Lecture 22: Economics of Power Generation

Course: MECH-422 – Power Plants

Instructor: Kashif Liaqat

Term: Fall 2021

BUITEMS – DEPARTMENT OF MECHANICAL ENGINEERING

Introduction

- There are a lot of different technologies and fuels that can be used to generate electricity.
- Comparing them is often difficult because there is often a fundamental tradeoff between the cost to build a particular type of power plant and the cost to run a particular type of power plant.
- In this lesson, we'll explore the basic economics of power generation.
- Power generation often comes with significant environmental costs, and some technologies for generating electricity are heavily subsidized, which can affect overall project costs.

Basic Cost Concepts

- Total cost:
  - The total cost of producing Q MWh of electricity (takes units of dollars);
- Average cost of energy:
  - The average cost of producing one MWh of electric energy (takes units of dollars per MWh)
- Average cost of capacity:
  - The average cost of one MW of electric power capacity (takes units of dollars per MW)
- Marginal cost of energy:
  - The incremental cost, in dollars per MWh, of producing an additional unit of electric energy.
- Variable costs
  - are those that change when output changes. Examples of variable costs for power generation include the cost of fuel, the cost of labor or materials, costs to start up and shut down plants, and some types of environmental costs.
- Fixed costs
  - are those that remain at a fixed amount no matter how much electricity the plant produces. Examples of fixed costs include capital, some types of labor costs, insurance and land.

Fixed Cost Concepts for Power Generation

- The fixed costs of power generation are essentially capital costs and land.

- Operating costs for power plants include fuel, labor, and maintenance costs. Unlike capital costs which are "fixed" (don't vary with the level of output), a plant's total operating cost depends on how much electricity the plant produces.

Table 3.1: Example capital and operating costs for power plants. Note that these costs do not include subsidies, incentives, or any "social costs" (e.g., air or water emissions)

Technology	Capital Cost ($/kW)	Operating Cost ($/kWh)
Coal-fired combustion turbine	$500 — $1,000	0.02 — 0.04
Natural gas combustion turbine	$400 — $800	0.04 — 0.10
Coal gasification combined-cycle (IGCC)	$1,000 — $1,500	0.04 — 0.08
Natural gas combined-cycle	$600 — $1,200	0.04 — 0.10
Wind turbine (includes offshore wind)	$1,200 — $5,000	Less than 0.01
Nuclear	$1,200 — $5,000	0.02 — 0.05
Photovoltaic Solar	$4,500 and up	Less than 0.01
Hydroelectric	$1,200 — $5,000	Less than 0.01

Variable Cost Concepts for Power Generation

- The simplest model for variable cost of power generation is:
  - Marginal cost of generation ($/MWh) = Marginal cost of Fuel + Variable operations and maintenance costs.
- The marginal cost of generation for power plants that run on fossil fuels plants (coal, oil, gas) is dominated by fuel costs. Labor and maintenance are additional costs, but these are smaller (less than 10% of total variable cost), and often times we will simply assume that these costs are negligible, or zero.
- The marginal fuel cost of a plant that uses coal, oil or natural gas is determined by the plant's efficiency or "heat rate," which is the the ratio of input energy to output energy [BTU/kWh], or how much fuel it takes to produce a unit of electrical energy.

Marginal Cost

- For a plant with a heat rate HR and fuel cost F (in units of $/mmBTU), the short run marginal cost of generation (ignoring labor and O&M), in $/MWh, would be the product of the fuel price and the heat rate:

$$MC = HR \times F$$

Example

Natural gas costs $5 per million BTU. The heat rate of your natural gas plant is 8 mmBTU/MWh. The plant's marginal cost, in $/MWh, would be given by:

$$\$5 / mmBTU \times 8\ mmBTU / MWh = \$40 / MWh$$

Basic Terms

(i) Interest

- The cost of use of money is known as interest.

(ii) Depreciation

- The decrease in the value of the power plant equipment and building due to constant use is known as depreciation.

(iii) Salvage Value

- Scrap value is also known as residual value, salvage value, or break-up value. Scrap value is the estimated cost that a fixed asset can be sold for after factoring in full depreciation.

(iv) Overhaul

- Overhaul is defined as the major examination and repair of the equipment, which will. extend its economic life.

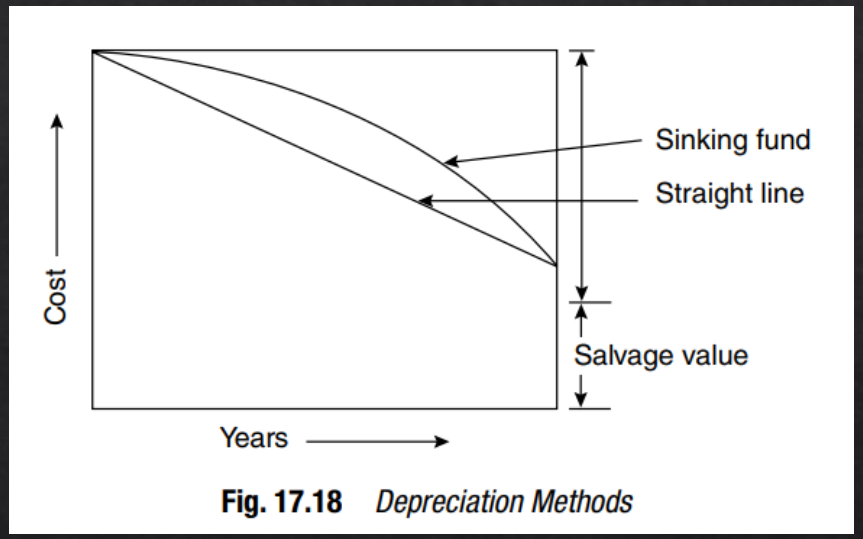


Fig. 17.18 *Depreciation Methods*

Levelized cost ofelectricity (LCOE)

- Levelized cost of electricity (LCOE) is a convenient measure of the overall competiveness of different generating technologies.
- It represents the per--kilowat-- hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle.
- Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type.

Calculating LCOE

- To calculate LCOE the following assumptions are made:

(n) -the plant life in years

(d) -discount rate

(I) -capital cost measured in dollars,

(O&M) -Fixed Operation and Maintenance costs

(F) -variable costs like fuel F in dollars

(E) – The amount of energy generated, is expressed in MWh.

* -If there is a degradation of the output over time, this should be accounted into the amount of the energy generated.

Formula

$$\mathrm{LCOE} = \frac{(\text{sum of costs over lifetime})}{(\text{sum of energy generated over lifetime})}$$

$$\mathrm{LCOE} = \frac{\sum (\mathrm{I} + \mathrm{O\,\&\,M} + \mathrm{F}) \times \dfrac{1}{(1+\mathrm{d})^{\mathrm{n}}}}{\sum \mathrm{E} \times \dfrac{1}{(1+\mathrm{d})^{\mathrm{n}}}}$$

LCOE

- As a financial tool, LCOE is valuable for the comparison of various generation options. A relatively low LCOE means that electricity is being produced at a low cost, with higher likely returns for the investor.

Tariffs

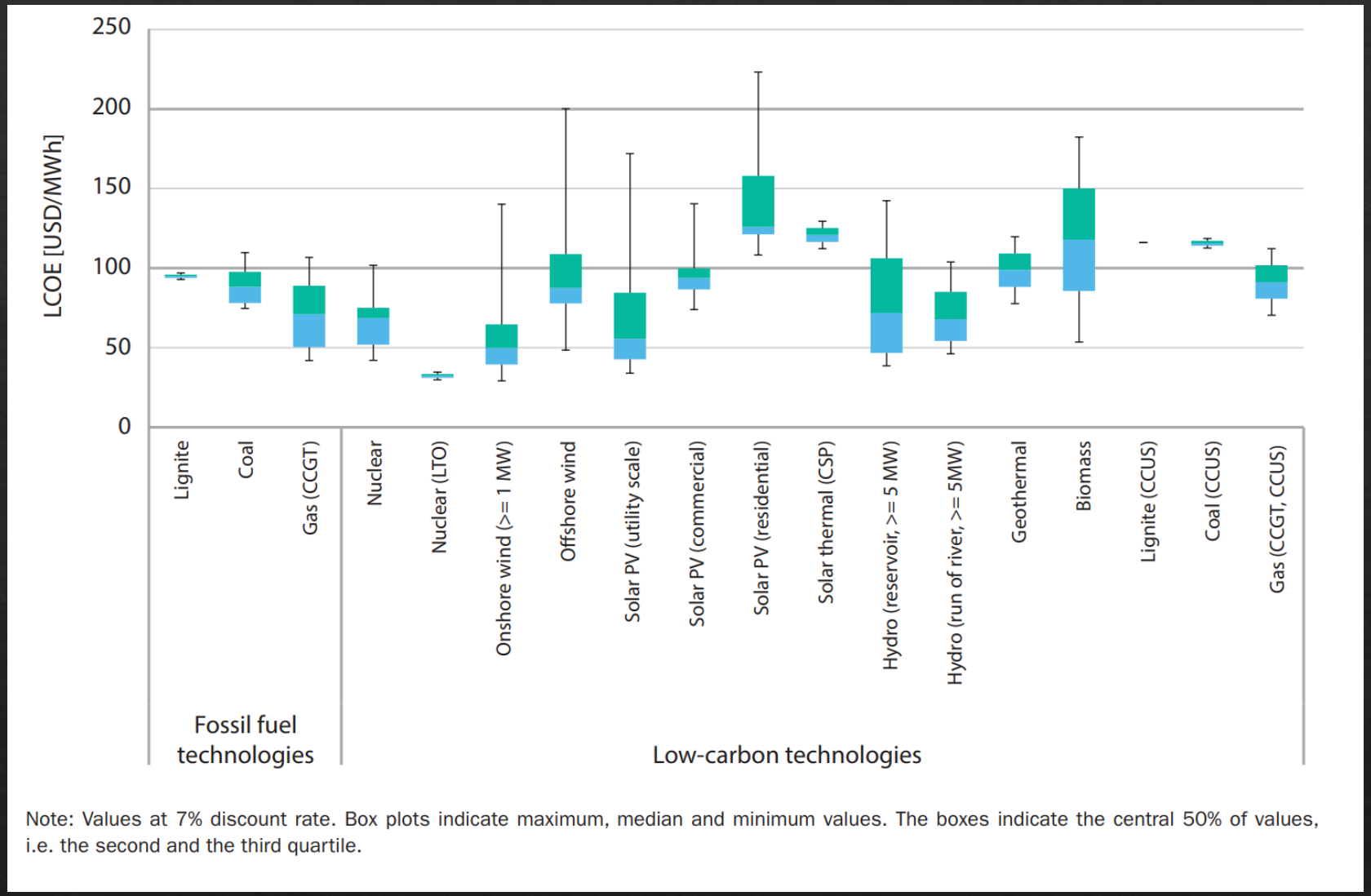
- Energy rates are the different methods of charging the consumers for the consumption of electricity.
- It is desirable to charge the consumer according to his maximum demand (kw) and energy consumed (kwh).
- The tariff chosen should recover the fixed cost, operating cost and profit etc.

Power Purchase Agreement (PPA)

- A PPA is a legal contract between an electricity generator (seller) and a power purchaser (buyer). During the period of the contract the power purchaser buys electrical energy, and sometimes capacity, from the electricity generator.
- The Seller (IPP-Independent power producers) is (often) the developer, owner and operator of the technology that generates electricity.
- The Buyer is (often) a utility company that purchases the electricity generated from the seller.
- Dependent on the type of (renewable) technology utilized for power generation, PPAs need to be tailored to relevant requirements and specific issues.

Long term relationship

- In the PPA a long-term relationship between the utility and the IPP will be created (15 or 20 years – up to 25)
- For the IPP a long-term stream of revenues is necessary for securing the financing and the rate of return
- For the utility the delivery of a defined amount of electrical energy has been secured
- In the case of renewable energy a step has been made towards achieving goals on the targets as set for renewable energy and reduction of the usage of fossil fuels



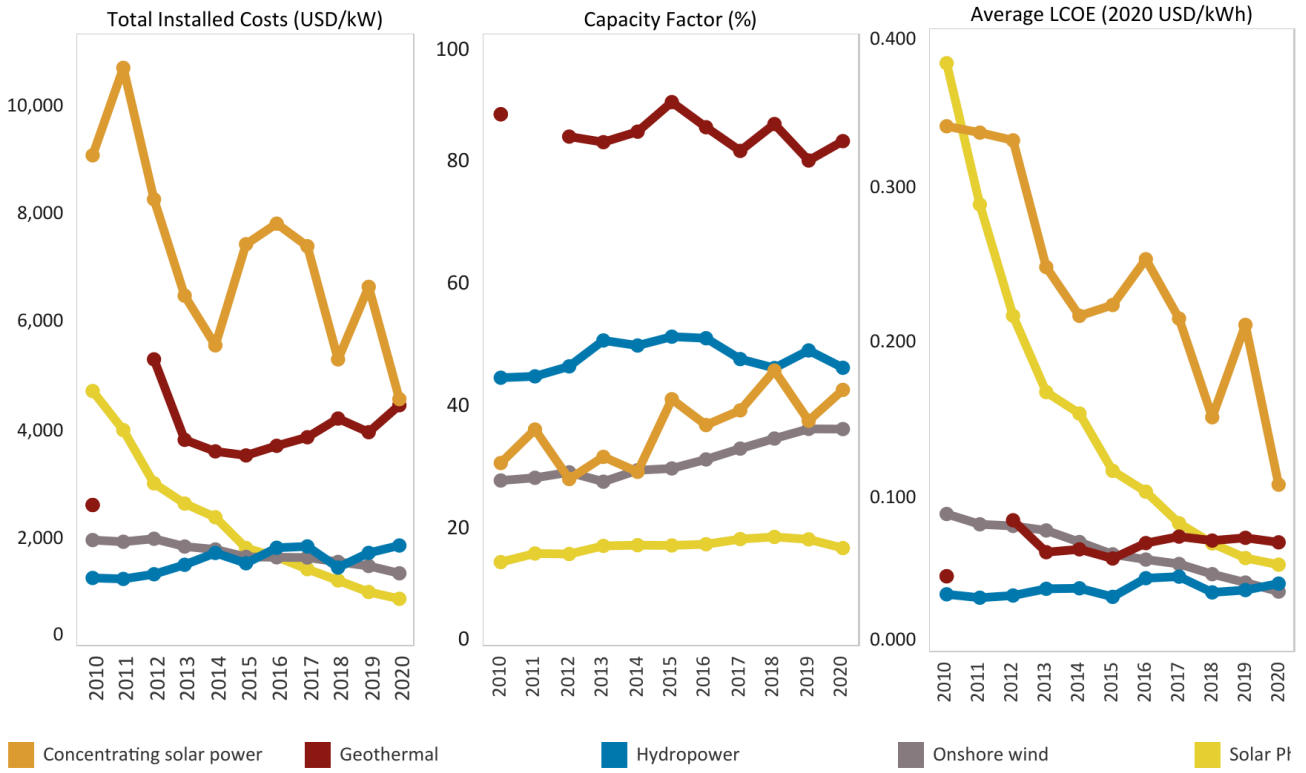
Note: Values at 7% discount rate. Box plots indicate maximum, median and minimum values. The boxes indicate the central 50% of values, i.e. the second and the third quartile.

Projected-Costs-of-Generating-Electricity-2020 – EIA

Global weighted average total installed costs, capacity factors and LCOE 2010-2020

Hover over data point for the raw values and key highlights

Technology
Multiple values



Note: All LCOE values are calculated based on project level data for total installed costs and capacity factors from the IRENA Renewable Cost Database, with other assumptions necessary for LCOE detailed in the source link below, notably an assumption of a weighted-average cost of capital of 7.5% real in the OECD and China and 10% elsewhere.
Source: IRENA (2021), Renewable Power Generation Costs in 2020, International Renewable Energy Agency, Abu Dhabi
https://www.irena.org/publications/2021/Jun/IRENA_Power_Generation_Costs_2020.pdf

End of Lecture!