Multi-Carrier Model Data
Detailed Version

LAST UPDATED | August 1, 2018

Numerical Data

Table 1: Load and VRE generation profiles, gas demand

Param.	Value	Unit	Notes
γ_t^S	$[0,1]^T$	p.u.	**Computed** from [1], normalised yearly profile.
$\gamma_t^{W_{off}}$	$[0,1]^T$	p.u.	**Computed** from [2], normalised yearly profile.
$\gamma_t^{W_{on}}$	$[0,1]^T$	p.u.	**Computed** from [2], normalised yearly profile.
γ_t^L	$[0,1]^T$	p.u.	**Computed** from [3], normalised yearly profile.
π_t^{NG}	Time Series	MWh	**Computed** from [4].

Table 2: Power and energy capacity parameters

Param.	Value	Unit	Notes
κ_t^L	Time Series	MW	**Derived** from 2016 peak load; 1% yearly increase.
κ_0^S	3000.0	MW	Retrieved from [1].
κ_{max}^S	25000.0	MW	**Assumed**.
$\kappa_0^{W_{off}}$	900.0	MW	Retrieved from [2].
$\kappa_{max}^{W_{off}}$	25000.0	MW	**Assumed**.
$\kappa_0^{W_{on}}$	1750.0	MW	Retrieved from [2].
$\kappa_{max}^{W_{on}}$	25000.0	MW	**Assumed**.
κ_{max}^{PtG}	16500.0	MW	**Assumed**, estimation of peak electricity demand.
$\kappa_{max}^{H_2tP}$	16500.0	MW	**Assumed**, estimation of peak electricity demand.
$\kappa_{max}^{H_2tCH_4}$	16500.0	MW	**Assumed**, estimation of peak electricity demand.
$\kappa_{t,0}^{NG}$	Time Series	MW	Retrieved from [5].
κ_{max}^{NG}	16500.0	MW	**Assumed**, estimation of peak electricity demand.

κ^{PtPH}_{max}	1300.0	MW	Retrieved from [5].
κ^{PHtP}_{max}	1300.0	MW	Retrieved from [5].
κ^{disp}_{max}	1700.0	MW	**Derived** from [5].
$\Xi^{H_2}_{max}$	396.0	GWh_{th}	**Assumed**, 24 hours of peak electricity demand.
$\Xi^{CH_4}_{max}$	12.0	TWh_{th}	**Assumed**, 30 days of peak electricity demand.
Ξ^{PH}_{max}	5.3	GWh	Retrieved from [5].
κ^{NG}_{net}	90.0	GWh_{th}	**Assumed**, linepack flexibility of Fluxys H & L grids.
$\kappa^{NK}_{t,0}$	Time Series	MW	CHECK Retrieved from [5].
κ^{trs}_{max}	6500.0	MW	Retrieved from [6].
$\Psi^{CO_2}_{max}$	7.0	Mt	**Extrapolated** from [7] and [8], very sensitive parameter.

Table 3: Efficiencies

Param.	**Value**	**Unit**	**Notes**
η^{NGtP}	[45.0, 65.0]	%	Retrieved from [9], technology dependent (OCGT → CCGT), 2020.
η^{H_2tP}	{42.0, 70.0}	%	Retrieved from [10], hydrogen gas turbine technology, 2008-9.
η^{H_2tP}	[45.0, 60.0]	%	Retrieved from [11], fuel cell technology, 2012.
η^{disp}	45.0	%	**Computed** from [9], aggregate value for various techs, 2010.
η^{PtG}	70.0	%	Retrieved from [12], alkaline electrolysis technology.
$\eta^{H_2tCH_4}$	78.0	%	Retrieved from [12], fixed-bed reactor catalytic methanation.
η^{PtPH}	90.0	%	**Approximated** from [13], to match round-trip efficiency of 80%.
η^{PHtP}	90.0	%	**Approximated** from [13], to match round-trip efficiency of 80%.

Table 4: Storage and emission parameters

Param.	**Value**	**Unit**	**Notes**
σ^{H_2}	0.0	%	**Assumed**, non-zero value forces construction of technology.
σ^{CH_4}	0.0	%	**Assumed**, non-zero value forces construction of technology.
σ^{PH}	0.0	%	**Assumed**, fully usable PH capacity.
σ^{NG}	0.0	%	**Assumed**, as capacity is linepack operational flexibility.

μ^{disp}	20.0	%	**Assumed**, must-run condition.
μ^{NK}	TBD	%	**Assumed**.
μ^{trs}	15.0	%	**Assumed**, half the current value for Belgium.
ν^{NG,CO_2}	0.18	t/MWh	Retrieved from [14].
ν^{CH_4,CO_2}	0.018	t/MWh	**Assumed**, 10% of NG emissions.
ν^{disp,CO_2}	0.35	t/MWh	**Approx.** from [14], aggregates technologies (biomass, waste).
ν^{trs,CO_2}	0.20	t/MWh	**Approximated** from [8], considering all interconnected countries' CO2 intensity.

Table 5: Technology capital and operational costs

Param.	**Value**	**Unit**	**Notes**
ς^{ENS}	3000	€/MWh	Retrieved from [15].
$\varsigma^{C,S}$	100	€/MWh	Retrieved from [15].
$\varsigma^{C,W_{on}}$	100	€/MWh	Retrieved from [15].
$\varsigma^{C,W_{off}}$	100	€/MWh	Retrieved from [15].
ζ^{S}	8×10^5	€/MW	Retrieved from [16], 2040 forecast.
$\zeta^{W_{on}}$	10^6	€/MW	Retrieved from [16], 2040 forecast.
$\zeta^{W_{off}}$	2.2×10^6	€/MW	Retrieved from [16], 2040 forecast.
ζ^{PtG}	$[8, 30] \times 10^5$	€/MW$_{el}$	Retrieved from [17], depending on AE, PEM or SE technology.
$\zeta^{H_2tCH_4}$	$[7, 15] \times 10^5$	€/MW	Retrieved from [18], depending on year (2030 $\rightarrow$ now).
$\zeta^{H_2tCH_4}$	$[1.3, 4] \times 10^5$	€/MW	Retrieved from [17], OUTOTEC GmBH data.
ζ^{CH_4}	50.0	€/MWh	**Assumed**, based on discussions with Fluxys.
$\zeta_s^{H_2}$	$[0.8, 7.2] \times 10^3$	€/MWh	Retrieved from [19], 0.8 € to $ rate assumed.
ζ^{NG}	$[550, 850] \times 10^3$	€/MW	Retrieved from [16], depends on technology (OCGT $\rightarrow$ CCGT).
ζ^{H_2}	10^6	€/MW	Retrieved from [10], hydrogen turbine technology.
ζ^{H_2}	$[6.4, 16] \times 10^5$	€/MW	Retrieved from [20], PEM and SO fuel cell technologies ($\rightarrow$ 2050).
θ^{CO_2}	[33.0, 126.0]	€/tCO2	Retrieved from [16].
θ^{disp}_{fuel}	6.0	€/MWh	Retrieved from [21], median in given range.
θ^{disp}_{v}	[3.0, 4.0]	€/MWh	Retrieved from [16].

θ_f^{disp}	4×10^4	€/MW	Retrieved from [16], new biomass technology, 2040 forecast.
θ_{fuel}^{NG}	[29.0, 35.0]	€/MWh	Retrieved from [16], depending on coal/gas merit order.
θ_v^{NG}	[2.0, 11.0]	€/MWh	Retrieved from [16], depending on technology (CCGT → OCGT).
θ_f^{NG}	[17, 21]$\times 10^3$	€/MW	Retrieved from [16], depending on technology (OCGT → CCGT).
$\theta_v^{H_2}$	[2.0, 11.0]	€/MWh	**Extrapolated** from [16], from NG-fired plant costs for H_2 turbine.
$\theta_f^{H_2}$	8.0	€/MW$_{el}$	Retrieved from [10], hydrogen gas turbine technology, 2008-9.
$\theta_f^{H_2}$	[3.2, 8] $\times 10^4$	€/MW$_{el}$	Retrieved from [19], fuel cell technologies (2050 → now).
$\theta_{s,f}^{H_2}$	[40, 360]	€/MWh	Retrieved from [19], 5% of CAPEX per year.
$\theta_f^{CH_4}$	2.5	€/MWh	**Assumed**, 5% of CAPEX per year.
$\theta_f^{W_{off}}$	7.7×10^4	€/MW	Retrieved from [16], 2040 forecast.
$\theta_f^{W_{on}}$	2.9×10^4	€/MW	Retrieved from [16], 2040 forecast.
θ_f^{S}	2×10^4	€/MW	Retrieved from [16], 2040 forecast.
$\theta_v^{W_{off}}$	0.0	€/MWh	**Assumed**.
$\theta_v^{W_{on}}$	0.0	€/MWh	**Assumed**.
θ_v^{S}	0.0	€/MWh	**Assumed**.
θ_f^{PtG}	$[1.6, 6.0] \times 10^4$	€/MW$_{el}$	**Extrapolated** from [18], 2% of CAPEX for alkaline electrolyser.
$\theta_f^{H_2tCH_4}$	$[3.5, 7.5] \times 10^4$	€/MW	**Extrapolated** from [18], 5% of CAPEX for catalytic methanation.
θ_f^{PH}	4.5×10^4	€/MW	Retrieved from [16], 2040 forecast.
θ_v^{PH}	8.0	€/MWh	Retrieved from [16].
θ^{el}	Time Series	€/MWh	Retrieved from [22].

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