GENeSYS-MOD - Input Data Guide

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Introduction

The following document provides additional information on the different parameters/sheets that need to be filled, in order to adapt the GENeSYS-MOD data files to the respective case-study.

In the following, you will find an overview of all Parameters, the ones that need to be adapted to ensure the model can be marked in red. These parameters include information specific to the regions used by the user and are therefore unique to the case study. Other parameters (e.g., capital cost) also need to be adapted for the case study, but the model can be used based on present data as long as all regional data is provided.

Sheets that do not need to be changed in the beginning but that are region-specific can be important when adapting the model runs to the specific needs of the case-study are marked in orange. In general, these Parameters have "world" data that will be used by the model unless the data for specific regions is provided.

For further information please also use the Technical Manual:
https://drive.google.com/drive/folders/1IPVzJs7gFc7eUe5uhHl6RdXrmP7Ky-bB

And also the main Folder with further information on the model:
https://drive.google.com/drive/folders/1NQN1wFiDozy7L8Vo1x_gK06aIjarRZQ3

Example Data files can be found:
https://drive.google.com/drive/folders/1BxtMvSjEi7tLABgAaZ8FFETP5zqdiN36

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Overview GENeSYS-MOD

GENeSYS-MOD is a cost-optimizing linear program, focusing on long-term pathways for the different sectors of the energy system, specifically targeting emission targets, integration of renewables, and sector-coupling. The model minimizes the objective function, which comprises total system costs (encompassing all costs occurring over the modeled time period).
(Final) Energy demands and weather time series are given exogenously for each modeled time slice, with the model computing the optimal flows of energy, and resulting needs for capacity additions and storages. Additional demands through sector-coupling are derived endogenously. Constraints, such as energy balances (ensuring all demand is met), maximum capacity additions (e.g. to limit the usable potential of renewables), RES feed-in (e.g. to ensure grid stability), emission budgets (given either yearly or as a total budget over the modeled horizon) are given to ensure proper functionality of the model and yield realistic results. The GENeSYS-MOD model version used in this paper uses the time clustering algorithm described in Gerbaulet and Lorenz [29] and Burandt et al. [13]. The years 2018-2050 are usually modeled in the following sequence: 2018, 2025, 2030, 2035, 2040, 2045, 2050. All input data is consistent with this time resolution, with all demand and feed-in data being given as full hourly time series. Since GENeSYS-MOD does not feature any stochastic features, all modeled time steps are known to the model at all times. There is no uncertainty about e.g. RES feed-in. The model allows for investment into all technologies and acts purely economical when computing the resulting pathways (while staying true to the given constraints). It usually assumes the role of a social planner with perfect foresight, optimizing the total welfare through cost minimization. All fiscal units are handled in 2018 terms (with amounts in other years being discounted towards the base year).

For more information, visit the GENeSYS-MOD GitHub page.

List of all Parameters in the input data file

Parameter	Explanation	Unit	
Sets	Set definition		1
Par_AnnualEmissionLimit	Limits the maximum amount of Emissions in a year.	Megatonnes	1
Par_AnnualExogenousEmission	Amount of external Emissions for a year in a certain region.	Megatonnes	1
Par_AnnualSectoralEmissionLimit	Limits the maximum amount of Emissions for a specific sector and region in a year.	Megatonnes	1
Par_AvailabilityFactor	Maximum time a technology may run for the whole year. Often used to simulate planned outages. GENeSYS-MOD will choose when to run or not run.	Fraction	1
Par_BaseYearProduction	Describes how much of a fuel has to be produced by specific technologies in the base year across all regions.	PJ	Not used
Par_BaseYearSlack	Slack for RegionalBaseyearproduction	Fraction	1
Par_CapacityFactor	Indicates the maximum time technology may run in a given time slice.	Fraction	Not used
Par_CapacityToActivityUnit	Converts capacity to activity. Here we use a factor of 31.536, which is the level of energy production in PJ produced from 1 GW operating for 1 year (1GW * 8760 * 3600 / 10^6)	PJ/GW-YR	1
Par_CapitalCost	Total capital cost (including interest paid during construction) per unit of capacity for new capacity additions	M€/GW	1
Par_CapitalCostStorage	Capital Cost of storages per energy content.	M€/PJ	1
Par_CommissionedTradeCapacity	Planned capacity	GW	1
Par_EmissionActivityRatio	Emissions factor per unit of activity.	Fraction	1
Par_EmissionContentPerFuel	Emission content per unit of energy per fuel.	Megatonnes/PJ	1
Par_EmissionPenaltyTagTech	Tags all technologies which produce emissions.	Binary	1
Par_EmissionsPenalty	Externality cost per unit of emission.	M€/Megatonnes	1
Par_FixedCost	The annual cost per unit of capacity of a technology.	M€/GW	1
Par_GeneralDiscountRate	Discount rate used in the model	Fraction	1
Par_GrowthRateTradeCapacity	Defines by how much the trade capacity between two regions can grow	Factor	1
Par_InputActivityRatio	The input (use) of fuel per unit of activity	Fraction	1

	for each technology. Describes, in combination with the OutputActivityRatio, the efficiency of the technology.		
Par_MinStorageCharge	Lower bound (fraction) of total storage capacity which always has to be charged.	Fraction	1
Par_ModalSplitByFuel	Describes the distribution of technologies within a specific modal type.	Fraction	1
Par_ModelPeriodActivityMaxLimit	Maximum total activity for the complete model period per region.	PJ	1
Par_ModelPeriodEmissionLimit	Total model period upper limit for a specific emission generated in the whole modelled region.	Megatonnes	1
Par_ModelPeriodExogenousEmission	Additional emissions over the entire modelled period, on top of those computed endogenously by the model.	Megatonnes	1
Par_OperationalLife	Operational lifespan of a process in years.	Years	1
Par_OperationalLifeStorage	Operational Life of Storages.	Years	1
Par_OutputActivityRatio	Ratio of output to activity. Describes, together with the InputActivityRatio, the efficiency of the technology.	Fraction	1
Par_ProductionChangeCost	Production change cost.	M€	1
Par_ProductionGrowthLimit	This parameter controls the maximal increase between two years of a specific fuel production from renewable energy sources.	Fraction	1
Par_RampingDownFactor	Ramping down factor.	*Fraction*	1
Par_RampingUpFactor	Ramping up factor.	Fraction	1
Par_RegionalAnnualEmissionLimit	Limits the maximum amount of Emissions for a certain region in a year.	Megatonnes	1
Par_RegionalBaseYearProduction	Describes how much of a fuel has to be produced by specific technologies in the base year per region.	PJ	1
Par_RegionalCCSLimit	Describes how much carbon can be stored per region.	Megatonnes	1
Par_RegionalModelPeriodEmissionLimit	Total model period upper limit for a specific emission generated in a certain modelled region.	Megatonnes	1
Par_REMinProductionTarget	Minimal production target for renewable energy sources	PJ	1
Par_ReserveMargin	The reserve (installed) capacity required relative to the peak demand.	Ratio	1
Par_ReserveMarginTagFuel	Indicates if the output fuel has a reserve margin associated with it	Binary	1

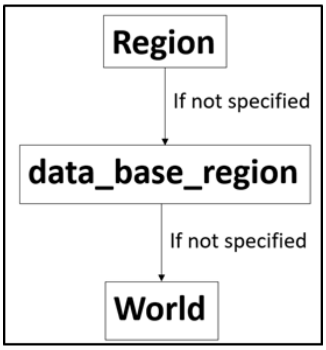
Par_ReserveMarginTagTechnology	Amount the technology contributes to the reserve margin 1=100% 0.2=20%.	Fraction	1
Par_ResidualCapacity	The capacity left over from periods prior to the modeling period.	GW	1
Par_ResidualStorageCapacity	Residual Storage Capacity.	PJ	1
Par_SelfSufficiency	Lower bound that limits the imports of fuels in a specific year and region	Fraction	1
Par_SocialDiscountRate	Social Discount rate	Fraction	1
Par_SpecifiedAnnualDemand	Total specified demand for a year.	PJ/Gtkm/Gpkm	1
Par_StorageLevelStart	Defines the level of storage at the beginning of a year.	PJ	1
Par_TagDemandFuelToSector	Assigns final demand fuels to the different sectors.	Binary	1
Par_TechnologyDiscountRate			1
Par_TagElectricTechnology	Indicates if a technology is considered to be "direct electrification".	Binary	1
Par_TagTechnologyToModalType	Tags technologies which belong to a certain modal type.	Binary	1
Par_TagTechnologyToSector	Assigns Technologies to the different sectors.	Binary	1
Par_TechnologyFromStorage	Connects Storaged to their respective dummy technologies and describes the efficiency of storage discharging	Fraction	1
Par_TechnologyToStorage	Connects Storaged to their respective dummy technologies and describes the efficiency of storage charging	Fraction	1
Par_TotalAnnualMaxActivity	Maximum total activity each year.	PJ	1
Par_TotalAnnualMaxCapacity	Maximum total (residual and new) capacity each year.	GW	1
Par_TotalAnnualMinActivity	Minimum total activity each year.	PJ	
Par_TotalAnnualMinCapacity	Minimum total (residual and new) capacity each year.	GW	1
Par_TradeCapacity	Defines the capacities for trade between two regions in a specific year and for a specific fuel.	GW for Power, PJ for Gas	1
Par_TradeCapacityGrowthCosts	Costs of expanding trade capacity.	M€/GW	1
Par_TradeCosts	Costs for trading a fuel from one region to another.	M€/PJ	1
Par_TradeRoute	Defines trade links between regions for specific fuels. If r is linked to rr, rr has also to be linked with r. Symmetrical matrix with	km	1

	diagonal of zeroes		
Par_TradeLossFactor	Percentage loss of traded fuel from one region to another. Used to model losses in power transmission networks.	Fraction	1
Par_VariableCost	Cost per unit of activity of the technology.	M€/PJ	1

General Information

Some general information to support the understanding of the model and its functionalities

Regions



The model's regions can be defined by the user (see section Sets). In addition to the user-defined regions and the "data_base_region" there is a "World" region. The model follows a hierarchy for how these regions are used for different parameters.
When regional data is provided by the user (e.g., region-specific demand), the model uses it. For some parameters, if data is only available for the data_base_region, the model applies it to all regions. If no regional or data_base_region data is provided, the model defaults to World data (when available). This is typically the case for parameters less dependent on region-specific variations, but users can override this with region-specific data if needed.
Below is an overview of parameters that are automatically filled using base_year_region or World data. These can be found in the genesysmod_dataload.jl file. Generally, region-specific data should be included in the model when applicable. If the data applies to all regions, data_base_region data can be used, and World data may come from previous studies but should be adjusted to regional values if necessary.
For the following parameters, the model defaults to World data if neither data_base_region nor regional data is provided. If only data_base_region data is available, it is used for the model runs. Regional data, if given, takes precedence.
AvailabilityFactor, InputActivityRatio, OutputActivityRatio, CapitalCost, FixedCost, VariableCost, EmissionActivityRatio, EmissionsPenalty, EmissionsPenaltyTagTechnology, CapacityFactor, ReserveMargin, ReserveMarginTagFuel, ReserveMarginTagTechnology, CapitalCostStorage

The following parameters are either region-specific (SpecifiedAnnualDemand) or include data that has no region dimension (eg. OperationalLife - Operational lifespan of a technology in years). For these parameters, no data_base_region or World value is taken into account.

CapacityToActivityUnit, RegionalBaseYearProduction, SpecifiedAnnualDemand, AnnualEmissionLimit, AnnualExogenousEmission, EmissionContentPerFuel, RegionalAnnualEmissionLimit, GrowthRateTradeCapacity, TradeCapacity, TradeRoute, TradeCapacityGrowthCosts, TradeCosts, ResidualCapacity, TotalAnnualMaxCapacity, TotalAnnualMinCapacity, TotalTechnologyAnnualActivityUpperLimit, TotalAnnualMaxActivity, TotalAnnualMinActivit, ModelPeriodActivityMaxLimit, OperationalLife, RegionalCCSLimit, OperationalLifeStorage, ResidualStorageCapacity, StorageLevelStart, TechnologyToStorage, TagTechnologyToSubsets, TechnologyFromStorage, ModalSplitByFuelAndModalType, TagDemandFuelToSector, TagElectricTechnology, TagTechnologyToModalType, TagTechnologyToSector

Explanation of Parameters

Sets

Region	Technology	Storage	Fuel	e_of_opera	Emission	ModalType	Sector	Year	Region2
World	A_Air	S_PHS	Area_Root	1	CO2	MT_PSNG_	Power	2018	World
	A_Rooftop_Commercial	S_Gas_H2	Area_Root	2		MT_PSNG_	Industry	2025	
	A_Rooftop_Residential	S_Battery_	Biomass	3		MT_PSNG_	Buildings	2030	
	CHP_Biomass_Solid	S_Battery_	Hardcoal	4		MT_PSNG_	Transport	2035	

There are multiple aspects in the Sets sheet that need to be filled in for the model to run. This is the key sheet to define all Regions, Technologies, Storages, Fuels, Mode of Operation, Emissions, ModalType, Sectors, and Years. This can all be changed to adapt the model to the user's needs.
Most information, however, can be kept and usually stays similar, the regions need to be defined as they are unique to each model application.

Region:

Define all Regions that should be part of the model by giving them an abbreviation. It is easy and convenient to use ISO codes, if applicable.
Lets use the 11 regions in Ethiopia as an example, a quick google search returns the following iso-codes:

Subdivision names are listed as in the ISO 3166-2 standard published by the ISO 3166 Maintenance Agency (ISO 3166/MA).

ISO 639-1 codes are used to represent subdivision names in the following administrative languages:

- (am): Amharic
- (en): English

Click on the button in the header to sort each column.

Code	Subdivision name (am) (BGN/PCGN 1967)	Subdivision name (am) [note 1]	Subdivision name (en)	Subdivision category
ET-AA	Ādīs Ābeba	አዲስ አበባ	Addis Ababa	administration
ET-AF	Āfar	ዓፋር	Afar	regional state
ET-AM	Āmara	አማራ	Amara	regional state
ET-BE	Bīnshangul Gumuz	ቤንሻንጉል ጉሙዝ	Benshangul-Gumaz	regional state
ET-DD	Dirē Dawa	ድሬዳዋ	Dire Dawa	administration
ET-GA	Gambēla Hizboch	ጋምቤላ ሕዝቦች	Gambela Peoples	regional state
ET-HA	Hārerī Hizb	ሐረሪ	Harari People	regional state
ET-OR	Oromīya	ኦሮሚያ	Oromia	regional state
ET-SI	Sīdama	ሲዳማ	Sidama	regional state
ET-SO	Sumalē	ሱማሌ	Somali	regional state
ET-TI	Tigray	ትግራይ	Tigrai	regional state
ET-SN	YeDebub Bihēroch Bihēreseboch na Hizboch	የደቡብ ብሔር ብሔረሰቦችና ሕዝቦች	Southern Nations, Nationalities and Peoples	regional state
ET-SW	YeDebub M'irab Ītyop'iya Hizboch	የደቡብ ምዕራብ ኢትዮጵያ ሕዝቦች	Southwest Ethiopia Peoples	regional state

2

We can use the code as our abbreviations to fill in all the regional states:

Region
World
ET-AF
ET-AM
ET-BE
...

It is important to keep the world region, as this provides generic data in many cases that can be used for the model runs.
If there are no predefined regional-codes, you can define them yourself!

Region2:
Region2 contains the same information as Region, it is a set that is needed for the model to enable trade between the regions. Simply fill in the info from the previous step.

Par_AnnualEmissionLimit

Limits the maximum amount of Emissions in a year. [Megatonnes]

Enables the user to set a maximum amount of emissions across all sectors for each model year. This can be used, for example, to gradually reduce emissions and reach a net-zero target in a specific year. https://carbonbudgetcalculator.com/ is a resource to generate different scenarios.

Par_AnnualExogenousEmission

Amount of external Emissions for a year in a certain region. [Megatonnes]

This parameter allows the user to add exogenous emissions to the model that would otherwise not be captured but are intended to be accounted for in the model setup. These can include emissions from, for example, cement production, international air travel, and agriculture.

Par_AnnualSectoralEmissionLimit

Limits the maximum amount of Emissions for a specific sector and region in a year. [Megatonnes]

This Parameter enables the user to set specific emission targets for each sector in the different regions per year. This allows for a more precise control over sectoral emissions and the impact this could have on model results.

Par_AvailabilityFactor

Maximum time a technology may run for the whole year. Often used to simulate planned outages. GENeSYS-MOD will choose when to run or not run. [Fraction]

Caps the maximum time a technology may run for the whole year. This can also be used to “turn-off” technologies if they are not to be used by the mode by setting their AvailabilityFactor to zero.

Par_BaseYearProduction

Describes how much of a fuel has to be produced by specific technologies in the base year across

all regions. [PJ]
→ Currently not used

Par_BaseYearSlack

Slack for RegionalBaseyearproduction [Fraction]

Defines by how much the regional base year production can vary from its value given in Par_RegionalBaseYearProduction.

Par_CapacityFactor

Indicates the maximum time technology may run in a given time slice. [Fraction]
→ Not used, defined in model

Par_CapacityToActivityUnit

Converts capacity to activity. [PJ/GW-YR]

For this parameter we use a factor of 31.536, which is the level of energy production in PJ produced from 1 GW operating for 1 year (1GW * 8760 * 3600 / 10^6). If non-energetic, the value is 1.

Par_CapitalCost

Total capital cost (including interest paid during construction) per unit of capacity for new capacity additions. [M€/GW]

The capital costs are provided for each region, technology, and year, allowing the user to account for changes over time due to technological improvements.

Par_CapitalCostStorage

Capital Cost of storages per energy content. [M€/PJ]
The capital costs for storages are provided per region, technology, and year, allowing for the consideration of changes over time due to technological improvements. Compared to the CapitalCost, this parameter is given in M€/PJ, as for storage technologies the amount of energy that can be stored is specified, not the power capacity in GW.

Par_CommissionedTradeCapacity

Planned capacity. [GW]
Commissioned trade capacity will be built by the model; however, other than residual capacity, all costs are accounted for. This feature can primarily be used to implement policy plans and other planned capacity.

Par_EmissionActivityRatio

Emissions factor per unit of activity. [Fraction]
The value is typically 1, representing full emissions, but it can vary for carbon capture and storage (CCS) technologies, as not all emissions are released into the atmosphere. In some cases, the value

can even be negative—such as with direct air capture (DAC) or bioenergy with carbon capture and storage (BECCS)—indicating net removal of CO_2.

Par_EmissionContentPerFuel

Emission content per unit of energy per fuel. [Megatonnes/PJ]
It allows the model to translate fuel consumption into associated emissions by multiplying it with the fuel input used in technologies. For example, hard coal has a value of 0.0939 Mt/PJ, meaning burning 1 PJ of hard coal emits 0.0939 Mt of CO_2.

Par_EmissionPenaltyTagTech

Tags all technologies which produce emissions. [Binary]
Par_emissionpenaltyttagtech is a binary parameter that tags technologies which produce emissions (e.g., CO_2). A value of 1 indicates the technology emits and may be subject to penalties or carbon pricing.

Par_EmissionsPenalty

Externality cost per unit of emission. [M€/Megatonnes]
This represents the carbon price and can be used instead of an emissions target to explore how different carbon prices influence scenario outcomes.

Par_FixedCost

The annual cost per unit of capacity of a technology. [M€/GW]
Represents the annual fixed cost associated with maintaining and operating one gigawatt (GW) of installed capacity for a given technology. It is measured in million euros per gigawatt per year (M€/GW) and includes costs that do not vary with output, such as maintenance, insurance, and administrative expenses.

Par_GeneralDiscountRate

Discount rate used in the model. [Fraction]
All fiscal units are handled in 2018 (or base year if different from 2018) terms (with amounts in other years being discounted towards the base year). The general discount rate used is 5%.

Par_GrowthRateTradeCapacity

Defines by how much the trade capacity between two regions can grow. [Factor]
Par_GrowthRateTradeCapacity defines the maximum rate at which trade capacity between two regions can grow each year, expressed as a factor of the previous year's total capacity, thereby limiting how much new capacity can be added annually. So, if the growth rate is 0.1 (10%), and the capacity last year was 100 MW, then at most 10 MW of new capacity can be added this year.

Par_InputActivityRatio

The input (use) of fuel per unit of activity for each technology. Describes, in combination with the OutputActivityRatio, the efficiency of the technology. [Fraction]
Let's take an example of a Power producing technology P_Gas_CCGT. The table below shows the

Fuels the technology can use, these correspond to the mode_of_operation. For each of the fuel, the InputActivityRatio is specified which is the amount of Gas that is needed to produce one unit of output. The efficiency therefore is 1/InputActivityRatio (see right column). The value can change over the years if an efficiency increase (or decrease) is expected.

PAR_InputActivityRatio

Region	Technology	Fuel	Mode_of_operation	Year	Value	Efficiency in %
World	P_Gas_CCGT	Gas_Natural	1	2018	1.724138	58%
World	P_Gas_CCGT	Gas_Bio	2	2018	1.724138	58%
World	P_Gas_CCGT	Gas_Synth	3	2018	1.724138	58%
World	P_Gas_CCGT	Gas_Natural	1	2025	1.639344	61%
World	P_Gas_CCGT	Gas_Bio	2	2025	1.639344	61%
World	P_Gas_CCGT	Gas_Synth	3	2025	1.639344	61%
World	P_Gas_CCGT	Gas_Natural	1	2030	1.612903	62%
World	P_Gas_CCGT	Gas_Bio	2	2030	1.612903	62%
World	P_Gas_CCGT	Gas_Synth	3	2030	1.612903	62%
World	P_Gas_CCGT	Gas_Natural	1	2035	1.612903	62%
World	P_Gas_CCGT	Gas_Bio	2	2035	1.612903	62%
World	P_Gas_CCGT	Gas_Synth	3	2035	1.612903	62%
World	P_Gas_CCGT	Gas_Natural	1	2040	1.612903	62%
World	P_Gas_CCGT	Gas_Bio	2	2040	1.612903	62%
World	P_Gas_CCGT	Gas_Synth	3	2040	1.612903	62%
World	P_Gas_CCGT	Gas_Natural	1	2045	1.6	63%
World	P_Gas_CCGT	Gas_Bio	2	2045	1.6	63%
World	P_Gas_CCGT	Gas_Synth	3	2045	1.6	63%
World	P_Gas_CCGT	Gas_Natural	1	2050	1.587302	63%
World	P_Gas_CCGT	Gas_Bio	2	2050	1.587302	63%
World	P_Gas_CCGT	Gas_Synth	3	2050	1.587302	63%

We then go into the Par_OutputActivityRatio. There we can see that for each of the mode_of_operations, the output is exactly 1 unit of power.

PAR_OutputActivityRatio

Regio	Technology	Fuel	Mode_of_operation	Year	Valu
World	P_Gas_CCGT	Power	1	2018	1
World	P_Gas_CCGT	Power	2	2018	1
World	P_Gas_CCGT	Power	3	2018	1
World	P_Gas_CCGT	Power	1	2025	1
World	P_Gas_CCGT	Power	2	2025	1
World	P_Gas_CCGT	Power	3	2025	1
World	P_Gas_CCGT	Power	1	2030	1
World	P_Gas_CCGT	Power	2	2030	1
World	P_Gas_CCGT	Power	3	2030	1
World	P_Gas_CCGT	Power	1	2035	1
World	P_Gas_CCGT	Power	2	2035	1
World	P_Gas_CCGT	Power	3	2035	1
World	P_Gas_CCGT	Power	1	2040	1
World	P_Gas_CCGT	Power	2	2040	1
World	P_Gas_CCGT	Power	3	2040	1
World	P_Gas_CCGT	Power	1	2045	1
World	P_Gas_CCGT	Power	2	2045	1
World	P_Gas_CCGT	Power	3	2045	1
World	P_Gas_CCGT	Power	1	2050	1
World	P_Gas_CCGT	Power	2	2050	1
World	P_Gas_CCGT	Power	3	2050	1

CHPs make up a special case as they can produce power and heat simultaneously in one mode of operation.

Example:

Par_InputActivityRatio

Region	Technology	Fuel	Mode_of_operation	Year	Value
World	CHP_Biomass_Solid	Biomass	1	2018	2.89017341
World	CHP_Biomass_Solid	Biomass	2	2018	3.571428571

For CHP_Biomass_Solid the value for the year 2018 is 2.890173 for the fuel Biomass in Mode_of_operation 1. This means the efficiency is 1 / 2.890173 = 0.346 so around 34.6%. If we want to know what Mode_of_operation 1 means, we can look it up in the Par_OutputActivityRatio**.**

Par_OutputActivityRatio

Region	Technology	Fuel	Mode_of_operati	Year	Value
World	CHP_Biomass_Solid	Power	1	2018	1
World	CHP_Biomass_Solid	Power	2	2018	1
World	CHP_Biomass_Solid	Heat_District	2	2018	2.568

Meaning that we produce one unit of power from the 2.890173 Units of Biomass we put in.

For mode of operation 2, we find the following InputActivityRatio 3.571428572. The technology produces 1 Unit of power and 2.568 Units of Heat_District from the 3.571428572 Units of Biomass (OutputActivityRatio). The model can decide which mode_of_operation to use. Total CHP System Efficiency would equate to (Power Output+Heat Output)/Input=(1+2.568)/3.571428571 = 0.999 or around 99%. The fact that the excess heat is used greatly improves the efficiency of the technology.

Par_MinStorageCharge

Lower bound (fraction) of total storage capacity which always has to be charged. [Fraction]
Par_MinStorageCharge defines the minimum fraction of total storage capacity that must remain charged at all times. It is applied as a lower bound on the storage level at the start of each time slice, ensuring that storage units are not completely depleted. This fraction is calculated based on the sum of newly installed and still-operational residual storage capacity. The parameter helps reflect technical constraints or policy requirements that require a certain minimum level of stored energy to always be available.

Par_ModalSplitByFuel

Describes the distribution of technologies within a specific modal type. [Fraction]
This parameter defines the distribution of technologies across different modal types. There are two fuels: Passenger Transport and Freight Transport, each with a specified annual demand. Both fuel categories have different technologies (ModalTypes) that can meet this demand. The **ModalSplitByFuel** parameter defines the minimum share of each technology.
Example: For the fuel **Mobility Passenger**, there are three main Modal Types (MT_PSNG_ROAD, MT_PSNG_RAIL, MT_PSNG_AIR), meaning that passenger transport can be carried out via road, rail, or air. The values indicate that 91.3% of Passenger Transport in 2018 was done via Road (e.g., cars), 7.6% via Rail, and 1% via Air transport. The total for 2018 is 100%, meaning the model has no remaining capacity to allocate any additional shares.

Regio	Fuel	ModalType	Year	Value
Test	Mobility_Passenger	2018	MT_PSNG_ROAD	0.913732
Test	Mobility_Passenger	2018	MT_PSNG_RAIL	0.076184
Test	Mobility_Passenger	2018	MT_PSNG_AIR	0.010084

For the three main Modal Types, there are also subtypes that can be defined by the user. For **MT_PSNG_RAIL**, for example, there are two Modal Types: **CONV** (Conventional - Fossil Fuel) and **RE** (Renewable - Power). These subtypes contribute 6.47% and 1.09%, respectively, to make up **MT_PSNG_RAIL** (7.6%), leaving a small margin for the model to decide which one to use.

1	Regio	Fuel	ModalType	Year	Value
55	Test	Mobility_Passenger	2018	MT_PSNG_ROAD_CONV	0.891814
62	Test	Mobility_Passenger	2018	MT_PSNG_ROAD	0.913732
69	Test	Mobility_Passenger	2018	MT_PSNG_RAIL_RE	0.064756
82	Test	Mobility_Passenger	2018	MT_PSNG_RAIL_CONV	0.010968
94	Test	Mobility_Passenger	2018	MT_PSNG_RAIL	0.076184
99	Test	Mobility_Passenger	2018	MT_PSNG_AIR_CONV	0.010084
104	Test	Mobility_Passenger	2018	MT_PSNG_AIR	0.010084

As the years progress, the model is typically given more flexibility in selecting the technologies used. The **ModalSplitByFuel** parameter then establishes a lower limit for the share that a technology must maintain. In our example, the total share is at 92% in 2030, meaning the remaining 8% can be allocated by the model. This parameter allows the model to incorporate political plans or scenarios (e.g., 30% BEV by 2035 for passenger transport).

1	Regio	Fuel	ModalType	Year	Value
57	Test	Mobility_Passenger	2030	MT_PSNG_ROAD	0.845518
64	Test	Mobility_Passenger	2030	MT_PSNG_RAIL	0.072907
71	Test	Mobility_Passenger	2030	MT_PSNG_AIR	0.009908

The principle of this example applies to all Fuels and Modal Types for **ModalSplitByFuel**. In general, this data serves as a guide for the model, and the user can decide how much flexibility to allow the model, considering that everything beyond the base year is based on assumptions.

Overview of ModalTypes and Technologies from Parameter Par_TagTechnologyToModalType

Note!The number in () denotes the mode of operation, if different from 1, see Par_InputActivityRatio for more information on the mode of operation.

Mobility Freight					
ROAD		RAIL		SHIP	
ROAD_CONV	ROAD_RE	RAIL_CONV	RAIL_RE	SHIP_CONV	SHIP_RE
FRT_Road_ICE	FRT_Road_BEV	FRT_Rail_Conv	FRT_Rail_Electric	FRT_Ship_Conv	FRT_Ship_Bio
FRT_Road_PHEV	FRT_Road_H2		FRT_Rail_Conv(2)	FRT_Ship_LNG	FRT_Ship_Conv(2)
FRT_Road_LNG	FRT_Road_OH		FRT_Rail_Conv(3)		FRT_Ship_LNG
	FRT_Road_LNG				
	FRT_Road_ICE(2)				
	FRT_Road_PHEV(2)				
	FRT_Road_ICE(3)				

FRT_Road_PHEV(3)

Mobility Passenger					
ROAD		RAIL		AIR	
ROAD_CONV	ROAD_RE	RAIL_CONV	RAIL_RE	AIR_CONV	AIR_RE
PSNG_Road_ICE	PSNG_Road_BEV	PSNG_Air_Conv	PSNG_Rail_Electric	PSNG_Air_Conv	PSNG_Air_Bio
PSNG_Road_PHEV	PSNG_Road_H2	PSNG_Rail_Conv	PSNG_Rail_Conv(2)	PSNG_Air_Conv(2)	PSNG_Air_H2
PSNG_Road_LNG	PSNG_Road_LNG		PSNG_Rail_Conv(3)		
	PSNG_Road_ICE(2)				
	PSNG_Road_PHEV(2)				
	PSNG_Road_ICE(3)				
	PSNG_Road_PHEV(3)				

Some general points:

- To find all technologies linked to the ModelTypes, check the Parameter
- Ship usually accounts for all transport done on water within a country
- Air usually accounts for all inland flights

Par_ModelPeriodActivityMaxLimit

Maximum total activity for the complete model period per region.[PJ]

This parameter defines the maximum values for Resource Technologies (e.g., R_Coal_Hardcoal, R_Gas, etc.), which represent the extraction of resources. It indicates the maximum potential of a resource in a specific region, essentially reflecting the reserves that can potentially be accessed.

To calculate this, one might take the resource reserves and multiply them by the energy content specific to the fuel to get the value in PJ as required for GENeSYS-MOD.

A potential source for 2018 could be:
https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

Par_ModelPeriodEmissionLimit

Total model period upper limit for a specific emission generated in the whole modelled region. [Megatonnes]

Par_ModelPeriodEmissionLimit sets a maximum allowed amount of a specific emission (in megatonnes) across all regions over the entire model period, ensuring total emissions stay within a defined global limit.

Par_ModelPeriodExogenousEmission

Additional emissions over the entire modelled period, on top of those computed endogenously by the model. [Megatonnes]

Par_ModelPeriodExogenousEmission defines the total amount of external (exogenous) emissions—such as from cement, agriculture, or international travel—that are not captured by the modeled technologies but must still be included in the overall emission accounting for the model period. These emissions are added to the model's total emissions and count against the Par_ModelPeriodEmissionLimit.

Par_OperationalLife

Operational lifespan of a process in years. [Years]
Par_OperationalLife defines the number of years a technology remains operational after installation. It determines how long newly installed capacity contributes to the system before it retires.

Par_OperationalLifeStorage

Operational Life of Storages. [Years]
Par_OperationalLife defines the number of years storages remain operational after installation. It determines how long newly installed capacity contributes to the system before it retires.

Par_OutputActivityRatio

Ratio of output to activity. Describes, together with the InputActivityRatio, the efficiency of the technology [Fraction]
See Par_InputActivityRatio for further information

Par_ProductionChangeCost

Production change cost. [M€]
Cost associated with increasing or decreasing the output of a dispatchable technology within a year, measured in million euros (M€). It reflects operational costs like fuel ramping penalties, wear and tear, or market balancing charges.

For example, if CHP_Coal_Hardcoal has a value of 13.8889 M€, and its production ramps up or down by 1 PJ across timeslices, the model will assign 13.8889 M€ in ramping cost for that change.

Par_ProductionGrowthLimit

This parameter controls the maximal increase between two years of a specific fuel production from renewable energy sources. [Fraction]
Par_ProductionGrowthLimit defines the maximum allowed annual increase in the production of a specific fuel from renewable energy technologies, expressed as a fraction of the previous year's production, to ensure a gradual and realistic scale-up.

Par_RampingDownFactor

Ramping down factor. [Fraction]
Limits the rate at which a dispatchable technology can decrease its output during a given timeslice, in this case, per hour. It is a unitless factor that represents a fraction of the technology's available capacity.

This factor ensures that the model reflects the physical constraints of power plants, which typically cannot abruptly reduce their output due to operational limits like thermal inertia.

Example: For a coal plant with a ramping down factor of 0.02, the maximum reduction in output allowed per hour is 2% of the plant's available capacity. This prevents rapid shutdowns, ensuring that power plants follow a more gradual decrease in output over time.

Par_RampingUpFactor

Ramping up factor. [Fraction]
Same as Par_RampingDownFactor, but for increasing output.

Par_RegionalAnnualEmissionLimit

Limits the maximum amount of Emissions for a certain region in a year. [Megatonnes]
Par_RegionalAnnualEmissionLimit sets an upper limit on the amount of a specific emission (in megatonnes) that can be released in a given region during a single year, helping enforce regional environmental or regulatory targets.

Par_RegionalBaseYearProduction

Describes how much of a fuel has to be produced by specific technologies in the base year per region.[PJ]
Based on historical data, helps to calibrate the model in the base year primarily for the power sector **but should also be applied to the heating sector to allow for the model to build capacity based on this information!** In the base year, the model will generate the exact amount of power given for each region and technology, using existing capacities only, as it cannot build new ones to ensure accurate historical representation. Therefore, it's crucial to provide sufficient residual capacities to match the regional production of the base year (for heat, the technology can be built endogenously by doing a model run). To allow for some flexibility, the model can vary production within a set range, given via the Parameter **BaseYearSlack** (Fraction).

Par_RegionalCCSLimit

Describes how much carbon can be stored per region. [Megatonnes]
Par_RegionalCCSLimit sets the maximum amount of CO_2 that can be stored via carbon capture and storage technologies in a given region over the entire model period, ensuring storage remains within regional capacity limits.

Par_RegionalModelPeriodEmissionLimit

Total model period upper limit for a specific emission generated in a certain modelled region. [Megatonnes]
Par_RegionalModelPeriodEmissionLimit sets an upper limit, in megatonnes, on the total amount of a

specific emission that can be released in a particular region over the entire model period, ensuring long-term regional emission targets are met.

Par_REMinProductionTarget

Minimal production target for renewable energy sources. [PJ]
Par_REMinProductionTarget defines the minimum amount of energy (in PJ) that must be produced from renewable sources for a specific fuel in a given region and year, ensuring that the modeled energy system meets predefined renewable production targets.

Par_ReserveMargin

The reserve (installed) capacity required relative to the peak demand. [Ratio]
Specifies the required ratio of reserve capacity relative to peak demand, ensuring that the system has enough extra capacity to maintain reliability during high-demand periods or unexpected outages.

Par_ReserveMarginTagFuel

Indicates if the output fuel has a reserve margin associated with it. [Binary]
A binary indicator that defines whether a specific fuel type should be included in the calculation of demand requiring reserve capacity.

Par_ReserveMarginTagTechnology

Amount the technology contributes to the reserve margin 1=100% 0.2=20%. [Fraction]
Indicates the fraction of a technology's capacity that can contribute to the reserve margin, reflecting its suitability for reliably providing backup capacity.

Par_ResidualCapacity

The capacity left over from periods prior to the modeling period.[GW]

Residual Capacity is the existing capacity that the model can utilize. It essentially represents the current capabilities/capacities of the region under consideration. It is important to take into account the lifespan of the technologies and/or any planned decommissions.

For Transport there is usually no data, as this will be done by running the model once and allowing the model to build new capacities based on the modal split. For heating, it is done in a similar way, by using the information from the RegionalBaseYearProduction. Please see the running guide on how to let the model built capacities for the baseyear.

Example: A coal power plant of 2MW that will be decommissioned in 2030 will be available for the model in the base year 2018 and in 2025. In 2030, however, the model would need to build new capacities (including capital costs etc.).

	A	B	C	D	E	F
1	**Region**	**Technology**	**Year**	**Value**		Unit
2	SA-MP	P_Coal_Hardcoal	2020	2		GW
3	SA-MP	P_Coal_Hardcoal	2025	2		GW
4	SA-MP	P_Coal_Hardcoal	2030	0		GW

Residual Capacity for Heating and Transport

The capacities for the heating and transport sectors in the baseyear are generated by the model based on information from the modal split and the *RegionalBaseYearProduction*. The main issue with this approach is that all capacities are assumed to be built in 2018. The model then applies the OperationLife to these capacities, which would lead to a large number of technologies being decommissioned simultaneously at the end of their lifespan. This results in an unrealistic, abrupt drop in capacity.

In reality, technologies such as cars are decommissioned gradually over time. **To better reflect this in the model, we convert the capacity built in 2018 from the results into *ResidualCapacity*. This is done by taking the built capacities from the results file and entering them into *Par_ResidualCapacity*. To make this more realistic, we then reduce the residual capacity incrementally in each model period. This ensures that, for example, by 2025 a portion of the capacity must be replaced, mimicking the continuous turnover observed in the real world. It is important that baseyearbounds=1 is active (particularly for heat) as we want the capacity to correspond with the demand for production in the base year.**

Example:

The model builds the technology **PSNG_Road_ICE** in a specific region, with a total capacity of 100. This technology has an *OperationLife* of 20 years. If the model builds this capacity in 2018, it will all be decommissioned at once by 2040, resulting in an unrealistic, sudden drop in capacity. In reality, many of the cars currently in use will be decommissioned much earlier.

To address this, we use the model's built capacity as the basis for our *ResidualCapacity* in 2018. However, we apply a gradual reduction over time to better reflect real-world decommissioning. Specifically:

- In 2025, we reduce the residual capacity to 90% of the original 2018 value.
- By 2030, it will be reduced to 60% of the original capacity.
- In 2035, only 30% of the original capacity remains.
- After 2035, no residual capacity remains.

Technology	Year	Value		Unit	Source
PSNG_Road_ICE	2018	100		GW	Calibrated from model run - Assumption
PSNG_Road_ICE	2025	90		GW	Calibrated from model run - Assumption
PSNG_Road_ICE	2030	60		GW	Calibrated from model run - Assumption
PSNG_Road_ICE	2035	30		GW	Calibrated from model run - Assumption
PSNG_Road_ICE	2040	0		GW	Calibrated from model run - Assumption

This can be repeated for all technologies in the Transport & Industry sector taking into account their Par_OperatinalLife. If the lifespan is longer, the reduction on technologies each year also needs to be adjusted.

This approach ensures that the model must replace decommissioned capacity in each model period, creating a more realistic trajectory. Where available, census or other national data can be used to refine these assumptions and improve accuracy.

Par_ResidualStorageCapacity

The capacity left over from periods prior to the modeling period. [GW]
Par_ResidualStorageCapacity defines the amount of existing storage capacity (in GW) available at the start of the modeling period, originating from installations made before the model's first year.

Par_SelfSufficiency

Lower bound that limits the imports of fuels in a specific year and region. [Fraction]
Par_SelfSufficiency sets a lower bound on the share of domestic fuel production in a given region and year, limiting the extent to which fuels can be imported by requiring that a minimum fraction of total fuel supply be produced locally.

Par_SocialDiscountRate

Social Discount rate. [Fraction]
See Par_GeneralDiscountRate

Par_SpecifiedAnnualDemand

Total specified demand for a year.[PJ/Gtkm/Gpkm]

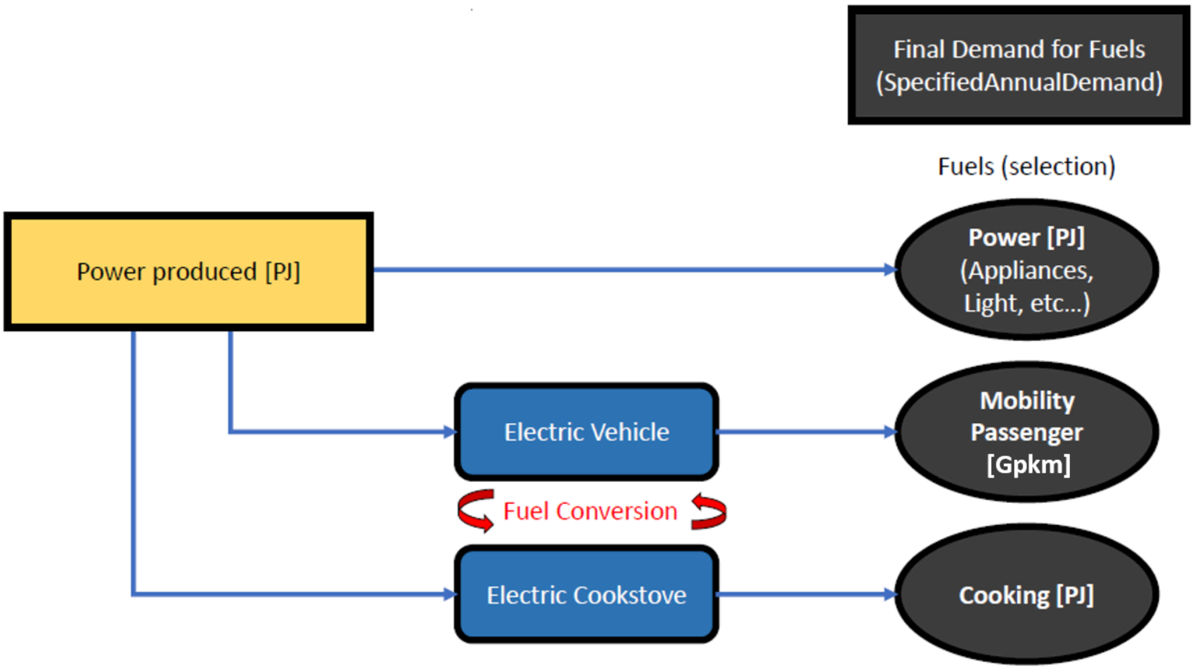
GENeSYS-MOD models the **Specified Annual Demand** for all fuels and regions from the base year to the final year, covering electricity, heat, and mobility. Base year data typically comes from statistical sources, while future development is guided by scenario assumptions. The model then endogenously determines the technologies required to meet demand, ensuring a comprehensive energy system representation.

Final energy consumption is categorized into three main groups: **electricity, heat, and mobility (If Cooking is added as fuel in the model it will also have to have a SpecifiedAnnualDemand)**. The heat sector is further divided into **low-temperature heat** (for water and space heating/cooling) and **process heat** (above 100°C). The mobility sector distinguishes between **passenger transport**, measured in billion passenger-kilometres (**Gpkm**), and **freight transport**, measured in billion tonnes-kilometres (**Gtkm**). All other energy data, including power and heat, is expressed in **Petajoules (PJ)**.

The total industrial heat demand is divided in Heat_Low_Industrial (<100 degrees), Heat_Medium_Industrial (100-1000 degrees) and Heat_High_Industrial (>1000 degrees).

The specified annual demand data in GENeSYS-MOD represents the final demand for different fuels, meaning that the fuel will no longer undergo further conversion. Specifically, "Power demand" in specified annual demand refers to the actual use of power in applications such as appliances, lighting, and various operations. Power used in the Transport Sector, however, is classified differently:

it appears as a demand for either "Mobility Passenger" or "Mobility Freight," depending on the context, rather than as a power demand. For example, for electric vehicles that require power, the demand will show-up in the fuel mobility_passenger (Gpkm) as power will be used to produce the fuel mobility_passenger (conversion of fuel power to fuel Mobility Passenger). Figure 1 aims to visualize this concept



To ensure accuracy, data from official sources must be analyzed to exclude transport-related power consumption from the actual power demand in GENeSYS-MOD. Instead, such data should be recorded under mobility demand in units of Gpkm (billion passenger kilometres) or Gtkm (billion ton kilometres), rather than PJ (petajoules). The same concept applied to all other fuels.

This setup supports sector coupling, allowing the model to select technologies and fuels to best meet the final fuel demands. For the Base Year, regional production data is used to realistically represent the existing energy landscape in the base year.

Par_StorageLevelStart

Defines the level of storage at the beginning of a year. [PJ]
→ Currently not used

Par_TagDemandFuelToSector

Assigns final demand fuels to the different sectors. [Binary]
This binary parameter assigns final demand fuels (e.g., electricity, heat, gasoline) to specific sectors such as transport, industry, or buildings. A value of 1 links the fuel to the sector, allowing sector-specific demand tracking and policy application.

Par_TechnologyDiscountRate

→ Currently not used

Par_TagElectricTechnology

Indicates if a technology is considered to be "direct electrification". [Binary]
A binary indicator that marks whether a technology qualifies as direct electrification (e.g., electric vehicles or electric heating). A value of 1 allows the model to identify and group technologies that directly consume electricity, often for electrification targets or analysis.

Par_TagTechnologyToModalType

Tags technologies which belong to a certain modal type. [Binary]
This binary parameter tags each technology as belonging to a specific modal type (e.g., road, rail, shipping). A value of 1 indicates the technology is part of that mode, allowing the model to group and apply constraints or policies (such as efficiency targets or mode-specific emissions) to all technologies within that type.

Par_TagTechnologyToSector

Assigns Technologies to the different sectors. [Binary]
This binary parameter assigns each technology to a particular sector (e.g., transport, industry, residential). A value of 1 indicates inclusion in that sector, enabling sector-based aggregation, analysis, and application of sector-specific targets or limits.

Par_TechnologyFromStorage

Connects Storaged to their respective dummy technologies and describes the efficiency of storage discharging. [Fraction]
This fractional parameter connects storage technologies to their associated discharge dummy technologies, specifying the efficiency of discharging energy from storage. For example, a value of 0.9 means 90% of stored energy is delivered when discharged.

Par_TechnologyToStorage

Connects Storaged to their respective dummy technologies and describes the efficiency of storage charging. [Fraction]
This fractional parameter links storage technologies to their charging dummy technologies, defining the efficiency of storing energy. A value of 0.85 means only 85% of input energy is successfully stored, with the rest lost in the charging process.

Par_TotalAnnualMaxActivity

Maximum total activity each year. [PJ]
This Parameter is similar to the Parameter TotalAnnualMaxCapacity but is mainly used for Biomass. Biomass potentials are given in PJ, representing the maximum availability each year, effectively creating an upper limit. This is not the demand in Biomass, but the maximal amount available each year.

Par_TotalAnnualMaxCapacity

Maximum total (residual and new) capacity each year.[GW]
Total Annual max capacity represents the maximum amount of capacity that can be built in a region.

This is the upper limit for a technology and could be constrained in reality by, for example, available land in the case of wind onshore or solar pv. It is usually the same value each year as this upper limit does not change.

This parameter can also be used to constrain capacity when necessary, ensuring that the model's early years remain within specific limits. For instance, if political plans require that capacity does not exceed a certain threshold in a given year (e.g., 2025), this parameter can be applied to restrict capacity expansion accordingly. However, users should apply this constraint cautiously, as it may prevent the model from selecting the most cost-effective solutions. It should only be used when necessary to enhance the model's realism.

Par_TotalAnnualMinCapacity

Minimum total (residual and new) capacity each year. [GW]
Using the Parameter TotalAnnualMinCapacity, the minimum total capacity (**residual and new capacity!**) each year can be specified. This can be used to implement policy plans and include commissioned capacity.

Par_TradeCapacity

Defines the capacities for trade between two regions in a specific year and for a specific fuel.[GW/PJ]
Trade capacities for power are given in GW and trade capacity for Gas, H2 etc. are given in PJ. They are defined for each year and represent the currently available trade capacities and take into account their expected life-time. The model is able to build new trade capacities if it needs to, taking into account the associated costs.

Par_TradeCapacityGrowthCosts

Costs of expanding trade capacity. [M€/GW]
Par_TradeCapacityGrowthCosts defines the cost, in million euros per gigawatt (M€/GW), of expanding trade capacity (e.g., transmission lines) between regions, and is used to account for investment costs in cross-regional infrastructure.

Par_TradeCosts

Costs for trading a fuel from one region to another.[M€/PJ]
Specifies the costs for trading a fuel between two different regions in M€ per PJ. To generate the trade costs, the distance of TradeRoute is multiplied with the costs of Transporting a fuel in M€/PJ per km.

Assumptions must be made regarding the most common mode of transport for a given fuel between two countries, e.g., by ship, pipeline, or road. For the selected mode of transport, the trade costs in M€/PJ per km need to be calculated

Let’s calculate the costs for LH2 transport by truck per km as an example:
The following table is taken from [Technology Data for Transport of Energy](#):

Fluid	Loading/ unloading hours, 2020/2030/2050	Reference	FixedCost €/t	Variable Cost €/(t*km)	Total 30 km €/t	Total 100 km €/t
LH2	5/4/3	*	37	1.1	71	149
CH2	4.25/4/3	**	132	2.6	211	396
NH3	3/2.5/2	***	4.5	0.13	8	17
DME	/2.5/2/2	****	3.7	0.12	7	16
Toluene	/2.5/1.5/1.5	****	2.1	0.08	5	10

To get a simplified value in M€/(PJ*km), we need the average transport distance for LH2. We get this value by adding up all the transport distances in Par_TradeRoute and dividing them by the total number of trade routes. For this example, we use the value for Europe: 528.82 km.

We further need to convert tons of LH2 into PJ. After a quick search, we find the energy density of LH2 to be 33.3 kWh/kg, which is equivalent to 0.00011988 PJ/t.

From the table, we take the fixed and variable costs:

37 €/t (=0.000037 M€/t)

1.1 €/(t*km) (=0.0000011 M€/(t*km))

Now, we can calculate the trade costs in M€/(PJ*km):

((Fixed Cost/average trade distance) + Variable Cost) * 1/energy density
= ((0.000037 M€/t)/528.82 km + 0.0000011 M€/(t*km)) * 1/(0.00011988 PJ/t)
= 0.009759485 M€/(PJ*km)

The trade costs are now determined by multiplying this factor with the trade distance between two regions.

For fuels that are primarily transported via pipeline, such as natural gas, the cost of constructing new pipelines is accounted for under TradeCapacityGrowthCosts. As a result, construction costs should not be factored in again for these fuels, only the O&M costs.

Par_TradeRoute

Defines trade links between regions for specific fuels. If r is linked to rr, rr has also to be linked with r. [km]
The trade route is defined by taking the distance (in km) from the centre point of one region to another. In general, there can only be connections between regions that are directly connected to each other. The flow always goes from Region to Region2 or from r to rr. This means that a connection between two regions needs to be defined both ways (Region1 -> Region2 & Region2 -> Region 1)

Par_TradeLossFactor

Percentage loss of traded fuel from one region to another. Used to model losses in power transmission networks. [Fraction]
Par_TradeLossFactor represents the fraction of energy lost when trading a fuel (typically power)

between regions, accounting for transmission losses in the network and reducing the amount of energy delivered relative to what was sent.

Variable Costs

Cost per unit of activity of the technology. [M€/PJ]
This parameter is used to define the variable costs for each technology in each year and region.
There are some specific variable cost for technologies that serve a specific purpose:

Z_Technologies are used to represent **Import** from outside the regions used in the model.
Z_Import_H2, as an example, represents the variable costs or market price associated with importing hydrogen (H2). This technology serves as a supply option that provides hydrogen at the cost specified in its variable cost parameter. If the model cannot produce hydrogen more cheaply through domestic technologies, it will choose to import it—provided that imports are allowed. A maximum import volume can be enforced by setting the Par_TotalAnnualMaxActivity parameter, which limits the total annual import activity for this technology.