose demand is specified in a bottom-up fashion. This file describes the number of energy consumers in the demand sector by consumer type, geography and time. The granularity at which this input is given is as defined by `DS_Cons1_Map` and the number of consumer levels defined for this DS.

Thus, `C*` in the column description above represents either one or two consumer type columns. The file would have one column with header `ConsumerType1` if this DS has only defined one level of consumer types (i.e. `Cons1_Cons2_Map` is empty for this DS) and it would have both consumer type columns with headers `ConsumerType1, ConsumerType2` if this DS has two levels of consumer types. If no first level consumer types are specified for some DS (i.e. if there is no row for that DS in `DS_Cons1_Map`), then this input should not be given for such a DS.

Similarly, `G*` represents up to 4 columns (with headers `ModelGeography, SubGeography1, SubGeography2`, `SubGeography3`) and `T*` represents up to 4 columns (with headers `Year, Season, DayType, DaySlice`) depending on the geographic and temporal granularity given in `DS_Cons1_Map.`

Thus, the file would have at least three columns (one each for C*, G*, T*) and at most 10 columns (2 for C*, 4 for G* and 4 for T*) corresponding to `C*, G*, T*`. In addition, it has the column `NumConsumers` which gives the number of consumers of this consumer type (specified in the C* columns) for this DS at this geographic (G*) and temporal (T*) granularity. The number of consumers is a positive integer.

Note that this input need not be given even if a demand sector (that has at least one consumer type) does have one or more DS-ES combinations whose demand is specified in a bottom-up fashion.

When this input is not given for such a demand sector, then for the purpose of energy demand computation (as well as for number of ST instances calculation) for the applicable bottom-up energy services, the `NumConsumers` value is taken as 1 – at the requisite consumer, geographic and temporal granularities.

Example:

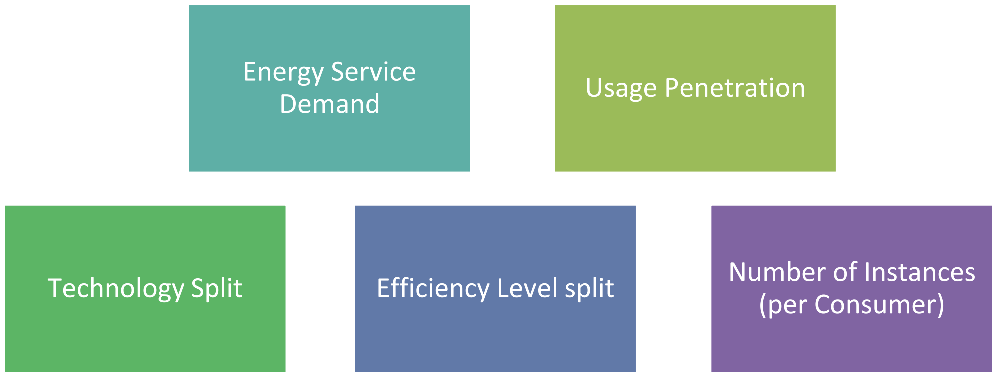
- `D_RES/NumConsumers.csv`: These rows indicate that, in 2021, in Maharashtra, there are 23000 rural quintile 1 households and, in 2024, in Tamil Nadu, there are 10000 urban quintile 5 households.
    - `RES_RURAL, RQ1, INDIA, WEST, MH, 2021, 23000`
    - `RES_URBAN, UQ5, INDIA, SOUTH, TN, 2024, 10000`
- `D_TRANS/NumConsumers.csv`: These rows indicate that, in 2025, in the Northern region, there are 10000 local passenger transport consumers and, in 2027, in the North-Eastern region, there are 2000 non-local freight transport consumers.
    - `TRANS_LOCAL, L_PASS, INDIA, NORTH, 2025, 10000`
    - `TRANS_NONLOCAL, N_FREIGHT, INDIA, NORTHEAST, 2027, 2000`
- `D_IND/NumConsumers.csv`: These rows indicate that, in 2023, there are 1000 large steel industrial consumers in India, and, in 2026, there are 1200 cement industries in India.
    - `IND_STEEL, LARGE_STEEL, INDIA, 2023, 1000`
    - `IND_CEMENT, ALL_CEMENT, INDIA, 2026, 1200`

3 Energy services that are modelled bottom-up

For each service technology (that provides some energy services using some energy carriers) being modelled, some additional information is expected as described below. Service technology details are obviously relevant only for DS-ES combinations whose demand is specified in a bottom-up fashion. For a given service technology, some inputs could in general vary by the demand sector in which they are used. Hence these parameters are to be given for each demand sector and therefore the files relevant to such inputs are provided in that demand sector's directory. As mentioned previously, the energy services provided by a service technology are actually the same as those provided by its parent ST category.

The files below are expected in the demand sector's directory, i.e. `Root/<DemandSector>`.

1. Specific Energy Consumption (SEC) of an ST (see Section 3.1 ST_SEC.csv).
2. Emission factor of an ST (see Section 3.2 ST_EmissionDetails.csv).



Furthermore, for the energy services that are modelled bottom-up in a demand sector, energy demand is calculated based on the quantity of energy service required, the service technologies providing that service, their specific energy consumption details, and the number of consumers using those technologies at various geographic and temporal units. Multiple ST categories can provide the same energy service, and a single consumer may use a combination of such ST categories to satisfy the energy service need. Rumi supports input specifications with such 'stacking' of technologies to avail a single energy service. In the case where multiple ST categories simultaneously provide an energy service, the usage of different combination of ST categories can be specified (refer to Section 3.4) and the corresponding energy service demand for each combination can be input (refer to Section 3.3). Thus, for any service technology, the following inputs are required from the modeller at the appropriate granularities. These inputs are provided in files whose details are as described subsequently in the corresponding sub-sections.

The files below are expected in a sub-directory named for the relevant energy service within the applicable demand sector's directory, i.e. `<DemandSector>/<EnergyService>`.

1. The amount of energy service demanded by a consumer type from each ST instance, specified at the ST category level[5] (see Section 3.3 <STC>_ES_Demand.csv).
2. For each combination of ST categories that can provide the same energy service, the share of consumers of each type who use that combination of ST categories (see Section 3.4 STC1+STC2+...+STCk+UsagePenetration.csv).
3. For each ST category, the relative share of consumers using each of the various underlying STs (see Section 3.5 TechSplitRatio.csv).

[5] The energy service demanded from all underlying STs of an ST category is identical to this demand specified at the ST category level - for each consumer type in each geographic and time unit.

4. For each consumer type, the split of the usage of an ST across the various efficiency levels of the ST (see Section 3.6 EfficiencyLevelSplit.csv)
5. The number of instances of an ST per consumer of a given type (see Section 3.7 NumInstances.csv).

3.1 ST_SEC.csv

Directory: `Root/<DemandSector>`

Columns: `ServiceTech, EfficiencyLevelName, C*, G*, Year, EnergyService, EnergyCarrier, SpecificEnergyConsumption`

This input specifies the specific energy consumption (SEC) details of each energy service technology i.e. the amount of energy required by the service technology, from each energy carrier that it uses, to provide one unit of energy service – for each energy service that it provides. Note that an ST can have multiple efficiency levels; hence the specific energy consumption details should be provided for each such level. Moreover, these details can vary by each year of the model period; hence they should be provided by model period years as well. Finally, these details can vary by each consumer type defined for the given demand sector as well as by geographic sub-unit; hence these details should be specified by the applicable consumer and geographic granularities as well.

The `ServiceTech` column is the name of the ST, the `EfficiencyLevelName` column gives a name for the efficiency level, the `Year` column is the year for which the SEC value applies.

`C*, G*` stand for columns corresponding to consumer type and geographic units respectively, as described in Section 2.10. For each ST, its SEC input values should be given at consumer type and geographic granularities that are coarser than or equal to the respective consumer type and geographic granularities specified in `DS_ES_STC_DemandGranularityMap` – for the parent ServiceTechCategory (STC) of that ST, providing the specified energy service (in the `EnergyService` column) in the specified demand sector. The actual number of columns for each of `C*` and `G*` in the `ST_SEC` parameter file depends on the finest consumer type and geographic granularities respectively among those that are used for each of the STs in the file. For a particular ST though (i.e. for each row in the file pertaining to that ST), depending on the granularities actually decided for that ST, only the relevant consumer type and geographic granularity columns need to have values and the other granularity columns (if any) should be left empty. Note that the time granularity does not apply to this parameter, since we assume that SEC can vary at most on a yearly basis.

The `EnergyService` and `EnergyCarrier` columns are the energy service and energy carrier names respectively for which the SEC value is specified. Since an ST can provide multiple energy services, SEC values should be provided for each of those ES. Since an ST can use multiple energy carriers, for each such ES, SEC values should be provided for each of these EC. The `SpecificEnergyConsumption` column is a positive number that describes the amount of energy required (in the energy units of the specified `EnergyCarrier`) from that EC to provide one unit of the specified `EnergyService` in that `Year` at that `EfficiencyLevelName` – for the specified consumer type in the specified geographic unit. In order to provide one unit of an ES, various EC quantities could be required *together* by an ST; these would be specified as different SEC values in different rows, one per energy carrier – for a given ES and ST, in a given year, at a given efficiency level, for a given consumer type, in a given geographic unit.

Thus, implicitly, the SEC values do not change within a year. Moreover, note that the SEC values given here for various ES-EC combinations, correspond to that of the entire *stock* of instances of the specified service technology and efficiency level that exists in the specified year and geography among the specified consumer type – and not just the *new* instances of that technology and efficiency level that are purchased or acquired or installed in that year and geography by that consumer type. Thus, the given SEC is intended to represent the weighted average SEC of all instances of the ST in existence in the year and geographic unit for the consumer type, irrespective of when the ST 'came into being'.

Note that for a given ES provided by a given ST at a given efficiency level in a given year and geography for a given consumer type, there can be multiple SEC values – one each for each EC used by the ST. This signifies that in order to provide one unit of the given ES, the ST requires (at that efficiency level in that year and geography among that consumer type) the corresponding amounts of energy from all those ECs simultaneously.

Note that the `ST_EC_Map` does allow an ST to use one or more non-physical primary energy carriers (NPPEC). However, SEC values should not be supplied for any such NPPECs that may be used by an ST. In case SEC values do happen to be supplied for such NPPECs used by an ST, they will be ignored.

For each ST, SEC values should be supplied for all its applicable ES and EC combinations where the EC is not an NPPEC – at all relevant consumer and geographic granularities, for all years and across all efficiency levels defined for that ST.

Example:

- `D_RES/ST_SEC.csv`: The following rows indicate that for residential energy services, there are three types of electric light technologies corresponding to incandescent bulbs, CFLs and LEDs and that the stock of these technologies in 2021 among all consumer types all over India have specific energy consumption values of 60W, 15W and 9W respectively (i.e. 0.06 kWh / hour, 0.015 kWh / hour and 0.009 kWh / hour respectively). They also indicate that there are two types of ACs (3-star and 5-star) which have SEC values of 0.055 and 0.046 kWh/CDH respectively for the stock of these ACs among urban quintile 5 Punjab households in 2025. Further, it states that in 2024 among rural quintile 5 households in Tamil Nadu, LPG stoves (just one efficiency level) require 1.54 MJ to produce one 'useful MJ' of heat – i.e. have a 65% efficiency. Similarly, induction stoves among rural quintile 5 households in Tamil Nadu in 2024 require 0.33 kWh to produce one useful MJ – i.e. an 85% efficiency.
    - `ELEC_LIGHT, INCAND, , , INDIA, , , 2021, LIGHTING, ELECTRICITY, 0.06`

- o ELEC_LIGHT, CFL, , , INDIA, , , 2021, LIGHTING, ELECTRICITY, 0.015
  - ELEC_LIGHT, LED, , , INDIA, , , 2021, LIGHTING, ELECTRICITY, 0.009
  - AC, 3STAR, URBAN, UQ5, INDIA, NORTH, PB, 2025, COOL, ELECTRICITY, 0.055
  - AC, 5STAR, URBAN, UQ5, INDIA, NORTH, PB, 2025, COOL, ELECTRICITY, 0.046
  - COOK_LPG, LPGSTOVE, RURAL, RQ5, INDIA, SOUTH, TN, 2024, COOK, LPG, 1.54
  - COOK_ELEC, INDUCTION, RURAL, RQ5, INDIA, SOUTH, TN, 2024, COOK, ELECTRICITY, 0.33
- `D_IND/ST_SEC.csv`: This states that industrial 3-star and 5-star ACs have SEC values of 0.79 and 0.63 kWh/CDH respectively in 2025 – for all industrial consumers across India.
  - AC, 3STAR, INDIA, 2025, COOL, ELECTRICITY, 0.79
  - AC, 5STAR, INDIA, 2025, COOL, ELECTRICITY, 0.63
- `D_TRANS/ST_SEC.csv`: This states that, in 2026 for all consumers in India, compact petrol cars require 1.1 and 0.1 MJ from petrol and ethanol respectively, per passenger-km – when used for short distance travel. When used for long distance travel though, the same compact petrol cars require 1.0 and 0.09 MJ from petrol and ethanol respectively, per passenger-km. The subsequent lines provide similar specifications for petrol limousines.
  - MS_CAR, COMPACT, INDIA, 2026, SHORT_DIST, MS, 1.1
  - MS_CAR, COMPACT, INDIA, 2026, SHORT_DIST, ETHANOL, 0.1
  - MS_CAR, COMPACT, INDIA, 2026, LONG_DIST, MS, 1.0
  - MS_CAR, COMPACT, INDIA, 2026, LONG_DIST, ETHANOL, 0.09
  - MS_CAR, LIMO, INDIA, 2026, SHORT_DIST, MS, 3.0
  - MS_CAR, LIMO, INDIA, 2026, SHORT_DIST, ETHANOL, 0.28
  - MS_CAR, LIMO, INDIA, 2026, LONG_DIST, MS, 2.7
  - MS_CAR, LIMO, INDIA, 2026, LONG_DIST, ETHANOL, 0.25

3.2 ST_EmissionDetails.csv

Directory: `Root/<DemandSector>`

Columns: `ServiceTech, Year, EnergyService, EnergyCarrier, EmissionType, DomEmissionFactor, ImpEmissionFactor`

This is an optional parameter. It is required only when using an ST results in emissions that are different from the default emissions for any of the various physical energy carriers used by it; here, default emissions for an EC refer to those specified in the common input specifications. It is only the usage of a physical energy carrier that can result in emissions; hence this parameter is only relevant for those input carriers of an ST that are physical carriers. If this input is not given, then the respective physical carriers' default emission details are used.

This information is given for each model year for the ST. It is assumed that emissions do not vary by geographic area. The emission factors for a given EC used by an ST can in general vary by the various energy services produced by it – hence the information has to be given by each energy service produced by the ST. Obviously, the information also has to be given by each of the physical energy carriers used by the ST. If the ST uses a primary physical EC, then for each applicable emission type, two emission values can be specified corresponding to usage of a domestic variant of the carrier or an imported variant. For derived ECs, since imports are not supported, only the domestic emission factor column is used; though imported emission factor also must be specified for syntactic reasons. The emission types specified must be one of those given in the common inputs.

In some cases, just using the ST itself can also lead to emissions − independent of the emissions arising from the EC(s) used by the ST. The information for such non-EC based ST emissions too can be supplied in this parameter. In order to specify such an EmissionFactor for non-EC based ST emissions, the EnergyCarrier column should be left empty. The concept of two separate factors viz. DomEmissionFactor and ImpEmissionFactor does not apply to such non-EC based EmissionFactor(s). Hence only the domestic emission factor column is used in the case of non-EC based ST emissions; however, the imported emission factor too must be specified for syntactic reasons.

The unit for this non-EC based EmissionFactor is EmissionUnit/EnergyServiceUnit. Note that an ST can provide more than one ES. Hence for each ES provided by an ST, we could have separate non-EC based EmissionFactors (per year and per EmissionType). The emission types specified must be one of those given in the common inputs.

Example:

- `D_RES/ST_EmissionDetails.csv`: This indicates that there are 1800 units of CO2 emission per physical unit of input biomass in 2021, when used for cooking in the residential sector.
    - `COOK_BIOMASS, 2021, COOK, BIOMASS, CO2, 1800, 1800`
- `D_TRANS/ST_EmissionDetails.csv`: This indicates that when a petrol car is used for short distance travel in 2021 in the transport sector, it results in 1500 units of CO2 emission per physical unit of input petrol used as well as 800 units of CO2 emission per physical unit of input ethanol used. The same petrol car in the same year when used for long distance travel though, results in 1200 units of CO2 emission per unit of input petrol used as well as 700 units of CO2 emission per unit of input ethanol used.
    - `MS_CAR, 2021, SHORT_DIST, MS, CO2, 1500, 1500`
    - `MS_CAR, 2021, SHORT_DIST, ETHANOL, CO2, 800, 800`
    - `MS_CAR, 2021, LONG_DIST, MS, CO2, 1200, 1200`
    - `MS_CAR, 2021, LONG_DIST, ETHANOL, CO2, 700, 700`
- `D_IND/ST_EmissionDetails.csv:` This indicates that when Ordinary Portland Cement is produced in 2025 using the standard process, it results in 502 units of CO2 emission per unit of cement produced, whereas if the same process is used with carbon capture, utilisation and storage in 2025, then it results in 50 units of CO2 emission per unit of cement produced.
    - `OPC_Norm, 2025, CEMENT, , CO2, 502, 502`

- o OPC_CCUS, 2025, CEMENT, , CO2, 50, 50

3.3 <STC>_ES_Demand.csv

Directory: Root/<DemandSector>/<EnergyService>

The name of this file is the name of a service technology category (STC), appended with _ES_Demand.csv. It gives the demand of a particular energy service that is required from the chosen STC, in a particular demand sector. The name of the folder in which the file is located specifies the energy service, while the name of the folder above it specifies the demand sector. Thus, for example, AC_ES_Demand.csv located under D_RES/COOLING gives the space cooling demand from air conditioners in the residential sector.

In general, multiple STCs can provide the same energy service in a given demand sector; moreover, a single consumer may use a combination of such STCs to achieve the energy service. Hence this file is structured to provide the energy service demanded from the specified STC when it is used singly – as well as when it is used in combination with one or more other STCs providing the same service in that demand sector. Effectively, this allows the modelling of the feature that is known as 'stacking' in the household cooking energy literature – where multiple cooking appliances may be present and used in the same household. Similarly, Rumi allows combinations of ST categories that provide an energy service as relevant in the corresponding DS-ES being modelled (e.g. space cooling, passenger transport, industrial heating etc.). The geographic and temporal granularity at which these inputs are provided are as defined in the file DS_ES_STC_DemandGranularityMap (Section 2.6).

The file has a header row with values C*, G*, T*, STC, STC+STC1, STC+STC2, STC+STC1+STC2 … where

- C*, G*, T* stand for columns corresponding to consumer type, geographic units and temporal units respectively, as described in Section 2.10. The input should be given at the same consumer type, geographic and temporal granularities as those specified in DS_ES_STC_DemandGranularityMap for the specified STC providing the specified energy service in the specified demand sector. Thus, if the granularity for this DS, ES, STC in the aforementioned map is specified as <CONSUMERTYPE1, SUBGEOGRAPHY1, DAYSLICE>, then the C*, G*, T* columns would have headers ConsumerType1, ModelGeography, SubGeography1, Year, Season, DayType, DaySlice.
- STC stands for the name of the ST category, for which input is being provided (and should match the ST category used in the file name). The column with header as just STC gives the energy service demand for this specific energy service (in the energy service units as given in the STC_ES_Map file) when only this ST category (i.e. without other ST categories providing the same service) is used – by consumer types in the C* columns in the geography given in the G* columns and in the time unit corresponding to the T* columns.

Note that the energy service demand values specified in this column should be for *one instance* of any underlying ST for the concerned service technology category (i.e. `STC`). The number of instances of each underlying service technology for this ST category, used by this consumer, is specified by the `NumInstances` parameter (Section 3.7).

- The columns `STC+STC1, STC+STC2, STC+STC1+STC2` etc. correspond to using `STC` in conjunction with one or more other ST categories (`STC1, STC2` etc.) to provide the same specified energy service to consumers defined in the `C*` column in the geography and time defined by the `G*` and `T*` columns. Note that the column entry corresponds to the energy service demanded only from `STC` (i.e. the service technology category in the file name) but when it is used in conjunction with these other service technology categories, where the column header defines which are the other ST categories. The energy service demanded from each of those other ST categories, when used in conjunction with this ST category under consideration, is provided in the respective files for those other ST categories. Also note that the values in these columns are applicable only to those consumers who use this combination of STs. Once again, the energy service demand values specified in all such columns should be for *one instance* of any underlying ST for the concerned service technology (i.e. `ST`).
  If a particular combination of valid ST categories is not present as a column name, it signifies that there is no demand from the specified ST category when used in that particular combination - for the specified energy service in the specified demand sector, for any consumer-type in any geographic and time unit.
- If some rows (i.e. some valid combinations of C*, G*, T*) are not supplied in this file, then the energy service demand values for such unspecified combinations, in all the specified columns, will be taken as 0.

Example:

- `D_RES/LIGHTING/ELEC_LIGHT_ES_Demand`: This gives the lighting energy service demand from `ELEC_LIGHT` service technology category in the residential sector and since the `LIGHTING` energy service is provided by only this ST category in this sector, there's just one column giving energy service demand (since it can't occur in conjunction with other STCs).
  - `RURAL, RQ1, INDIA, WEST, MH, 2021, WINTER, SEASONDAY, MORN, 1`: says that 1 hour of lighting is required in rural Maharashtra quintile 1 households on 2021 winter mornings
- `D_RES/COOLING/FAN_ES_Demand`: This gives the cooling energy service demand from `FAN` service technology category which provides the (space) `COOLING` energy service - which is also provided by `COOLER` and `AC` ST categories. Hence there are columns for when a fan is used in conjunction with these in addition to just using a fan by itself. Thus, the last three column headers are `FAN, FAN+COOLER, FAN+AC`. The `FAN+AC+COOLER` column is not specified, implying no consumer will use all three – fans, coolers and ACs.

- o URBAN, UQ3, INDIA, SOUTH, TN, 2023, SUMMER, SEASONDAY, MID, 3, 1.33, 1.33: indicates that, in TN urban Q3 households on 2023 summer mid-days, the energy service required per fan is 3, 1.33 and 1.33 cooling hours respectively when used by itself, in combination with a cooler and in combination with an AC.
- D_TRANS/PASS_MOBILITY/TWH_ES_Demand: Gives the demand from TWH (two-wheelers) for passenger mobility. This demand may also be provided by PCAR (passenger car). Thus, the last two columns have headers TWH, TWH+PCAR.
    - o URBAN, UQ3, INDIA, SOUTH, AP, 2025, 1200, 500: This states that, in AP urban Q3 HHs in 2025, the energy service required per two-wheeler is 1200 and 500 pkm respectively when used by itself and in combination with a car.

3.4 STC1+STC2+…+STCk+UsagePenetration.csv

Directory: Root/<DemandSector>/<EnergyService>

Columns: C*, G*, T*, UsagePenetration

The name of this file is similar to the column headers of the file <STC>_ES_Demand.csv (described in Section 3.3), in that it allows the modeller to combine multiple ST categories, all of which provide the energy service corresponding to the name of the directory in which this file exists. The intent of this file is to supply the 'consumer usage penetration' of each combination of ST categories (as specified in the file name) that provides the energy service, for each consumer type (in a particular demand sector) in each geographic and time unit. Thus each row specifies the fraction of consumers of that consumer type who use the particular combination of ST categories to avail that particular energy service in that geographic and time unit. The name of the folder in which the file is located specifies the energy service, while the name of the folder above it specifies the demand sector.

The C*, G*, T* columns have the usual interpretation as explained in previous sections. This input should be given at the coarsest consumer type, geographic and temporal granularities among these respective granularities specified in DS_ES_STC_DemandGranularityMap – for any ST category in the combination for this file, providing the given ES in the given DS. The UsagePenetration column is a fraction between 0 and 1 (both inclusive) representing the share of C* using this ST-combination in this <G*, T*>. A few points to note:

- If the file for a particular combination of ST categories doesn't exist, then it is assumed that there is no usage of that combination for any consumer-type in any geographic and time unit.
- The order of the names of the ST categories in the file name is not material. For example, to specify the usage penetration of combination of FAN and AC, the modeller could name the corresponding file as either FAN+AC+UsagePenetration.csv or as AC+FAN+UsagePenetration.csv. But only one of these must be provided.
- For any <C*, G*, T*>, the usage penetrations of the various combinations of ST categories offering the same ES in a DS (as specified in multiple files representing combinations of the ST

categories) have to add up to a value between 0 and 1, since this sum represents the total share of consumers of that type availing that service through any combination of ST categories – in that geographic and time unit.

- However, this sum can be less than 1, because some consumers of a given type may not avail the energy service at all.
- A given ST category may possibly provide more than one energy service. Since this usage penetration parameter is specified per energy service in a given DS, it implies that the usage fractions of such an ST category may conceivably be different for each energy service it provides. This is permitted since the share of consumers "using" the same ST category for different services may be different. For example, the share of households that may use a car for short distance travel may be different from the share of households using a car for long distance travel – for a given `<C*, G*, T*>`.
- If some rows (i.e. some valid combinations of C*, G*, T*) are not supplied in this file, then the usage penetration values for such unspecified combinations will be taken as 0.

Example:

- `D_RES/LIGHTING/ELEC_LIGHT+UsagePenetration.csv` gives the usage penetration of electric lighting among household consumers
    - `RURAL, Q1, INDIA, WEST, MH, 2021, 1`: indicates that all households (100%) in rural Q1 Maharashtra in 2021 use electric lighting
- `D_RES/COOLING/FAN+UsagePenetration.csv`, `D_RES/COOLING/COOLER+FAN+UsagePenetration.csv`, `D_RES/COOLING/AC+FAN+UsagePenetration.csv` give inputs about the share of households that use only fans, or fans with coolers or fans with ACs respectively. If these three files respectively have rows as given below, it indicates that, in 2023, in TN, 68% urban Q3 households use only fans, 25% use coolers and fans, and 5% use ACs and fans. Under the twin assumptions that a household that owns an AC or a cooler necessarily owns a fan and that no household uses both ACs and coolers (indicated by the absence of files `COOLER+UsagePenetration.csv`, `AC+UsagePenetration.csv`, `COOLER+AC+UsagePenetration.csv`, `COOLER+AC+FAN+UsagePenetration.csv`), this implicitly implies that 2% of urban Q3 TN households use no cooling appliance at all in 2023, i.e. are outside of the 68% + 25% + 5%.
    - `URBAN, Q3, INDIA, SOUTH, TN, 2023, 0.68`
    - `URBAN, Q3, INDIA, SOUTH, TN, 2023, 0.25`
    - `URBAN, Q3, INDIA, SOUTH, TN, 2023, 0.05`

3.5 TechSplitRatio.csv

Directory: `Root/<DemandSector>/<EnergyService> or Root/<DemandSector>`

Columns: `ServiceTechCategory, C*, G*, T*, ServiceTech, TechSplitRatio`

An ST category can consist of several underlying STs – as specified in `STC_ST_Map`. Hence, in addition to specifying the fraction of consumers who use a particular ST category, it is also required to specify the usage split across the underlying STs – among consumers who use that ST category.

The intent of this file is to supply the relative consumer usage shares of the underlying STs, for each ST category that provides a specified energy service in a specified demand sector.

The name of the folder in which the file is located specifies the energy service, while the name of the folder above it specifies the demand sector.

Since this information is given for each ST category, the same usage split of consumers across various underlying STs for the specified ST category will carry through when that ST category is used in any combination with other valid ST categories in the specified demand sector for the specified energy service – for a given consumer type in a given geographic and time unit.

Note that for a given STC, the tech split-ratio values can be different for each of the various energy services provided by that STC in the given DS.

The information to be given in each column is as follows:

- `ServiceTechCategory` is the name of the ST category (STC).
- `C*, G*, T*` have the usual interpretation. For each STC, this input should be given at consumer type, geographic and temporal granularities that are coarser than or equal to the respective consumer type, geographic and temporal granularities specified in `DS_ES_STC_DemandGranularityMap` – for that STC providing the specified energy service in the specified demand sector.
- The actual number of columns for each of `C*, G*, T*` in this file depends on the finest consumer type, geographic and temporal granularities respectively among those that are used for each of the STCs in this file. For a particular STC though (i.e. for each row in the file pertaining to that STC), depending on the granularities actually decided for that STC, only the relevant consumer type, geographic and temporal granularity columns need to have values and the other columns (if any) should be left empty.
- `ServiceTech` is the name of the ST for which the usage split share is being given; it should match one of the names given in `STC_ST_Map` for the specified ST category.
- `TechSplitRatio` is the relative share of consumers in this `<C*, G*, T*>` who use the specified ST, among all those consumers who use the specified ST category for the specified ES in the specified DS, and is a fraction between 0 and 1 (both inclusive). Since this input is just a split of the consumers using an ST category across its various underlying STs, the sum of the tech split-ratios of the different underlying STs of any given ST category for each `<C*, G*, T*>` should add up to 1. Else, an error would be issued.
- In case some tech split-ratio value is not specified for some underlying ST of a given ST category for some `<C*, G*, T*>`, it would be implicitly considered as zero.

- If an ST category happens to have only one underlying ST though, the tech split-ratio value for that sole ST, if explicitly specified, necessarily has to be 1. In case it is not specified, it would be implicitly considered as 1.
- This file can also be supplied directly under a demand sector folder. Such a file, supplied directly under a demand sector folder, serves as the default TechSplitRatio file for all applicable bottom-up energy services for that demand sector. In other words, in case a TechSplitRatio file is not supplied for some of the applicable bottom-up energy services needed in a demand sector, then the default TechSplitRatio file (that is placed directly under the demand sector folder) will be used for all such energy services. If a TechSplitRatio file is actually supplied under some energy service sub-folder, then for that energy service, all the rows in such a file will obviously override the corresponding rows in the default file. If some rows are unspecified in the TechSplitRatio file supplied under an energy service sub-folder, then values for those rows will be used from the corresponding rows, if specified, in the default file. Note that in such a default TechSplitRatio file, for each STC, the input should be given at consumer type, geographic and temporal granularities that are each respectively coarser than or equal to the coarsest among these respective granularities specified across all energy services in `DS_ES_STC_DemandGranularityMap` for that STC in the specified demand sector.

Example:

- `D_TRANS/LONG_DIST/TechSplitRatio.csv` This file gives the tech split-ratio of ST categories that provide long distance travel as an energy service in the transport demand sector.
  - `CAR, URBAN, Q3, INDIA, NORTH, PB, 2024, MS_CAR, 0.3`
  - `CAR, URBAN, Q3, INDIA, NORTH, PB, 2024, HSD_CAR, 0.7`

  The above two rows indicate that in 2024 among urban Q3 households of Punjab, of the transport consumers who use the car ST category for long distance travel, 30% use a petrol car – while 70% use a diesel car.

3.6 EfficiencyLevelSplit.csv

Directory: `Root/<DemandSector>/<EnergyService> or Root/<DemandSector>`

Columns: `ServiceTech, C*, G*, T*, EfficiencyLevelName, EfficiencySplitShare`

In addition to identifying the share of consumers who use a particular ST category to avail an energy service as well as the usage split ratio among the underlying STs, it is also necessary to specify the split of different efficiency levels of an ST among the consumers using that ST. For each ST offering a particular energy service in a particular demand sector and for each consumer type of that DS at each geographic and time unit, this file specifies the split of the different efficiency levels among those of this CT who use this ST for the specified ES. The name of the folder in which the file is located specifies the energy service, while the name of the folder above it specifies the demand sector.

Since this information is given for each ST, the same split of consumers across efficiency levels for the specified ST will carry through when the ST category of this ST is used in any combination with other valid ST categories in the specified demand sector for the specified energy service – for a given CT in a given geographic and time unit.

Note that for a given ST, the efficiency split-share values can be different for each of the various energy services provided by that ST in the given DS.

The information to be given in each column is as follows:

- `ServiceTech` is the name of the ST.
- `C*, G*, T*` have the usual interpretation. For each ST, this input should be given at consumer type, geographic and temporal granularities that are coarser than or equal to the respective consumer type, geographic and temporal granularities specified in `DS_ES_STC_DemandGranularityMap` – for the parent STC of that ST providing the specified energy service in the specified demand sector.
- The actual number of columns for each of `C*, G*, T*` in this file depends on the finest consumer type, geographic and temporal granularities respectively among those that are used for each of the STs in this file. For a particular ST though (i.e. for each row in the file pertaining to that ST), depending on the granularities actually decided for that ST, only the relevant consumer type, geographic and temporal granularity columns need to have values and the other columns (if any) should be left empty.
- `EfficiencyLevelName` is the name of the efficiency level for which the split share is being given; it should match one of the names given in `ST_SEC` for the specified ST.
- `EfficencySplitShare` is the share of consumers in this `<C*, G*, T*>` using this ST for the specified ES, who are using this efficiency level of the ST, and is a fraction between 0 and 1 (both inclusive). Since this input is just a split of the consumers using an ST into its various efficiency levels, the sum of the split-shares of the different efficiency levels of any given ST for each `<C*, G*, T*>` should add up to 1. Else, an error would be issued.
- In case some split-share value is not specified for some efficiency level of a given ST for some `<C*, G*, T*>`, it would be implicitly considered as zero.
- If an ST happens to have only one efficiency level, the corresponding split-share value, if explicitly specified, necessarily has to be 1. In case it is not specified, it would be implicitly considered as 1.
- This file can also be supplied directly under a demand sector folder. Such a file, supplied directly under a demand sector folder, serves as the default EfficiencyLevelSplit file for all applicable bottom-up energy services for that demand sector. In other words, in case an EfficiencyLevelSplit file is not supplied for some of the applicable bottom-up energy services needed in a demand sector, then the default EfficiencyLevelSplit file (that is placed directly under the demand sector folder) will be used for all such energy services. If an EfficiencyLevelSplit file is actually supplied under some energy service sub-folder, then for that

energy service, all the rows in such a file will obviously override the corresponding rows in the default file. If some rows are unspecified in the EfficiencyLevelSplit file supplied under an energy service sub-folder, then values for those rows will be used from the corresponding rows, if specified, in the default file. Note that in such a default EfficiencyLevelSplit file, for each ST, the input should be given at consumer type, geographic and temporal granularities that are each respectively coarser than or equal to the coarsest among these respective granularities specified across all energy services in `DS_ES_STC_DemandGranularityMap` for the parent STC of that ST in the specified demand sector.

Example:

- `D_RES/LIGHTING/EfficiencyLevelSplit.csv`: the following lines indicate that among quintile 1 households in rural West Bengal in 2024, the usage of electric lighting appliances is split as 50% incandescent bulbs, 10% CFLs and 40% LED lamps. In this specific example, `ELEC_LIGHT` happens to be the single underlying ST under its parent ST category, which also happens to be named `ELEC_LIGHT` (as shown in a previous example).
    - `ELEC_LIGHT, RURAL, RQ1, INDIA, EAST, WB, 2024, INCAND, 0.5`
    - `ELEC_LIGHT, RURAL, RQ1, INDIA, EAST, WB, 2024, CFL, 0.1`
    - `ELEC_LIGHT, RURAL, RQ1, INDIA, EAST, WB, 2024, LED, 0.4`
- `D_RES/COOLING/EfficiencyLevelSplit.csv`: the following lines indicate that among urban quintile 3 households of Gujarat in 2027, AC usage is split as 40% using 3-star ACs, 30% using 4-star ACs and 30% using 5-star ACs. Again, `AC` happens to be the single underlying ST under its parent ST category, which also happens to be named AC (as shown in a previous example.
    - `AC, URBAN, UQ3, INDIA, WEST, GJ, 2027, 3STAR, 0.4`
    - `AC, URBAN, UQ3, INDIA, WEST, GJ, 2027, 4STAR, 0.3`
    - `AC, URBAN, UQ3, INDIA, WEST, GJ, 2027, 5STAR, 0.3`
- `D_TRANS/SHORT_DIST/EfficiencyLevelSplit.csv`: the following lines indicate that among urban quintile 5 households of Punjab in 2025, petrol car usage for short distance travel is split between compacts and limousines as 80% and 20% respectively.
    - `MS_CAR, URBAN, UQ5, INDIA, WEST, PB, 2025, COMPACT, 0.8`
    - `MS_CAR, URBAN, UQ5, INDIA, WEST, PB, 2025, LIMO, 0.2`
- `D_TRANS/LONG_DIST /EfficiencyLevelSplit.csv`: the following lines indicate that among the same urban quintile 5 households of Punjab in 2025, petrol car usage for long distance travel is split between compacts and limousines as 30% and 70% respectively.
    - `MS_CAR, URBAN, UQ5, INDIA, WEST, PB, 2025, COMPACT, 0.3`
    - `MS_CAR, URBAN, UQ5, INDIA, WEST, PB, 2025, LIMO, 0.7`

This information will be used to derive the demand for an ST by efficiency level in any time/geographic unit, even when it occurs in combination with other STs of other ST categories that provide the specified energy service in the specified demand sector. For example, for some `<C*, G*, T*>` if

- The AC service demand is 4 CDH (when used with a fan) and 8 CDH (when used by itself),
- The share of households using ACs with a fan is 5% and using only ACs is 0.1%,
- The split share of 3-, 4- and 5-star ACs is 50%, 30%, 20% respectively and
- There are 100,000 households (consumers) each owning 1 AC then
- The detailed break-up of AC service demand for that `<C*, G*, T*>` would be
    - 3-star ACs: 4 cdh from each of 2500 ACs (that are used with fans) + 8 cdh from each of 50 ACs (that are used just by themselves)
    - 4-star ACs: 4 cdh from each of 1500 ACs + 8 cdh from each of 30 ACs
    - 5-star ACs: 4 cdh from each of 1000 ACs + 8 cdh from each of 20 ACs

3.7 NumInstances.csv

Directory: `Root/<DemandSector>/<EnergyService> or Root/<DemandSector>`

Columns: `ServiceTech, C*, G*, T*, NumInstances`

The final input required for bottom-up demand estimation is the number of instances of any ST that a consumer type uses in a geographic and time unit – for a specified energy service in a specified demand sector. This file captures that information. The name of the folder in which the file is located specifies the energy service, while the name of the folder above it specifies the demand sector.

The `ServiceTech, C*, G*, T*` columns have the usual interpretation. The `NumInstances` column is a positive number (not necessarily an integer) representing the average number of instances of the ST used by this consumer type in this geographic and time unit for the specified energy service – with the important caveat that only consumers who use the ST for that ES are considered while calculating this average number. Thus this input allows modelling of cases where multiple instances of an ST may be used by a consumer.

Since this information is given for each ST, the same number of instances for the specified ST will carry through when the ST category of this ST is used in any combination with other valid ST categories in the specified demand sector for the specified energy service – for a given CT in a given geographic and time unit.

As with most other inputs related to STs, for each ST, this input should be given at consumer type, geographic and temporal granularities that are coarser than or equal to the respective consumer type, geographic and temporal granularities specified in `DS_ES_STC_DemandGranularityMap` – for the parent STC of that ST providing the specified energy service in the specified demand sector. The actual number of columns for each of `C*, G*, T*` in this file depends on the finest consumer type, geographic and temporal granularities respectively among those that are used for each of the STs in this file. For a particular ST though (i.e. for each row in the file pertaining to that ST), depending on the granularities actually decided for that ST, only the relevant consumer type, geographic and temporal granularity columns need to have values and the other columns (if any) should be left empty.

This file can also be supplied directly under a demand sector folder. Such a file, supplied directly under a demand sector folder, serves as the default NumInstances file for all applicable bottom-up energy services for that demand sector. In other words, in case a NumInstances file is not supplied for some of the applicable bottom-up energy services needed in a demand sector, then the default NumInstances file (that is placed directly under the demand sector folder) will be used for all such energy services. If a NumInstances file is actually supplied under some energy service sub-folder, then for that energy service, all the rows in such a file will obviously override the corresponding rows in the default file. If some rows are unspecified in the NumInstances file supplied under an energy service sub-folder, then values for those rows will be used from the corresponding rows, if specified, in the default file. Note that in such a default NumInstances file, for each ST, the input should be given at consumer type, geographic and temporal granularities that are each respectively coarser than or equal to the coarsest among these respective granularities specified across all energy services in `DS_ES_STC_DemandGranularityMap` for the parent STC of that ST in the specified demand sector.

Example:

- `D_RES/COOLING/NumInstances.csv`: The following lines state that an urban quintile 3 household in TN in 2023 that has fans has 1.9 of them, and a similar household in the same year that has coolers has 1.2 of them.
    - `FAN, URBAN, UQ3, INDIA, SOUTH, TN, 2023, 1.9`
    - `COOLER, URBAN, UQ3, INDIA, SOUTH, TN, 2023, 1.2`

4 Energy services that are not modelled bottom-up

Energy services whose demand is not modelled in a bottom-up fashion in a given demand sector can be described in three ways: by providing the energy demand exogenously, or through GDP elasticity or as a residual of some other services. All the files relevant to such inputs are provided in that demand sector's directory.

4.1 ExogenousDemand.csv

Directory: `Root/<DemandSector>`

Columns: `EnergyService, EnergyCarrier, C*, G*, T*, EnergyDemand`

If the energy demand of an EC for an ES in a DS is specified exogenously, then it is given through this file. The `EnergyService` column indicates the ES for which this row contains exogenous demand, and must have been declared as such in `DS_ES_Map`. The `EnergyCarrier` column indicates the EC for which this row contains exogenous demand.

`C*` represents up to 2 columns (with headers `ConsumerType1, ConsumerType2`), `G*` represents up to 4 columns (with headers `ModelGeography, SubGeography1, SubGeography2`, SubGeography3) and T* represents up to 4 columns (with headers Year, Season, DayType, DaySlice). Thus, the file would have at least two columns (one each for G*, T* and none for C*) and at most 10 columns (2 for C*, 4 for G* and 4 for T*) corresponding to C*, G*, T*. The actual number of columns for each of C*, G*, T* depends on the finest consumer, geographic and temporal granularities respectively that are specified in DS_ES_EC_Map among all the EXOGENOUS type energy services in this given DS.

For a particular DS, ES, EC though (i.e. for a specific row in the file), depending on the granularity specified for that combination in DS_ES_EC_Map, only the relevant granularity columns need to have values and the other columns (if any) should be left empty.

EnergyDemand represents the energy demanded at this granularity and is expressed in the energy units of the energy carrier. Note that this exogenous demand is the aggregate demand for the entire specified consumer category at the specified time and geographic units – unlike the per-consumer demand input required for bottom-up energy services.

If some rows (i.e. some valid combinations of EnergyService, EnergyCarrier, C*, G*, T*) are not supplied in this file, then the energy demand values for such unspecified combinations will be taken as 0.

Example:

- D_IND/ExogenousDemand.csv: The following indicates an energy demand of 1 million MJ from coal for industrial heating in large steel industries in OD in 2023, 2 million MJ from coal for industrial heating in cement plants in JH in 2025 and half a million MJ from other petroleum products for industrial heating in cement plants in JH in 2025.
    - IND_HEATING, COAL, IND_STEEL, LARGE_STEEL, INDIA, EAST, OD, , 2023, , , , 1000000
    - IND_HEATING, COAL, IND_CEMENT, ALL_CEMENT, INDIA, EAST, JH, , 2025, , , , 2000000
    - IND_HEATING, OTHER_PP, IND_CEMENT, ALL_CEMENT, INDIA, EAST, JH, , 2025, , , , 500000

4.2 BaseYearDemand.csv

Directory: Root/<DemandSector>

Columns: EnergyService, EnergyCarrier, C*, G*, T*, BaseYearDemand

This input is required to compute demand which is modelled based on GDP elasticity. Two inputs are required to estimate such demand: one is the demand for the carrier (at the right granularity) in the 'start year' and the second is the elasticity of demand with respect to GDP for the subsequent years. This file captures the first of these inputs.

Since GDP is typically computed at annual time granularity, GDP-elasticity related demand inputs (i.e. the second of these inputs) too are specified only at an annual level and the same elasticity is used for all finer time levels, if the balancing time of the energy carrier is finer.

Since the intent is to compute the energy demand for the entire model period, the 'starting year' for which demand has to be provided exogenously is the year just before the model's first year. This year is called the 'base year' and hence this demand is called the base year demand. The column headers of the file are fairly self-explanatory and have the following additional conditions:

- The `EnergyService` must have been declared as being of the GDP elasticity type in `DS_ES_Map`.
- `C*, G*, T*` have the usual interpretation, as described in Section 4.1. The actual number of columns for each of `C*, G*, T*` depends on the finest consumer, geographic and temporal granularities respectively that are specified in `DS_ES_EC_Map` among all the `GDPELASTICITY` type energy services in this given DS. The `Year` column should contain only the base year.
- The `BaseYearDemand` is specified in the energy units of the `EnergyCarrier` and is the aggregate energy demand for the entire `C*` in `<G*, T*>`.

This input needs to be provided for all energy carriers providing any energy service for this demand sector which has been declared to be of the GDP elasticity type. If some rows (i.e. some valid combinations of EnergyService, EnergyCarrier, C*, G*, T*) are not supplied in this file, then the base year demand values for such unspecified combinations will be taken as 0.

Example:

- `D_TRANS/BaseYearDemand.csv`: This indicates that 234234 MJ of MS and 50000 MJ of HSD is demanded in the base year 2019 for local passenger mobility in India.
  - `PASS_MOBILITY, MS, TRANS_LOCAL, L_PASS, INDIA, 2019, 234234`
  - `PASS_MOBILITY, HSD, TRANS_LOCAL, L_PASS, INDIA, 2019, 50000`

4.3 DemandElasticity.csv

Directory: `Root/<DemandSector>`

Columns: `EnergyService, EnergyCarrier, C*, G*, Year, Elasticity`

This is the second input required for GDP elasticity based demand computation. This input is only accepted at an annual granularity since GDP values are only available at that granularity. The same elasticity is applied to all finer time units. GDP elasticity values have to be given for each model year for each DS-ES-EC combination where the ES is of `GDPELASTICITY` type. Here too, the actual number of columns for `C*` and `G*` depends on the finest consumer and geographic granularities respectively that are specified in `DS_ES_EC_Map` among all the `GDPELASTICITY` type energy services in this given DS.

Since this input is specified at an annual time granularity, the time granularity specified in the relevant rows of `DS_ES_EC_Map` is not applicable to this input. `Elasticity` is a real number which would be multiplied by the GDP growth rate to arrive at the energy demand growth rate for that year for that `C*` in that `G*`.

If GDP values are provided at a finer (or equal) geographic granularity than that for elasticity, then GDP values will be aggregated up to the geographic granularity of elasticity to calculate the relevant GDP growth rates. If GDP values are provided at a coarser geographic granularity than that for elasticity, then GDP growth rates calculated at the coarser level are assumed for all the corresponding finer geographic granularities at which elasticities are given. Note that, since elasticity is a real number, it can also be negative – indicating a negative correlation between GDP and energy demand[6].

If some rows (i.e. some valid combinations of EnergyService, EnergyCarrier, C*, G*, Year) are not supplied in this file, then the elasticity values for such unspecified combinations will be taken as 0.

Example:

- `D_TRANS/DemandElasticity.csv`: This file states that the GDP elasticity of demand for MS in 2024 is 0.92 and GDP elasticity of demand for HSD in 2023 is 0.67 for local passenger mobility in India.
    - `PASS_MOBILITY, MS, TRANS_LOCAL, L_PASS, INDIA, 2024, 0.92`
    - `PASS_MOBILITY, HSD, TRANS_LOCAL, L_PASS, INDIA, 2023,0.67`

4.4 ResidualDemand.csv

Directory: `Root/<DemandSector>`

Columns: `EnergyService, EnergyCarrier, C*, G*, T*, ResidualShare`

This input captures the information required to calculate demand by the residual method. It is to be provided for only that energy service (if any) in a given demand sector, which is of `RESIDUAL` type. As mentioned earlier, there can at most be one residual type energy service in any demand sector.

The columns are very similar to the columns in `ExogenousDemand.csv`, except that the last column (`ResidualShare`) is a positive real number which will be multiplied by the total demand of this EC from all other energy services in this DS for this `<C*, G*, T*>` - to get the residual demand of this EC in this DS in the same `<C*, G*, T*>`. The granularities for `C*, G*, T*` are as specified in `DS_ES_EC_Map` for the specified DS, ES and EC. In addition, they need to respect the coarseness constraint for `RESIDUAL` services mentioned in the description of `DS_ES_EC_Map` (Section 2.5). Note

[6] This will typically happen only for 'inferior' energy carriers whose usage reduces with increasing prosperity – e.g. solid biomass for cooking, kerosene for lighting etc.

that though only one energy service can be a residual service in a demand sector, each carrier providing that service can have a different residual share for each `<C*, G*, T*>`.

If some rows (i.e. some valid combinations of EnergyService, EnergyCarrier, C*, G*, T*) are not supplied in this file, then the residual share values for such unspecified combinations will be taken as 0.

Example:

- `D_RES/ResidualDemand.csv`: The following indicates that residual residential electricity demand is 36% of all other residential electricity demand in rural quintile 3 Gujarat on a 2028 autumn evening.
    - `RES_OTHERS, ELECTRICITY, RURAL, RQ3, INDIA, WEST, GJ, 2028, AUTUMN, SEASONDAY, EVENING, 0.36`

5 Demand profiles

The inputs provided thus far allow energy demand to be computed for each DS, CT, ES, ST (where applicable) and EC at the geographic and time granularity as given by the modeller. In particular, these granularities (at which energy demands are computed for an EC) may be different from the balancing area and balancing time for the EC, which are the granularities at which supply has to match demand. If the computed demand for an EC is at a finer geographic or time granularity than its balancing area or time, then it is a simple matter to aggregate it up to the balancing area or time, which the demand module does as explained in the next section. However, if the granularity is specified such that the EC demand is computed at a coarser granularity for one or both of geography and time, then it needs to be broken down to the balancing area and time. This break down or "profile" can either be specified by the modeller, or "discovered" by the supply module so that the resultant profile has the least cost (the parameter that the supply module optimises for), or a combination of both.

A simple example that will help illustrate the need for such a profile is estimating electricity demand for (say) the transport demand sector. On the demand side, it is natural to specify the energy service demand (as, say, passenger-km) for electric trucks, electric cars, electric buses, electric two-wheelers etc. at the annual (and perhaps national) level. Given such inputs, the electricity demand would also be computed at the annual (and perhaps national) level. However, since electricity demand and supply are matched at a finer time granularity (perhaps at a `DAYSLICE`) and perhaps also at a finer geographic granularity, the computed demand needs to be broken down to finer levels. In this case, the modeller might wish to say that (for example), the bulk of electricity demand for charging of buses happens at night, but that for charging of cars and two-wheelers happen during the day because of policies that encourage employers to provide charging facilities, and let the supply module discover the best times to charge trucks because cost is the most important factor for them. Note that allowing the supply module to discover the profile for all uses may lead to impractical solutions since it would only find a cost-optimal profile – for example, it might discover that the best time to charge buses is in the middle of the day when cheap solar electricity is available. However, this is clearly impractical – hence the need to also allow the modeller to provide some inputs on the profile of how particular energy services or technologies get used.

Note that the modeller may want to specify only a 'partial profile', i.e. break down the demand up to a certain level that is still coarser than the balancing level, and let the supply module figure out the further details of the profile to get balancing area/time level values. For example, in the case of electric trucks, the modeller might want to break up the annual electricity demand into seasonal values based on an understanding of how the trucking industry operates, but leave the further detailing of the exact profile to the `DAYSLICE` level to the supply module. In general, the modeller may even want to give different profiles for different *combinations* of geographies and times – e.g. the seasonal breakup of truck electricity demand may vary by region, with (for example) the share of monsoon demand in the annual demand being greater in the northern region than the southern region.

This input is intended to allow providing such profile specifications to enable breaking down energy carrier demand computed at coarser than balancing area/time granularities to finer granularities up to the balancing area/time granularities, if the modeller so desires. However, this is an optional parameter, since it is only the supply module that 'needs' the energy carrier demand at balancing area/time, and the supply module can discover a cost-optimal break-down to the balancing area/time if required.

5.1 <EC >_GTProfile.csv

Directory: `Root/<DemandSector>` (or) `Root/<DemandSector>/<EnergyService>`

Columns: `[ServiceTech], G*, T*, GTProfile`

The name of this file is the name of an energy carrier, appended with `_GTProfile.csv`. For each energy carrier, it is an optional file. If the file is not given, then it is assumed that any breaking down of demand computed at coarser granularities to finer granularities will be done by the supply module to optimise cost.

The file may be given at the DS level, in which case it acts as the default profile to be used for that EC for any ES or ST in that DS, for which the profile is not explicitly specified. This file just has `G*, T*, GTProfile` as its columns – the meaning of these columns is explained below.

If the file is over-ridden in an ES directory, then the over-ridden version is used for that ES. If the ES is not specified in a bottom-up manner, then it just has the `G*, T*, GTProfile` columns. However, if the ES is specified in a bottom-up manner, then it has an extra `ServiceTech` column at the beginning to indicate which ST the profile is being given for, since the ES may be provided through multiple STs and the modeller may want different profiles for each ST.

The geographic and time granularities, at which the profile is specified, should not be finer than the balancing area and balancing time of the specified EC, but can be coarser. The columns in each row are interpreted as follows.

The `ServiceTech` column, if it exists (for an ES in a DS where it is specified in a bottom-up manner), indicates the name of the ST for which the profile is being specified. If this column is left empty, then the profile defined for this unspecified ST is used as the default profile for any ST providing this ES in this DS, for which a profile has not explicitly been defined.

`G*, T*` represent the geography and time columns for which the profile is being given. The actual number of columns for each of `G*` and `T*` depends on the finest geographic and temporal granularities at which profiles are provided for this EC. Since the complete specification of either a geographic unit (similarly time unit) requires the specification from `ModelGeography` downwards (similarly `Year` downwards for time), `G*, T*` columns always begin from `ModelGeography` and `Year` respectively.

- If the file corresponds to an ES specified in a bottom-up manner, then the number of `G*, T*` columns correspond to the finest granularities at which profile is provided across all the specified STs. For STs for which the profile is only provided up to a coarser level, the corresponding (finer granularity) columns should be empty. E.g., if for one ST, the modeller wishes to specify profiles from `ModelGeography` to `SubGeography3` but for another, only from `ModelGeography` to `SubGeography2`, then the file will have `G*` columns up to `SubGeography3` but while specifying the profiles for the second ST, the entries in the `SubGeography3` column will be left empty.
- If the file corresponds to an ES not specified in a bottom-up manner, then the number of `G*, T*` columns correspond to the finest granularities at which profile is provided
- If the file is specified at the demand sector level, then the number of `G*, T*` columns correspond to the finest granularities at which profile is provided.

`GTProfile` is intended to capture the energy demand in the particular `G*, T*` given in that row, as a share of the aggregate energy demand which is being computed at a coarser level. For example, it may be convenient to think of `GTProfile` values as weights to be attached to the aggregate demand which is computed at the coarser level – in which case, they would add up to 1 for each time and geography combination at the coarser granularity. But in general, they can be any numeric values and all the `GTProfile` values are just treated as relative shares. For example, if the demand is calculated at a particular coarseness (say, `YEAR` and `SubGeography1` granularities), and the `GTProfile` values to split this to some finer granularity (say, `SEASON` and `SubGeography2` granularities) for a particular `YEAR` and `SubGeography1` combination are (say) $v_1, v_2, \dots, v_n$, then the share of the aggregate demand in a particular `G*, T*` at the finer granularity, which has a `GTProfile` value of v_i is $v_i / (v_1 + v_2 + \dots + v_n)$.

When the source time granularity is SEASON or coarser and the destination time granularity is finer than SEASON, then the above expression (i.e. for the share of the aggregate demand in a particular `G*, T*` at the finer granularity, which has a `GTProfile` value of v_i) needs to become:

$$v_i / (w_1 * v_1 + w_2 * v_2 + \dots + w_n * v_n)$$

where each w_i = DaysPerSeason(i) * DayTypeWeight(i)

Note that the relative ratios across all the v_is remain the same, in spite of this change in the denominator – which is indeed what is desired/required.

Note further that now the weighted sum of these shares (rather than just the simple sum of these shares, as in the original expression), adds up to 1; again, which is what is indeed desired/required. For the weighted sum, the weights are the same w_is as mentioned above.

Example:

Consider an example in which the time and geography elements specifications are depicted in Figure 1. For convenience, only one year has been assumed in the model period. Suppose that the balancing area and balancing time for ELECTRICITY energy carrier are SUBGEOGRAPHY2 and DAYSLICE respectively. Furthermore, suppose that the number of days in SUMMER is 180 and that in WINTER is 185.

Year	Season	DayType	DaySlice
2023	SUMMER	ALLDAY	DAY
	WINTER		NIGHT

ModelGeography	SubGeography1	SubGeography2
INDIA	NR	UP, PB
	SR	TN, KA

Figure 1. Time and Geography Elements

Sr. No.	ModelGeography	SubGeography1	SubGeography2	Year	Season	DayType	DaySlice	GTProfile
1	INDIA	NR	UP	2023	SUMMER	ALLDAY	DAY	0.147
2	INDIA	NR	UP	2023	SUMMER	ALLDAY	NIGHT	0.147
3	INDIA	NR	UP	2023	WINTER	ALLDAY	DAY	0.0504
4	INDIA	NR	UP	2023	WINTER	ALLDAY	NIGHT	0.0756
5	INDIA	NR	PB	2023	SUMMER	ALLDAY	DAY	0.0648
6	INDIA	NR	PB	2023	SUMMER	ALLDAY	NIGHT	0.0432
7	INDIA	NR	PB	2023	WINTER	ALLDAY	DAY	0.0216
8	INDIA	NR	PB	2023	WINTER	ALLDAY	NIGHT	0.0504
9	INDIA	SR	TN	2023	SUMMER	ALLDAY	DAY	0.084
10	INDIA	SR	TN	2023	SUMMER	ALLDAY	NIGHT	0.036
11	INDIA	SR	TN	2023	WINTER	ALLDAY	DAY	0.024
12	INDIA	SR	TN	2023	WINTER	ALLDAY	NIGHT	0.096
13	INDIA	SR	KA	2023	SUMMER	ALLDAY	DAY	0.0512
14	INDIA	SR	KA	2023	SUMMER	ALLDAY	NIGHT	0.0128
15	INDIA	SR	KA	2023	WINTER	ALLDAY	DAY	0.0096
16	INDIA	SR	KA	2023	WINTER	ALLDAY	NIGHT	0.0864
							Yearly Total	**1**

Figure 2. D_IND/ELECTRICITY_GTProfile.csv

The contents of the D_IND/ELECTRICITY_GTProfile.csv are as shown in Figure 2 – wherein the first column and the last row shown are not actually part of the input file, but have been added in the figure only for the purpose of easy reference/explanation for this example.

This file is thus the GTProfile for electricity in the industry demand sector, provided at the DS level. This means that this is the default profile to be used for electricity for all energy services and service technologies in this DS, unless overridden by the same named file under some ES sub-folders.

The geography and time granularity of this profile is SUBGEOGRAPHY2 and DAYSLICE respectively i.e. the same as the balancing area and time of the EC. Thus this profile input allows electricity demand at any coarser granularity to be broken down to its balancing area and time granularity.

Suppose electricity demand for some ES in industry is computed at the SUBGEOGRAPHY1 and SEASON granularities. Then in order to break this coarser granularity demand into a finer granularity of SUBGEOGRAPHY2 and DAYSLICE, the GTProfile values shown in Figure 2 will be used as described below.

- Consider a particular combination of geography and time at the SUBGEOGRAPHY1 and SEASON granularities, say, <INDIA, NR>, <2023, SUMMER>.
- This <INDIA, NR>, <2023, SUMMER> combination corresponds to 4 combinations at the SUBGEOGRAPHY2 and DAYSLICE granularities viz.
    - <INDIA, NR, UP>, <2023, SUMMER, DAY>;
    - <INDIA, NR, UP>, <2023, SUMMER, NIGHT>;
    - <INDIA, NR, PB>, <2023, SUMMER, DAY>;
    - <INDIA, NR, PB>, <2023, SUMMER, NIGHT>
- The GTProfile values for these 4 combinations listed above are 0.147, 0.147, 0.0648, 0.0432 respectively (Sr. Nos. 1, 2, 5, 6 in Figure 2). The sum of these 4 values is 0.402.
- Hence the share of <INDIA, NR, UP>, <2023, SUMMER, DAY> in electricity demand computed for <INDIA, NR>, <2023, SUMMER> would be 0.147/(0.402 * 180). The number 180 in the denominator signifies the 180 number of days in SUMMER. Similarly, the shares of the other 3 combinations at the finer granularities listed above, in electricity demand computed for <INDIA, NR>, <2023, SUMMER> would be 0.147/(0.402 * 180), 0.0648/(0.402 * 180) and 0.0432/(0.402 * 180) respectively.
- This same mechanism would apply to all the other combinations of geography and time at the SUBGEOGRAPHY1 and SEASON granularities viz. <INDIA, NR>, <2023, WINTER>; <INDIA, SR>, <2023, SUMMER> and <INDIA, SR>, <2023, WINTER>. For WINTER, we would need to use the 185 number of days of that Season.

6 Demand estimation and Outputs

Based on the various input files described in the previous sections, the total energy demand for each combination of demand sector, energy service, service technology category + service technology (where applicable) and energy carrier is calculated at the consumer type, geographic and time unit granularities specified for the combination in the associated demand granularity map file (viz. DS_ES_EC_Map or DS_ES_STC_DemandGranularityMap for non-bottom-up and bottom-up energy services respectively). Note that energy demand for an EC is always computed in energy terms, in the energy units specified for that EC. Furthermore, energy demand is not calculated for any non-physical primary energy carrier.

In the next step, if any geography-time profile inputs have been provided for any ECs, these are appropriately used to convert the applicable EC demands computed at coarser granularities to finer granularities, as specified in the respective profile inputs. The various EC demands so obtained, after this step, are used to produce the various demand output files – described further in the table below.

In order to compute the demand output that can be used as an input to the supply module, one additional step is performed. For each EC, its various demands at each particular geography/time granularity combination are aggregated across all demand sectors, consumer types, energy services and service technologies (where applicable). Any EC demand computed at a geographic/time granularity finer than its balancing area/time, is aggregated up to its balancing area and balancing time. This aggregate demand is provided as an input to Rumi's supply module.

As described above, the demand component of Rumi estimates the energy demand projections for the model period at the required granularities. All the outputs are produced by default in a directory called `Demand/Output` under the root directory of the scenario that is specified, though this can be over-ridden by the user through a command line parameter (see the `README.md` file available in the root directory of the Rumi platform repository). Under the `Demand/Output` folder, there is a further sub-folder structure and the various demand outputs files are produced inside this sub-folder structure. This has been illustrated in the table below.

The following table provides a list of the files that are produced by the demand component and a brief description of the information they contain, as well as the specific sub-folder under the `Demand/Output` folder in which they are produced. Note that each indicated filename may represent many actual files, depending on the model set-up.

Filename	Description	Sub-folder under root
EndUseDemandEnergy.csv	For each energy carrier, its aggregate end-use demand (in energy terms, in the energy units of the EC) at possibly various applicable geographic and temporal granularities, that are no finer than its balancing geography/time. This is the file used by the supply module	`Demand/Output/`
<EC>_Demand.csv	The aggregate demand (in energy terms) of energy carrier <EC>, in its energy units, at the coarsest geographic and temporal granularities among all those computed for that EC across all applicable demand sectors, energy services, STCs and STs	`Demand/Output/EnergyCarrier/`

<DS>_<EC>_Demand.csv	The aggregate demand (in energy terms) of <EC> in its energy units for a particular demand sector <DS>, at the coarsest consumer type, geographic and temporal granularities among all those computed for that EC in that DS across all applicable energy services, STCs and STs	`Demand/Output/DemandSector/<DS>/`
<ES>_<EC>_Demand.csv	The aggregate demand (in energy terms) of <EC> in its energy units for a particular energy service <ES>, at the coarsest geographic and temporal granularities among all those computed for that ES, EC combination across all applicable demand sectors, STCs and STs	`Demand/Output/EnergyService/<ES>/`
<DS>_<ES>_<EC>_Demand.csv	The aggregate energy demand of <EC>, in its energy units, for <ES> in a demand sector <DS>, at the coarsest consumer type, geographic and temporal granularities among all those computed for that DS, ES, EC combination across all applicable STCs and STs	`Demand/Output/DemandSector/<DS>/<ES>/`
<DS>_<ES>_<ST>_<EC>_Demand.csv	The energy demand of <EC>, in its energy units, used by service technology <ST> to provide <ES> in <DS>, at the consumer type, geographic and temporal granularities computed for that DS, ES, ST, EC combination	`Demand/Output/DemandSector/<DS>/<ES>/`
<DS>_<EC>_ ES_ ST_Demand.csv	The energy demand of <EC> used in <DS> for providing some energy service that requires that <EC> - either directly or through the use of a service technology that uses <EC>, at the applicable consumer type, geographic and temporal granularities. Thus this file has columns for listing the EnergyService, ServiceTechCategory and ServiceTech – the latter two being blank where not applicable.	`Demand/Output/DemandSector/<DS>/`
TotalNumInstances_<ST>.csv	The number of instances of service technology <ST>, by each of its efficiency levels, in each demand sector at consumer type, geographic and temporal granularities that are the finest among the corresponding granularities used for the UsagePenetration, TechSplitRatio, EfficiencyLevelSplit and NumInstances parameters of that ST/ST category as well as those used for the NumConsumers parameter of the concerned demand sector	`Demand/Output/TotalNumInstances/`