Nomenclature

Set

Set		Numbers in set
$c \in C$	Commodity	7
$y \in Y$	Year	30
$t \in T$	Technology	4
$e \in E$	Emission	1

Parameters

Parameters		Unit	Non-zero value range
df_period	Cumulative discount factor over period duration	--	0.06
$duration\_period$	Duration of multi-year period	y	5-30
$resource\_cost$	Extraction costs for resources	CNY/t	400-16685
inv_cost	Investment cost	CNY/t	2578-15495
fix_cost	Fixed o&m cost	CNY/t	76.3-774.75
var_cost	Variable o&m cost	CNY/t	2701-8491
$input$	Consumption amount of input commodity	t/t	0.0004-12.03
$output$	Production amount of output commodity	t/t	0.0011-1
$technologica\_lifetime$	Technology lifetime	Year	20
$remain\_capacity$	Factors account for remaining capacity		1
$emission\_factor$	Emission factor	tC02/t	0.05-4.75
$capacity\_factor$	Technology utilization rate	--	0.5-1
$demand\_fixed$	Demand	t	2.66-4.16($\times 10^8$)
$historical\_new\_capacity$	Historical data on new capacity	t	0.01-2.38($\times 10^8$)

Variables

Variables		
EXT	Resources extraction amount	t
CAP	Installed capacity	t
totaCost	Total cost	CNY
investmentCost	Total investment cost	CNY
materialCost	Total raw material cost	CNY
OMCost	Total operation and maintenance cost	CNY
$COMMODIT\_BALANCE$	Auxiliary variable for right-hand side of Auxiliary COMMODITY_BALANCE constraint	t

Decision variables

	Decision variables	
CAP_NEW	Newly installed capacity	t
ACT	Activity of technology	t
$EMISS$	Auxiliary variable for aggregate emissions by technology type	t
$STOCK\_CHG$	Input or output quantity into intertemporal commodity stock (storage)	t

One criteria of our model analysis are the accumulative total cost of the liquid fuel supply system for China's transportation sector from 2020 to 2060. The mathematical expression of total cost is defined by Eq (1)

$$tatalCost = materialCost + investmentCost + OMCost \tag{1}$$

Total cost in our model consists of three parts, which includes:

1) Total raw material cost is defined by Eq (2)

$$Marterialcost = \sum_{y\in Y}\sum_{c\in C} df\_period_y \cdot resource\_cost_{c,y} \cdot EXT_{c,y} \tag{2}$$

2) Total investment cost, which refers to the cost of building production capacities (i.e., plants) of different technologies and is defined by Eq (3)

$$Investmentcost = \sum_{y\in Y}\sum_{t\in T} df\_period_y \cdot inv\_cost_{t,y} \cdot CAP\_NEW_{t,y} \tag{3}$$

3) Total operation and maintenance cost, which donates the cost to maintain the well function of the plant. All costs are occurring in the future, so they are all discounted into the present value of the base year. The mathematical expression is defined by Eq (4)

$$OMcost = \sum_{y\in Y}\sum_{t\in T} df\_period_y \cdot \left(fix\_cost_{t,y^V,y} \cdot CAP_{t,y^V,y} + var\_cost_{t,y^V,y} \cdot ACT_{t,y^V,y}\right) \tag{4}$$

Where *y* is time period (year), df_period_y denote the cumulative discount factor over period duration of *y* years, *t* is technology, $resource\_cost_{c,y}$ is the extraction costs for resources commodity *c* at year *y*, while $EXT_{c,y}$ is the resources commodity *c* extraction amount at time *y*. $inv\_cost_{t,y}$ is the capital investment cost for technology *t* at time *y*, while $CAP\_NEW_{t,y}$ is newly installed production capacity of technology *t* at time *y*. Similarly, $fix_cost_{t,y^V,y}$and $var\_cost_{t,y^V,y}$ denote fixed and variable operation and maintenance cost of technology *t* in year *y* of vintage y^V. $CAP_{t,y^V,y}$ is the cumulative installed capacity of technology *t* in *y* of vintage y^V.$ACT_{t,y^V,y}$ denotes the activity of technology *t* in year *y* of vintage y^V.

Other environmental outcomes or criteria including emissions. Detailed mathematical expressions in Eq. (5).

Outcome 2:

$$EMISS_{e,t,y} = \sum_{t,y^V\leq y} emission\_factor_{t,,y^V,y,e} \cdot ACT_{t,,y^V,y} \tag{5}$$

Where $emission\_factor_{t,,y^V,y,e}$ is the emission factor

These objects also satisfying with a series of relations and constraints.

Let $EXT_{c,y}$ represent the quantity of the raw material commodity *c* used by technology t at time *y*, the $EXT_{c,y}$ is defined by Eq. (6)

$$EXT_{c,y} = \sum_{\substack{t \\ y^V \leq y}} input_{t,y^V,y,c} \cdot ACT_{t,y^V,y} \tag{6}$$

Where $input_{t,y^V y,c}$ is the input amount of resources commodity *c* by technology *t* in year *y* at vintage year y^V.

Besides, the actual activity of a technology cannot exceed available (maintained) capacity, including the technology capacity factor, which is denoted by Eq. (7)

$$ACT_{t,y^V,y} \leq capacity\_factor_{t,y^V,y} \cdot CAP_{t,y^V,y} \tag{7}$$

Where $capacity\_factor_{t,y}$ is the capacity factor of technology *t* ant year *y.*

Let $CAP_{t,y}$ denote the installed capacity of technology *t* at year *y,* then $CAP_{t,y}$ must satisfied with following constrict and relations:

The first constraint ensures that historical capacity (built prior to the model horizon) is available as installed capacity in the first model period.

$$\begin{aligned} & CAP_{t,y^V,first_{period}} \\ & \qquad \leq remain\_capacity_{t,y^v,first\ period} \cdot duration\_period_{y^V} \\ & \qquad \cdot historical\_new\_capacity_{\ t,y^V} \end{aligned}$$

If

$$y^V <' first\_period\ 'and\ |y| - |y^V| \ < technologica\_lifetime_{t,y^V} \tag{7}$$

The second constraint ensures that capacity is fully maintained throughout the model period in which it was constructed (no early retirement in the period of construction).

$$CAP_{t,y^V,y^V} = remain\_capacity_{t,y^v,y} \cdot duration_{period_{y^V}} \cdot CAPACITY\_NEW_{t,y^V,y-1} \tag{8}$$

The third constraint implements the dynamics of capacity maintenance throughout the model horizon. Installed capacity can be maintained over time until decommissioning, which is irreversible.

$$CAP_{t,y^V,y} = remain\_capacity_{t,y^v,y} \cdot CAPACITY\_NEW_{t,y^V,y-1}$$

if

$$y > y^V\ and\ y^V >' first\_period'\ and\ |y| - |y^V| \ < technologica\_lifetime_{t,y^V} \tag{9}$$

Let $COMMODITY\_BALANCE$ to be the auxiliary variable to represent commodity balance, which can be denote in Eq. (10)

$$\begin{aligned} & \sum_{\substack{t \\ y^V \leq y}} output_{t,y^V,y,c} \cdot ACT_{t,y^V,y} - \sum_{\substack{t \\ y^V \leq y}} input_{t,y^V,y,c} \cdot ACT_{t,y} + STOCK\_CHG_{c,y} \\ & \qquad -demand\_fixed_{c,y} = COMMODIT\_BALANCE_{c,y} \end{aligned} \tag{10}$$

$COMMODITY\_BALANCE$ is subjected to two constraints Eq. (11) and Eq. (12). Eq. (11) ensures that supply is greater or equal than demand for every commodity, while Eq. (12) denote that the supply is smaller than or equal to the demand for all commodity. These two constraints work together to ensure that supply is exactly equal to demand.

$$COMMODIT\_BALANCE_{c,y} \geq 0 \tag{11}$$

$$COMMODIT\_BALANCE_{c,y} \leq 0 \tag{11}$$