Sustainable Engineering Lab Clean Energy Model (SELCEM) formulation – Simple Single-Zone, One-Year Model

Nomenclature

A	capital annualization rate for annualization period *P* and interest rate i
$C_{capacity}$	total capital cost and fix operations and management cost [$]
$C_{generation}$	total generation cost and variable operations and management cost [$]
C_{cap}	capital cost [$/MW]
C_{fuel}	fuel cost based on thermal energy [$/MWh]
C_{omf}	fixed operations and management cost [$/MW-yr]
C_{omv}	variable operations and management cost [$/MWh]
D	electricity demand [MWh]
G	electricity generation [MWh]
i	interest rate
P	annualization period [years]
S	battery storage state of charge [MWh]
W	potential generation, normalized by installed capacity
X_{batt}	battery storage energy capacity installed [MWh]
X_g	generator capacity installed [MW]
η_g	generation efficiency
η_{batt}	battery storage roundtrip efficiency
φ	battery storage power-to-energy ratio
γ	increase in battery storage state of charge [MW]
δ	decrease in battery storage state of charge [MW]
κ	storage self-discharge

Subscripts and Superscripts

batt	battery storage
g	generator technology
T	total hours in the simulation
t	hourly time step

Formulation

The formulation below is for a simple single-zone, one-year model. The objective function minimizes the total cost, shown in Eqs. 1-4. The capacity cost includes installation cost and fixed operations and management cost of generators and batteries. And the generation cost includes fuel cost and variable operations and management cost of some generators. The annualization rate is calculated by Eq. 4 and can vary for different resources (denoted generically by *x*).

$$obj = minimize(C_{capacity} + C_{generation}) \tag{1}$$

$$C_{capacity} = \sum_{g} [\,(C_{g,cap} * A_g + C_{g,omf}) * X_g] + C_{batt,cap} * A_{batt} * X_{batt} \tag{2}$$

$$C_{generation} = \sum_{g} \sum_{t} [\,(\frac{C_{g,fuel}}{\eta_g} + C_{g,omv}) * G_g^t] \tag{3}$$

$$A_x = \frac{i(x) * (1 + i(x))^{P(x)}}{(1 + i(x))^{P(x)} - 1} \tag{4}$$

The constraints are shown in Eqs. 5-14. The decision variables in the model are all equal to or greater than 0. The energy balance in each region is set in Eq. 5:

$$D^t = \sum_{g} G_g^t - \gamma^t + \delta^t \qquad \forall t \tag{5}$$

In Eq. 6, the electricity generated to the grid is limited by the generator's normalized potential output, W. For gas turbines and nuclear generators, W is always 1; for wind and solar, W is a time series.

$$G_g^t \leq X_g * W_g^t \qquad \forall g, t \tag{6}$$

The battery constraints are described in Eqs. 7-11. The battery efficiency is applied to both charge and discharge processes. The battery is assumed to have the same initial and final state of charge.

$$\frac{\delta^t}{\sqrt{\eta_{batt}}} - \sqrt{\eta_{batt}} * \gamma^t = (1-\kappa) * S^{t-1} - S^t \qquad \forall t \tag{7}$$

$$S^t \leq X_{batt} \qquad \forall t \tag{8}$$

$$\delta^t \leq \frac{X_{batt}}{\psi} \qquad \forall t \tag{9}$$

$$\gamma^t \leq \frac{X_{batt}}{\psi} \qquad \forall t \tag{10}$$

$$S^{t=T} = S^{t=0} \tag{11}$$