Integrated Resource Planning Training for Decision Makers

Levelised Costs of Electricity for power system planning

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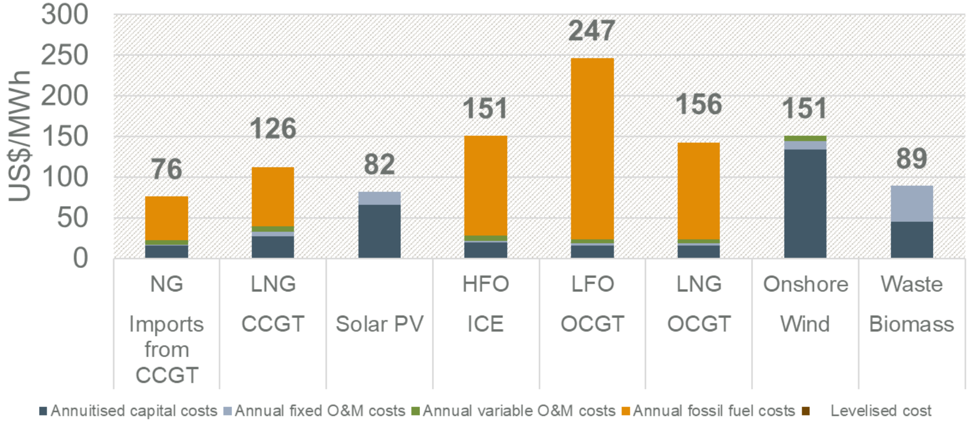
Content and objectives

- Content:
  - What is Levelised Costs of Electricity (LCOE)
  - How to calculate LCOE
  - What are the main advantages and disadvantages of LCOE
  - Screening curves
  - Exercises and case studies
- Objective:
  - How to assess the economic competitiveness of power plant technologies using LCOE.
  - Understand why LCOE cannot give us a complete assessment for power planning.

LCOE can be used to assess the economic competitiveness of power plants

- LCOE is cited as a measure for the comparison of the costs of alternative power plants.
- LCEO is a single $/MWh cost representing the per unit costs for the energy generation from power plants.
- LCOE are commonly used for power development planning to compare the costs of candidate power plants



$$LCOE\left(\frac{\$}{MWh}\right) = \frac{sum\ of\ costs\ over\ lifetime\ (\$)}{energy\ generated\ over\ lifetime(MWh)}$$

$$= \sum_{t=1}^{n} \frac{I_t + F\ O\&M_t}{(1+r)^t} / \sum_{t=1}^{n} \frac{G_t}{(1+r)^t} (\$/MWh)$$

$$+ F\ (\$/MWh) + V\ O\&M\ (\$/MWh)$$

- LCOE: is the levelised cost of electricity in $/MWh
- I_t : Investment costs in year t in $
- $F\ O\&M_t$: Fixed Operating and Maintenance costs in year t in $
- $V\ O\&M$: Variable operating and maintenance costs in $/MWh
- F: Fuel costs in $/MWh
- G: Energy generated at time t in MWh
- r: discount rate
- n: Economic lifetime of power plant

Example for the calculation of levelized costs of electricity

Power plant type		CCGT	CCGT	Solar PV	ICE	OCGT
Fuel type		Natural Gas	LNG	Solar PV	HFO	LFO
Capacity	MW	400	50	20	50	50
Available capacity	MW	400	50	20	50	50
Load Factor	%	70%	70%	19%	70%	70%
Annual energy generated	MWh	2,461,910	307,739	32,944	306,600	306,600
Lifetime	years	25	25	25	20	25
Unit capital costs, excl. financing	US$/kW	866	1,484	981	1,019	890
Capital costs	US$ m	346.4	74.2	19.6	51.0	44.5
Fixed O&M costs	US$/kW/yr	6.2	37.1	27.3	18.5	17.4
Variable O&M costs	US$/MWh	6	7	0	7	5
Heat rate	GJ/MWh	6.926	6.952	0.000	9.095	11.503
Fuel costs	US$/GJ	7.82	10.50	0.00	13.56	19.41
WACC (pre-tax real)	%	10%	10%	10%	10%	10%
Annuitised capital costs	US$ m	38.2	8.2	2.2	6.0	4.9
Annual fixed O&M costs	US$ m	2.5	1.9	0.5	0.5	0.9
Annual variable O&M costs	US$ m	13.6	2.0	0.0	2.0	1.4
Annual fossil fuel costs	US$ m	133.3	22.5	0.0	37.8	68.5
Total annual costs	US$ m	187.5	34.5	2.7	46.3	75.7
Annuitised capital costs	**US$/MWh**	**15.5**	**26.6**	**65.6**	**19.5**	**16.0**
Annual fixed O&M costs	**US$/MWh**	**1.0**	**6.0**	**16.6**	**1.7**	**2.8**
Annual variable O&M costs	**US$/MWh**	**5.5**	**6.5**	**0.0**	**6.5**	**4.7**
Annual fossil fuel costs	**US$/MWh**	**54.2**	**73.0**	**0.0**	**123.3**	**223.3**
Levelised cost	**US$/MWh**	**76.2**	**112.1**	**82.2**	**151.0**	**246.8**

Advantages and disadvantages of LCOE

Advantages

- Provides a common basis for the comparison of power generating technologies
- Relatively simple and easy to understand
- Reflects time value of money and inflation
- Is most useful for comparing similar technologies

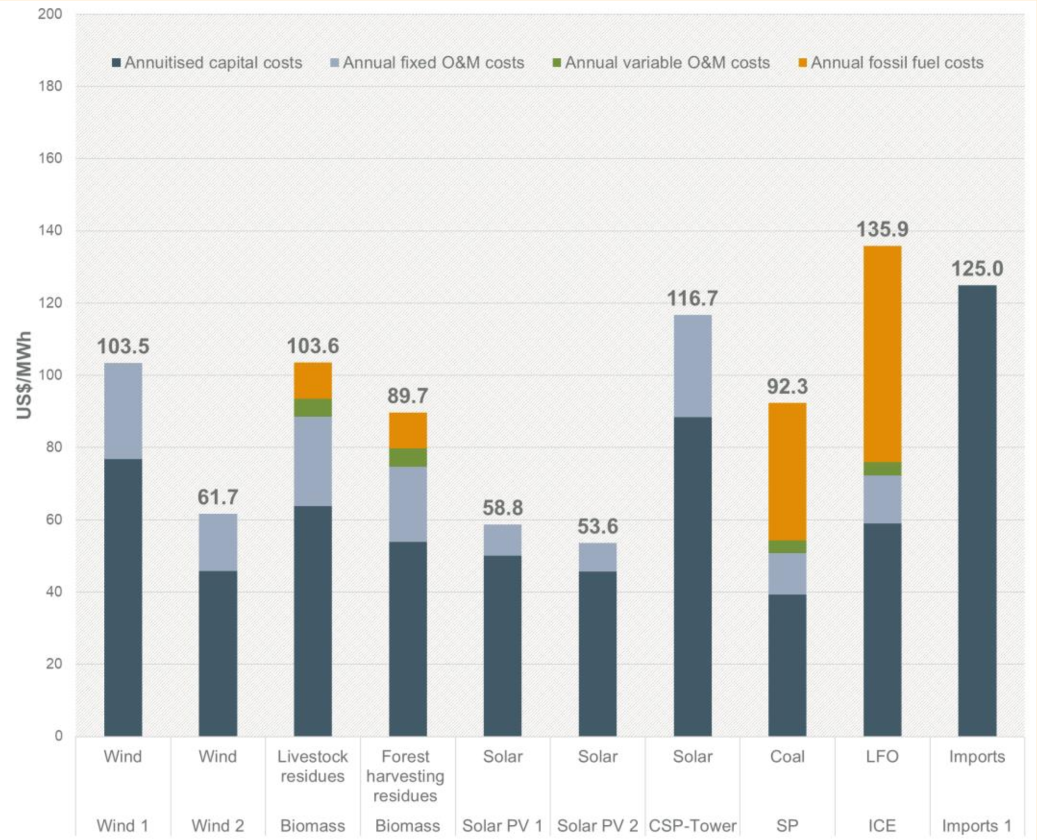
Disadvantages

- It can not provide a reliable comparison for scheduled against intermittent quantities
- It can be misleading in assets with long against short lifetime
- Does not capture the suitability of power plants for base vs peaking generation
- Does not show the cash flow of the investment and financial commitments
- It is heavily based on the assumption of energy generation

Why more sophisticated modelling is needed for power planning than a simple LCOE calculation?

- **LCOE** provide a simple, common basis for comparing generating technologies
  - But technologies are not the same
  - One kWh of electricity is not necessarily as valuable as another:
    - A kWh at peak worth more than at night
    - A dispatchable kWh worth more than non-dispatchable
    - A power plant can also provide other services
  - Does not tell you when to invest
  - Does not capture technical constraints
  - Dynamic dispatch decisions are necessary to assess hydro, pumped storage and batteries
  - Does not capture the intermittent nature of RES and grid constraints

- **LCOE example for a Southern African country (2018)**
  - *It does not tell you when, for how long and if will be dispatch, operational constraints (e.g. minimum stable load or ramping restrictions for thermal plants), if peak can be met, etc.*

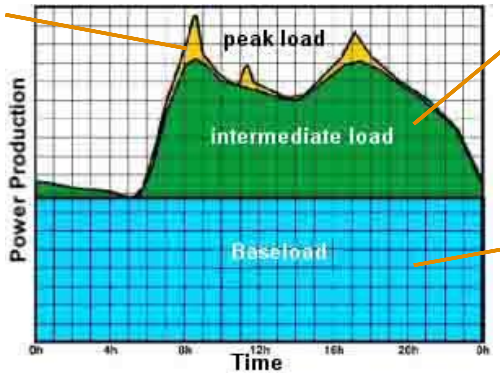


Source: Economic Consulting Associates (ECA) analysis, 2018

Why it matters if it is a base load or peak load power plant?

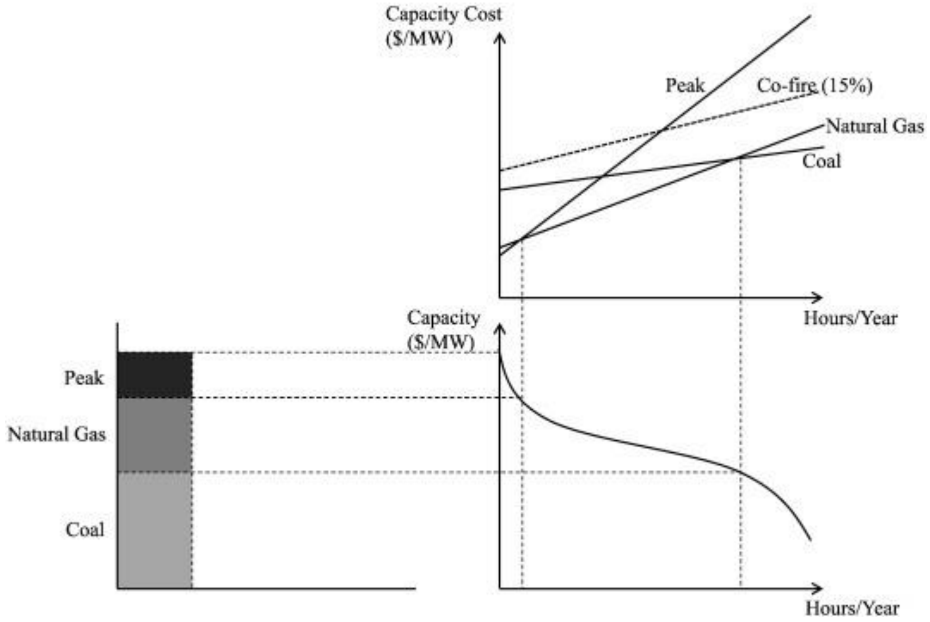
- **Base load power plants (Hydro, Coal, Natural gas, Solar, Wind, etc.)**
  - Capable of continuous operation
  - Typically they have lower operating costs but higher capital cost
  - Less operating flexibility
- **Peak load power plants (OCGT, ICE, Hydro, Storage, etc.)**
  - Required for a few hours within the year
  - It should be technical feasible to quickly turn them on/off
  - Typically they have higher operating costs but lower capital cost
  - Flexible operation

Peaking power plants operate for a few hours



Intermediate power plants operate for some hours

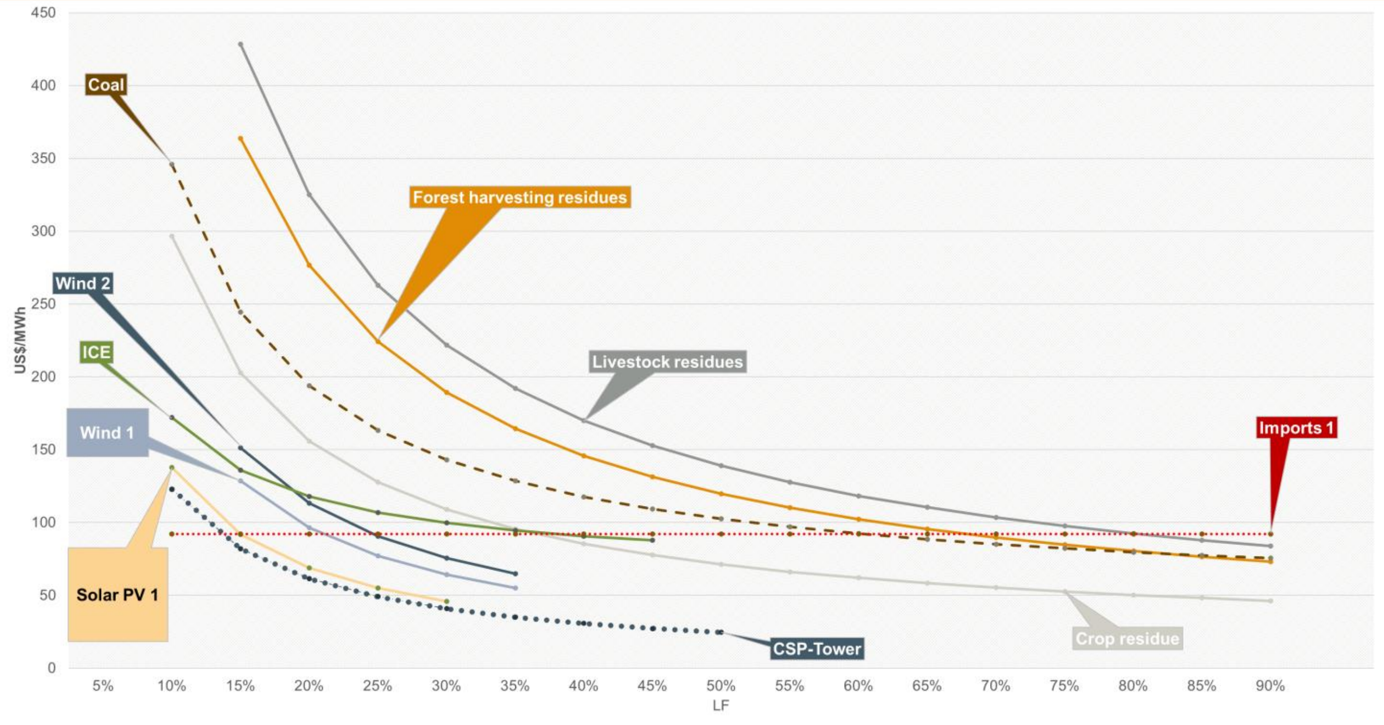
Base load power plants operate throughout the day



Screening curves can provide more clarity regarding the costs of candidate options but again not a complete assessment

- **Screening curves** provide the LCOE for a range of load factors
  - It is cited as a measure for the comparison of peaking, base or intermediate power plant costs.
  - It can tell you which options are clearly uneconomic for base load or peaking load.
  - It can be used to eliminate projects that are clearly uneconomic.

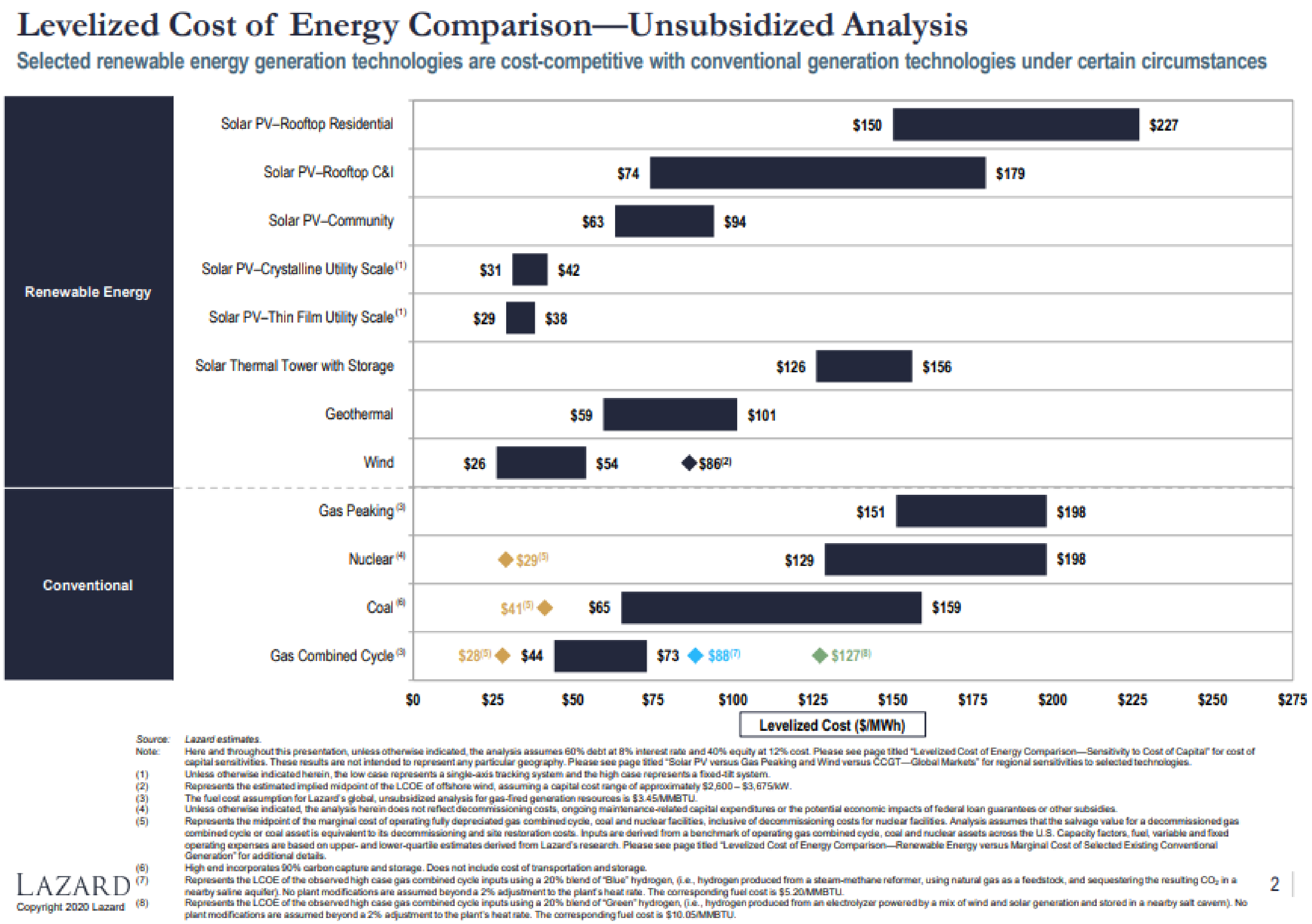
- **Screening curves example for a Southern African country (2018)**
  - *It does not tell you when, for how long and if will be dispatched, operational constraints (e.g. minimum stable load or ramping restrictions for thermal plants), if peak can be met, etc.*



Source: Economic Consulting Associates (ECA) analysis, 2018

Some international sources for LCOE of power plants

- Levelized Costs of New Generation Resources in the Annual Energy Outlook 2021, Energy Information Administration (eia)
- Lazard's Levelized Cost of Energy Analysis 2020, Lazard institute
- Power generation costs 2020, IRENA



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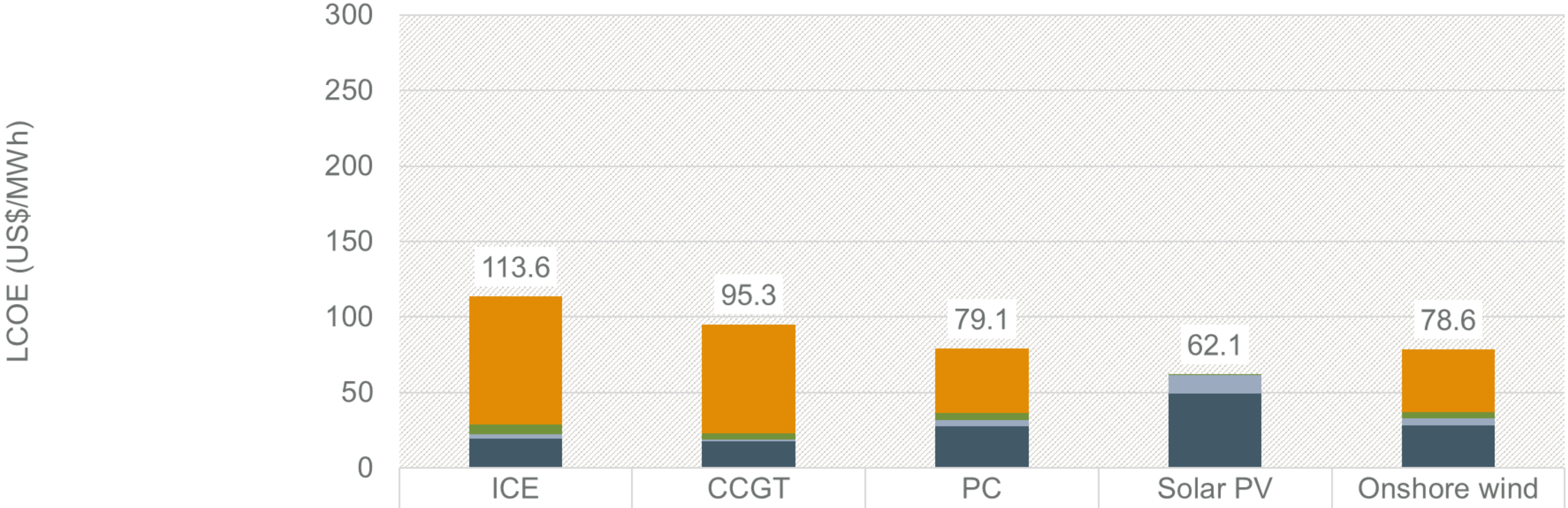
Exercise 1 – Calculation of LCOE

- Calculate the LCOE for the following projects.
  - To calculate the present value of the annuatised capital and fixed O&M costs you can use the following Excel function:

    = - PMT(Discount rate, Economic life, Costs)
- Are the underlying assumptions critical for the results?
- Which options would you choose as least cost options?

Power plant type		ICE	CCGT	PC	Solar PV	Onshore wind
Fuel type		HFO	LNG	Coal	Solar	Wind
Available capacity	MW	20	300	250	20	3.6
Load Factor	%	70%	70%	70%	25%	30%
Lifetime	years	20	25	35	25	25
Unit capital costs, excl. financing	US$/kWnet	1,019	996	1,622	981	1,577
Fixed O&M costs	US$/kW/yr	18.5	6.65	27.5	27.3	13
Variable O&M costs	US$/MWh	6.5	3.765	4.6	0.3	7
Heat rate	GJ/MWh	9.095	7.251	10.136	0	0
Fuel costs	US$/GJ	9.3	10	4.2	0	0
WACC (pre-tax real)	%	10%	10%	10%	10%	10%

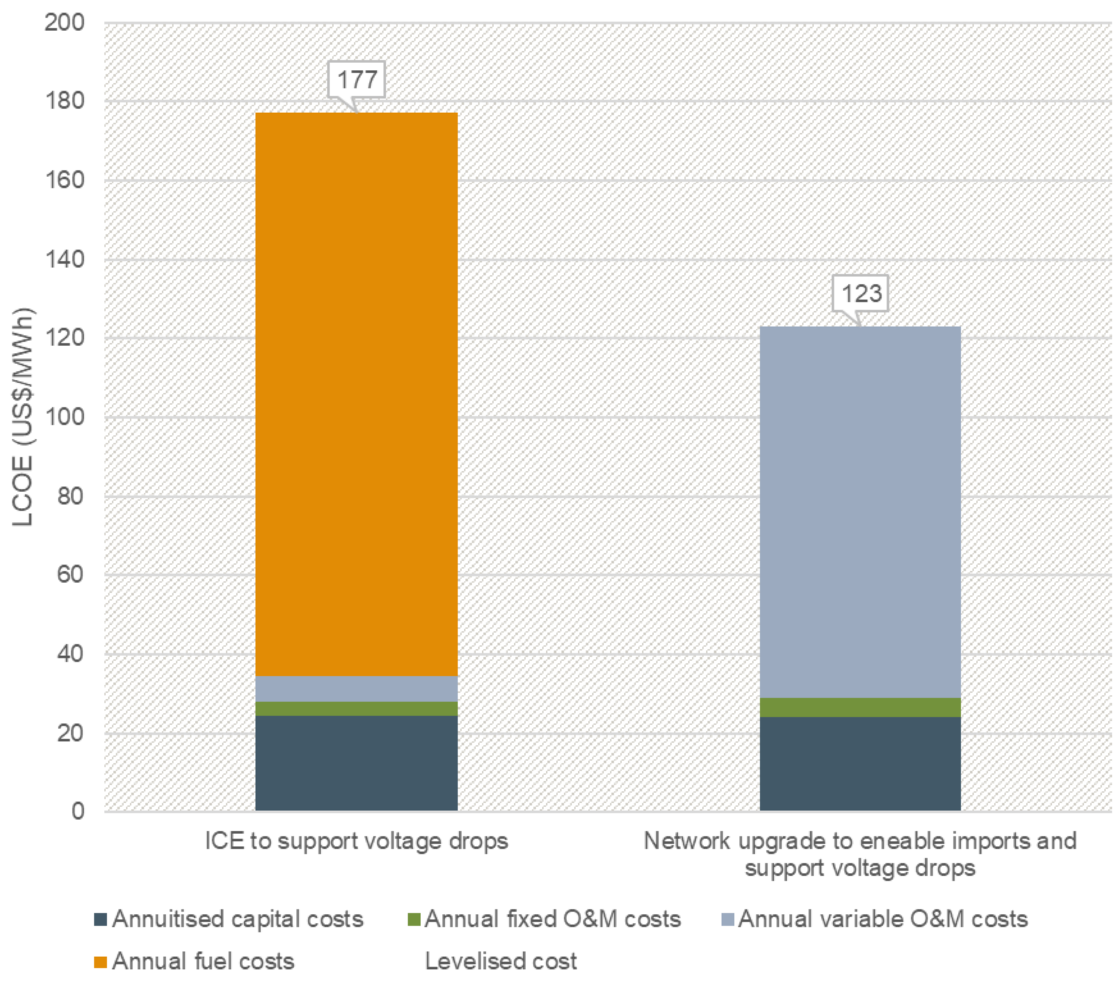
Exercise 1 - Solution



	ICE	CCGT	PC	Solar PV	Onshore wind
Annual fossil fuel costs	84.6	72.5	42.6	0.0	41.4
Annual variable O&M costs	6.5	3.8	4.6	0.3	4.5
Annual fixed O&M costs	3.0	1.1	4.5	12.5	4.7
Annuitised capital costs	19.5	17.9	27.4	49.3	28.0
Levelised cost	113.6	95.3	79.1	62.1	78.6

Case study

- The load flow analysis revealed that voltage drops may be excessive in a particular area unless local generation support or imports on MV level is available. To enable imports the grid has to be upgraded.
  - Which of the two options should be selected?
    - Grid upgrade vs local generation
  - How could the LCOE be used to inform our decision?
  - Would the LCOE be enough to provide an answer?



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