

A.5 Glossary of Parameters

This is a glossary of all parameters that appear in the objective function and constraints of the detailed model description.

α_k	The fraction of pre-2006 transmission line k 's capacity available to wind.	$CF_{c,i,m,l}$	Capacity factor by time-slice for new wind of at a class c , location l site in supply region i .
$BASE_CSP$	National CSP capacity at the start of the period. (MW)	$CF_{cCSP,m}$	Capacity factor by time-slice for new CSP at a class $cCSP$ site.
$BASE_CSP_inst_i$	Regional CSP capacity at the start of the period. (MW)	$CFO_{c,i,m,l}$	Average capacity factor of all existing type l , class c wind on pre-2006 lines in region i .
$BASETPCA$	National transmission capacity at the start of the period. (MW)	$CFO_{cCSP,m}$	Average capacity factor of all existing class $cCSP$ CSP on pre-2006 lines.
$BASE_WIND$	National wind capacity at the start of the period. (MW)	$CFTO_{c,i,m,l}$	Average capacity factor of all existing type l , class c wind on new lines in region i .
$BASE_WIND_inst_i$	Regional wind capacity at the start of the period. (MW)	$CFTO_{cCSP,m}$	Average capacity factor of all existing class $cCSP$ CSP on new lines.
$BioFeedstockLCOF_{bioclass,n}$	Levelized cost of feedstock at each step of the biomass supply curve.	CG_g	Increase in turbine price due to rapid growth in wind capacity. (\$/MW)
$BioSupply_{bioclass,n}$	Amount of feedstock available at a given step on the biomass supply curve.	$CG_{csp,gCSP}$	Increase in CSP plant cost due to rapid growth in CSP capacity. (\$/MW)
$CarbTax$	Amount of carbon tax. (\$/ton CO ₂)	$CG_{cspinst,gCSPinst}$	Increase in CSP installation cost due to rapid growth in CSP capacity. (\$/MW)
CCC_q	Overnight capital cost of conventional generating capacity. (\$/MW)	$CG_{inst,ginst}$	Increase in wind installation cost due to rapid growth in wind capacity. (\$/MW)
$CCONV_q$	Present value of the revenue required to pay the capital cost of conventional generating capacity (\$/MW) including interest, construction, finance, and taxes.	$CG_{Storage_{st,storagebp}}$	Increase in storage cost due to rapid growth in storage capacity. (\$/MW)
$CCONV_{f,q}$	Present value of the annual fixed operating costs over the evaluation period for conventional generating capacity. (\$/MW)	$CH_{HeatRate}_q$	Heat rate (inverse efficiency) of conventional technology. (MMbtu/MWh)
$CCONV_{n,q}$	Present value over the evaluation period of the variable operating and fuel costs for generation from conventional capacity. (\$/MWh)	$CH_{eatrate}_{st}$	Heat rate (inverse efficiency) of storage technology. (MMbtu/MWh)
$CCSP_{cCSP}$	Capital cost of class $cCSP$ CSP capacity. (\$/MW)	$CONV_{pol}_{q,pol}$	Emissions of pollutant for each MWh of generation by conventional technology q . (ton/MWh)
$CCt_{q,g}$	The present value of the cost of transmitting 1 MWh of power for each of E years between balancing authorities n and p .	$CONV_{old}_{n,q}$	Existing conventional generating capacity, prior to the current period. (MW)

$CONVret_{n,q}$	Retirements of aging conventional capacity in a given period.	$CSPRuc_{cCSP,i}$	Amount of solar resource available. (MW)
$Cost_Inst_Frac$	Fraction of wind farm capital cost assigned to installation rather than the turbines themselves.	$CSPTO_{cCSP,i,j}$	Existing class $cCSP$ CSP capacity on new transmission lines from region i to region j .
$cpop_{c,i,l}$	Fractional increase in wind capital cost due to population density.	$CSPTturO_{cCSP,i}$	Existing CSP capacity for which new transmission capacity was built. (MW)
CQS	Cost to modify a combustion turbine to provide a quick-start capability. (\$/MW)	$CSPTurO_{cCSP,i}$	Existing CSP capacity that utilizes pre-2006 lines. (MW)
CRF	Capital recovery factor, i.e. the fraction of the capital cost of an investment that must be returned each year to earn a given rate of return if income taxes and financing are ignored.	$CSRV_{n,q}$	Present value of the variable cost of spinning reserve provided over the evaluation period (\$/MWh)
$cslope_{c,i,l}$	Fractional increase in wind capital cost per degree of topographical slope.	$CSTOR_{st}$	Capital cost of storage capacity. (\$/MW)
$CSP2G_{cCSP,i,cspscp}$	New class $cCSP$ CSP resource in region i available at interconnection cost step $cspscp$.	$Ctranadder_q$	Transmission cost adder by conventional technology. (\$/MW)
$CSP2GPTS_{cCSP,i,cspscp}$	Cost to build transmission from a CSP site to the closest available grid transmission capacity.	$CVmar_{c,i,rto}$	(Capacity Value - marginal) The effective load-carrying capacity of 1 MW at a new wind or solar farm at a class c site in region i delivered to an rto .
$CspCVmar_{cCSP,i,rto}$	(CSP Capacity Value - marginal) The effective load-carrying capacity of 1 MW at a new CSP plant at a class $cCSP$ site in region i delivered to an rto .	$CVold_{c,i,rto}$	(Capacity Value - old) The effective load-carrying capacity of all the wind or solar capacity installed in previous periods whose generation is transmitted to an rto .
$CspCVold_{cCSP,i,rto}$	(CSP Capacity Value - old) The effective load-carrying capacity of all the CSP capacity installed in previous periods whose generation is transmitted to an rto .	CW_c	Present value of the revenue required to pay for the capital cost of class c wind capacity—including interest during construction, finance, and taxes. (\$/MW)
$CSPGridConCost$	Cost to connect a CSP plant to the grid. (\$/MW)	$CWOM_c$	Present value of operations and maintenance costs over the evaluation period for wind capacity—including property taxes, insurance, and production tax credit. (\$/MWh)
$CSP_inregion_dis_{cCSP,j,escp}$	Levelized cost—from the $escp$ step of the supply curve—for building a transmission line from a CSP site to a load center in the same region.	$Distance_{i,j}$	Distance between regions. (miles)
$CSPO_{cCSP,i,j}$	Existing class $cCSP$ CSP capacity on pre-2006 transmission lines from region i to region j .	$Distance_{n,p}$	Distance between balancing authorities. (miles)
$CSPOM_{cCSP}$	Present value of operations and maintenance costs over the evaluation period for CSP capacity (\$/MW)	F_q	Fraction of capacity that can be available as quickstart.
		FO_q	Forced outage rate of technology q .
		$Fprice_{q,n}$	Cost of input fuel for given technology. (\$/MWh)

$FSRV_q$ Fraction of capacity available for spinning reserve.	Her_n Annual hydro energy available in balancing authority n . (MWh)
$FSTOR_{st}$ Present value of the annual fixed operating costs over the evaluation period for storage capacity. (\$/MW)	$L_{j,m}$ Load by region and time-slice. (MW)
$GeoAdder_{geoclass,n}$ Additional capital cost for recoverable geothermal capacity along supply curve. (\$/MW)	$L_{n,m}$ Load by balancing authority and time-slice. (MW)
$GeoEGSadde_{egsclass,n}$ Additional capital cost for recoverable geothermal capacity along supply curve. (\$/MW)	$L_{rto,m}$ Load by rto and time-slice. (MW)
$GeoEGSmax_{egsclass,n}$ Amount of recoverable capacity at a given step on the EGS supply curve. (MW)	$lowsuladd_LCF_n$ Present value of 20-year expected additional levelized cost of fuel for using low sulfur coal.
$GeoEGSold_{egsclass,n}$ Existing EGS capacity, prior to the current period. (MW)	$minplantload_q$ The minimum level at which a conventional technology can run.
$GeoMax_{geoclass,n}$ Amount of recoverable capacity at a given step on the geothermal supply curve. (MW)	$MW_inregion_dis_{c,j,escp}$ Levelized cost—from the <i>escp</i> step of the supply curve—for building a transmission line from a wind site to a load center in the same region.
$GeoOld_{geoclass,n}$ Existing geothermal capacity, prior to the current period. (MW)	$NERCRm_r$ Reserve margin requirement in the nerc region containing each balancing authority.
$GridConCost$ cost to connect a wind farm or CSP plant to the grid. (\$/MW)	$nor2rto_{rto}$ The variance of the usual operating reserve requirement in RTO rto .
Gt_g A fractional multiplier on the national wind capacity that defines the national wind capacity in step g of the wind turbine price multiplier for rapid growth.	$NRRfrac$ The fraction of the normal reserve requirement.
$GtCSP_{gCSP}$ A fractional multiplier on the national CSP capacity that defines the national CSP capacity in step $gCSP$ of the CSP plant price multiplier for rapid growth.	$old_STOR_{n,st}$ Existing grid-based storage at the start of the period. (MW)
$GtCSPinst_{gCSPinst}$ A fractional multiplier on the CSP capacity in a region that defines the region's CSP capacity in step $gCSPinst$ of the CSP installation price multiplier for rapid growth.	$ORMAR_{c,i,rto,m}$ The operating reserve requirement induced by the marginal addition of one MW of class c wind or solar capacity in region i that is consumed in an rto .
$Gtinst_{ginst}$ A fractional multiplier on the wind capacity in a region that defines the region's wind capacity in step $ginst$ of the wind installation price multiplier for rapid growth.	P_n Peak load in balancing authority n . (MW)
H_m Number of hours per year in time-slice m .	P_{rto} Peak load in rto rto . (MW)
	$PcostFrac_q$ multiplier on the operating costs of conventional generating capacity for use as a peaker.
	PO_q planned outage rate
	$PostStamp_{ij}$ the number of balancing authorities that must be crossed to transmit wind between two supply regions.
	$qsfrac$ minimum fraction of operating reserve that can be met by quickstart technologies

<i>Resconfint</i> (Reserve Confidence Interval) Operating reserve minimum expressed in terms of the number of standard deviations of operating reserve required.	<i>TOWCOST</i> cost of wind transmission on pre-2006 lines (\$/MWh-mile)
<i>RPSfraction</i> national renewable portfolio standard level as a fraction of national electric generation.	<i>TNCOST</i> cost of new transmission lines (\$/MW-mile)
<i>RPSSCost</i> penalty imposed for not meeting the national RPS requirement. (\$/MWh)	<i>TNWCOST</i> cost to build a new transmission line. (\$/MW-mile)
<i>St_CSPRPSCost_{states}</i> penalty imposed for not meeting the state RPS requirement for solar. (\$/MWh)	<i>TPCA_Gt_{TPCA,g}</i> A fractional multiplier of the national transmission (MW) capacity <i>BASETPCA</i> used to establish the size of growth bin <i>tpca_g</i> .
<i>st_Inwincen_{states}</i> Before-tax value of state-level investment incentive for wind. (\$/MW)	<i>TPCAO_{n,p}</i> The transmission capacity between <i>n</i> and <i>p</i> that existed at the start of the period.
<i>STORpol_{st,pol}</i> Emissions of pollutant for each MWh of generation by storage technology <i>st</i> . (ton/MWh)	<i>TWLOSSnew</i> The fraction of wind power lost in each mile of transmission, for new wind.
<i>STOR_RTE_{st}</i> round-trip efficiency for storage technologies	<i>TWLOSSold</i> The fraction of wind power lost in each mile of transmission, for existing wind.
<i>st_Prodincen_{states}</i> Before-tax value of state-level production incentive for wind. (\$/MW-yr)	<i>VSTOR_{st}</i> present value over the evaluation period of the variable operating and fuel costs for generation from storage capacity (\$/MWh)
<i>St_RPSfraction_{states}</i> state renewable portfolio standard level as a fraction of state electric generation.	<i>WO_{c,i,j,l}</i> Existing class <i>c</i> wind of type <i>l</i> on pre-2006 transmission lines from region <i>i</i> to region <i>j</i> .
<i>St_RPSSCost</i> penalty imposed for not meeting the state RPS requirement. (\$/MWh)	<i>WR2G_{c,i,l,wscp}</i> New class <i>c</i> wind resource of type <i>l</i> in region <i>i</i> available at step <i>wscp</i> on the supply curve. (MW)
<i>SurplusMar_{c,i,rto,m}</i> Fraction of renewable (wind or solar) output (from a new class <i>c</i> source in region <i>i</i> to <i>rto</i> <i>rto</i>) curtailed in time slice <i>m</i> because must-run conventionals plus renewable output exceeds load.	<i>WR2GPTS_{c,i,l,wscp}</i> Cost associated with step <i>wscp</i> on the supply curve to build transmission from a wind site in region <i>i</i> to the closest available grid transmission capacity. (\$/MW)
<i>SurplusOld_{rto,m}</i> Fraction of renewable (wind or solar) output from all existing sources feeding <i>rto</i> <i>rto</i> curtailed in time slice <i>m</i> because must-run conventionals plus renewable output exceeds load.	<i>WRuc_{c,i,l}</i> amount of wind resource available. (MW)
<i>Tk_k</i> Capacity of transmission line <i>k</i> . (MW)	<i>WTO_{c,i,j}</i> Existing class <i>c</i> wind on new transmission lines from region <i>i</i> to region <i>j</i> .
<i>TLOSS</i> Fraction of conventional power lost in each mile of transmission.	<i>WturO_{c,i,l}</i> Existing wind capacity that utilizes pre-2006 lines. (MW)
<i>TOCOST</i> cost for wind to use pre-2006 transmission lines (\$/MWh-mile)	<i>WTturO_{c,i,l}</i> Existing wind capacity for which new transmission capacity was built. (MW)
<i>TOR_{rto,m}</i> The operating reserve requirement induced by the load, conventional generation, and existing wind capacity in an <i>rto</i> . (MW)	