Case study

Least cost planning of electricity generating systems

Shandong case study (CHINA)

Bioenergy and Energy Planning Research Group – BPE

1. Context of the case study

Shandong Electric Power Corporation (SEPCO) is the Electricity utility of Shandong, a Chinese province with a population in 2017 of 100 million inhabitants. The existing Power plants in the company had not enough capacity to meet the electricity demand in the medium and long term with the required quality of service.

SEPCO has decided to undertake a long term planning of the expansion of the electricity generating system.

The study period is 2009-2036 and the objective is to meet the electricity demand each year with the required quality of service and at the least cost.

2. Evolution at medium and long term of the Electricity demand

Electricity demand in 2006: 94'500 GWh.
Evolution between 2006 and 2009: 7% per year.
For the long term three scenarios were envisaged:

- The scenario A is an extrapolation of the current trend. The annual growths of the electricity demand are as follow:

2009-2016 : 6.5%
2016-2036 : 5.5%

- The scenario B reflects a possible economic evolution with low growth of GDP. The annual increase of the electricity demand is as follows:

2009-2016: 6.5%
2016-2036: 4%

- The scenario C expresses a strong economic growth and an accelerated equipment in electrical appliances by the households: The annual rates of the electricity demand are as follow:

2009-2016: 6.5%
2016-2036: 6.5%

The shape of the load duration curve is supposed to remain the same during the study period (see annex).

First part: Work on Excel

Questions A

Evaluate the maximum and minimum annual load of the demand from year 2009 to 2036 assuming that the shape of the load duration curve will not change during that period.

Questions B

B1 Taking into account the planned retirements of the old plants, please estimate the need for additional capacity.

B2 Using the annex 1, please estimate the annual costs (investment, maintenance and operation costs, fuel cost) for all candidate plants. It will be assumed a constant annual recovery cost during the lifetime of the plant using an annual discount rate of 8%.

B3 Using the Screening curve method presented in the annex 2, please propose for the scenario C of the electricity demand a realistic expansion plan. (In order to assure an acceptable quality of service, a minimum reserve margin of10% above the peak load should be considered. The proposed plan will also consider existence or non-existence of CO2 penalty. Please find out the level of CO2 penalty that would result in a significant change in the proposed plan. The set of candidates proposed for the expansion is it well balanced? If not please complement it by proposing another plant.

Second part : Work with Planelec Pro

Questions C

C1 Evaluate with Planelec the economic and environmental performances of the proposed plan using as indicators: the levelized cost of electricity generation and emission of CO_2.

C2 Discuss the effect of CO_2 penalty

C3 Find out the optimal plan that meets a maximum LOLP of 0.274% (one day per year).

Questions D

D1 Sensitivity analyses

D2 Proposition of a robust plan

Data for the different groups

Group of 2-3 students per group	**Scénario of demand**	**Strategy**	**Sensitivity analysis**
All Ph.D students	C	Reference case Coal, Natural gas and nuclear, without CO_2 penalty, at least 2 nuclear plants by 2026 and at least 2.4 GW of CCPP by 2026	CO_2 penalty
Group 1	C	Same as reference case but no constraint on the number of nuclear plants	Constraints on the emissions of CO_2
Group 2	C	Same as the reference case but no constraint on the nuclear plants and only a constraint of at least 1.2 GW on the CCPP by 2026	Fuel prices
Group 3	C	Same as the reference case but no constraint on the nuclear plants and a constraint of at least 3 GW on the CCPP by 2016 and at least 6 GW by 2026	Investment costs
Group 4	C	Same as the reference case but no constraint on the CCPP by 2026	Electricity demand: scenarios A and B

Annex 1

Case of Shandong

Reference data

1. General data of the case study

First year of the study: 2009

Last year of the study: 2036

Number of periods in one year: 1

Number of hydrological conditions: 1

Currency used in the study: Yuan

Currency in the administrator tables: $

Assumed exchange rate : 1$ = 6.89528Yuan

1€ = 7.31531Yuan

2. Load duration curve

The profile of load duration curve (lobule normalized load duration curve) is described by a 5th degree polynomial function the parameters of which are the followings:

ao = 1.0 a1 = -2.5 a2 = 10.6909 a3 = -23.1636

a4 = 24.0545 a5 = -9.6218

3. CO2 emission factors of the fuels

Coal: 0.42 tCO2 / Gcal

Natural gas: 0.23 tCO2 / Gcal

Nuclear: assumed to be zero

4. Other data

Annual discount rate: 8%

5. Evolution of the fixed system

The evolution of the fixed system is given from 2009 to 2026 (see Excel file in Annex 3). Beyond 2026 it is up to you to propose a hypothesis for the continuation of the decommissioning of the power stations.

6. Description of the variable system

1) Candidate plants

Designation of the plant	Pmax	Fuel	Specific Consumpt	Forced Outage rate	Maint. Prog.	Maint. & oper. cost		Fuel cost
						Fixed cost	Variable cost.	
	MW		kcal/kWh	%	Days/an	Yuan/kW/ mois	Yuan/ MWh	Yuan/Gcal
CCPP	300	gas	1496	5	21	6,22	4	148,7
Coal	600	coal	2356	6.3	56	8,89	21	35
Nuclear	1000	Nucl.	2647	5	28	18,22	4	21,4

2) Economic parameters of the candidate plants

Designation	Lifetime	Construction		Investment without interest during construction
		Construction time	Annual Interest rate during construction	
	ans	ans	%	Yuan/kW
CCPP	25	2	5	5000
Coal	30	3	5	5400
Nuclear	40	6	5	12000

For the evaluation with PLANELEC, additional data are available in the application.

3) Photovoltaic power plants

In addition to the candidate thermal power plants, there are candidate solar photovoltaic power plants. You must research the technical and economic characteristics of these plants. They can be put into service from 2020 onwards.

Annex 2: Screening curve method

The screening curve method is a very simplified tool used to pre-design the mix of electricity generating technology mixes. It is based of the search of a tradeoff between capitalistic technologies and low investment cost – high variable cost technologies (see fig. below)