Danish Energy Agency

Introduction and overview of the Levelized cost of energy (LCOE) method

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Objective of session

The objective of this session is to:

- Introduce the LCOE method
- Provide an overview of benefits and limitations of the method
- Present how it is used in the FIMOI project

Agenda – Introduction and overview of LCOE

- Intro to LCOE
- What has it been used for?
- Which alternative methods exist?
- Recommendations for how to use it
- Exercise

Introduction to LCOE method

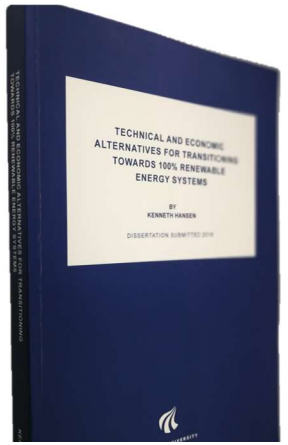
- What is the LCOE method?
- What is typically included in this method?

Background of the presentation

LCOE methods and energy system analysis was one of the main topics of my PhD

Focus on 100% Renewable Energy Systems and different methods and alternatives for achieving this

As part of this process, two papers were completed on LCOE



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Decision-making based on energy costs: Comparing levelized cost of energy and energy system costs

Comparison of Levelized cost of

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Highlights:

- Numerous evaluation factors for calculating LCOE are identified
- LCOE is calculated for electricity, cooling and heating
- LCOE values are compared across energy carriers
- The impact of central evaluation factors is evaluated for LCOE costs

https://vbn.aau.dk/da/publications/tekniske-og-%C3%B8konomiske-alternativer-for-en-omstilling-til-100-ved

https://www.sciencedirect.com/science/article/pii/S2211467X19300197

What is the LCOE method?

The LCOE concept allows for comparison between technologies despite of scales of operation, time periods and investments

This concept might also be referred to as the electricity generation or production costs

The concept has been used for many years and is widely used in many organizations

Definitions:

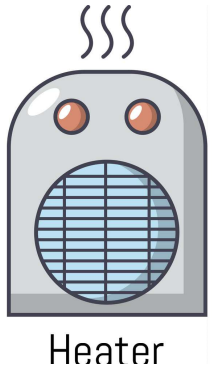
"The LCOE method is used for estimating the full life-cycle costs of an energy generating technology per unit of energy"

"The LCOE is the ratio of lifetime costs to lifetime electricity generation, both of which are discounted back to a common year using a discount rate that reflects the average cost of capital" (IRENA, 2020)

"Levelized cost of electricity represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle." (EIA, 2020)

LCOE = Levelized Cost of Energy

Typically understood as Levelized cost of Electricity



Might also be calculated for heating or cooling,

Or even for storage and other types of energy carriers

Simplified LCOE method

The simplified LCOE methodology is calculated as follows

I_t = Investment expenditures in year t
M_t = Operations and maintenance expenditures in year t
F_t = Fuel expenditures in year t
E_t = Energy generation in year t
r = Discount rate
n = Lifetime of the technology

Equation:

$$\frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Review of possible parameters to include?

Technical factors
Technology efficiencies/ Capacity factors (Full-load hours)
Costs for existing and/or for additional transmission/ distribution costs
Backup capacity
Construction time
Minimum load operation
Ramping rate
Quality of energy
Technical/economic lifetimes (scrap/residual values)
System costs
Installations in existing/new buildings (energy demand)

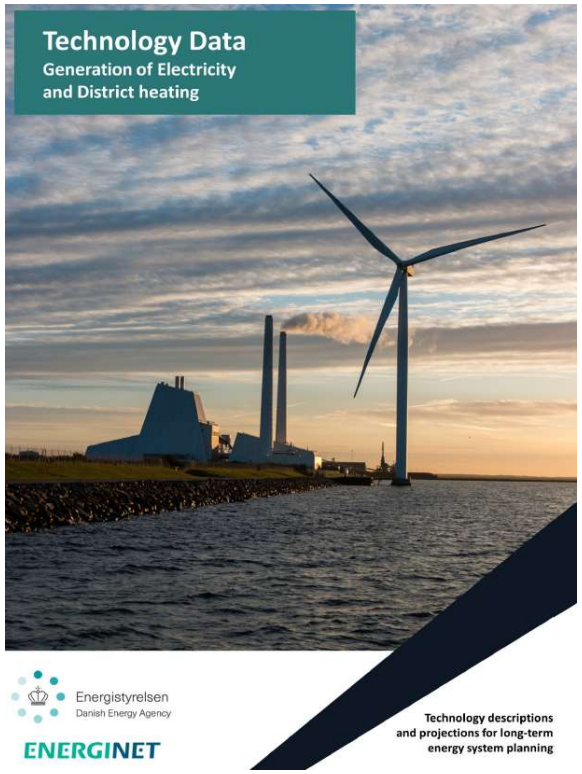
Review of possible parameters to include?

Technical factors	Economic factors
Technology efficiencies/ Capacity factors (Full-load hours)	Interest rate
Costs for existing and/or for additional transmission/ distribution costs	Investment and O&M costs (current and future, learning curves/rates)
Backup capacity	Fuel prices
Construction time	Opportunity costs/interest during construction
Minimum load operation	Land area and costs
Ramping rate	Job creation
Quality of energy	Financing (capital requirements)
Technical/economic lifetimes (scrap/residual values)	Economy of scale
System costs	Taxes and direct/indirect subsidies
Installations in existing/new buildings (energy demand)	Price variations between countries (labour costs, materials, etc.)
	Profile costs (relative value of generation to the market)
	Sunk costs and forced retirements

Review of possible parameters to include?

Technical factors	Economic factors	Externalities (mainly environmental)
Technology efficiencies/ Capacity factors (Full-load hours)	Interest rate	CO_2, air pollution and climate costs
Costs for existing and/or for additional transmission/ distribution costs	Investment and O&M costs (current and future, learning curves/rates)	Radioactivity costs
Backup capacity	Fuel prices	Decommissioning costs
Construction time	Opportunity costs/interest during construction	Use of water
Minimum load operation	Land area and costs	Damage to natural environment
Ramping rate	Job creation	
Quality of energy*	Financing (capital requirements)	
Technical/economic lifetimes (scrap/residual values)	Economy of scale	
System costs	Taxes and direct/indirect subsidies	
Installations in existing/new buildings (energy demand)	Price variations between countries (labour costs, materials, etc.)	
	Profile costs (relative value of generation to the market)	
	Sunk costs and forced retirements	

How to get the data inputs?



LCOE: $$\frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

I_t = Investment expenditures in year t
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F_t = Fuel expenditures in year t
E_t = Energy generation in year t
r = Discount rate
n = Lifetime of the technology

LCOE perspective

The LCOE method and calculations can be used for various perspectives depending on the scope and purpose:

- Societal
- Business
- Private/consumer

The main difference is the factors included

LCOE input differences

Societal	Business	Consumer
Societal discount rate	Financing costs	Transmission and distribution
No taxes and subsidies	Taxes and subsidies	Taxes and subsidies
Externalities	Return on equity	
Infrastructure		
System integration		

Using LCOE

- What has the LCOE method been used for?

Scope of LCOE

Scope:

- For single technologies
- Country or region
- Global perspective

LCOE has <u>focus on costs</u>

No inclusion of other factors such as:

- Environmental aspects
- CO2
- Primary energy
- Resource availability
- Fuel independence
- Job creation
- Etc.

Use of LCOE

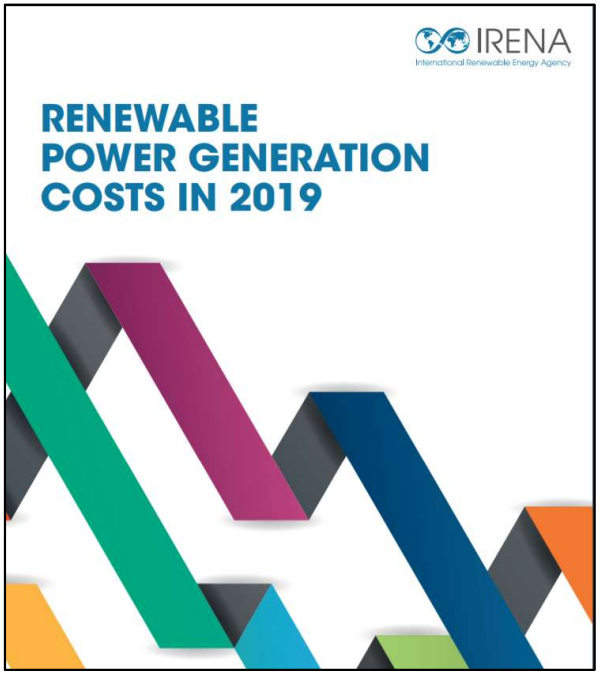
LCOE has previously been used for various purposes such as:

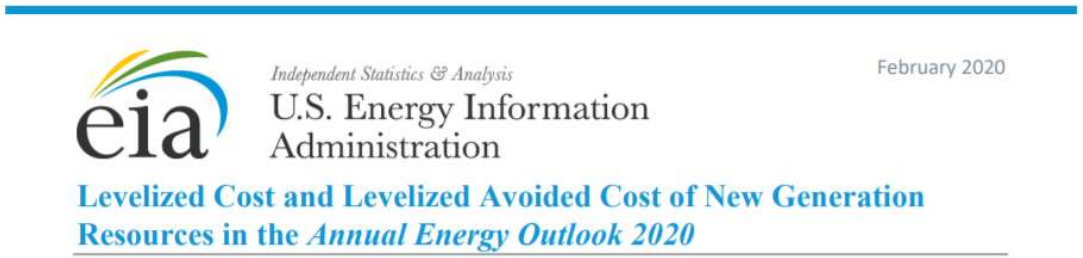
- Inputs to energy modelling
- Benchmarking between technologies
- Aiding in decision making
- Designing of energy policies

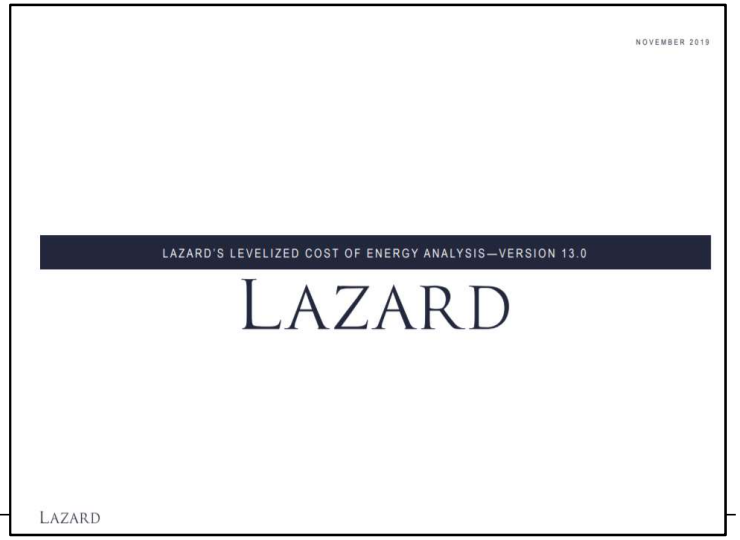
Political priority examples:

- DK for Ad Hoc political analysis, aligning with international organisations
- EU for CO2 subsidy schemes
- UK for nuclear energy support

Examples of LCOE use



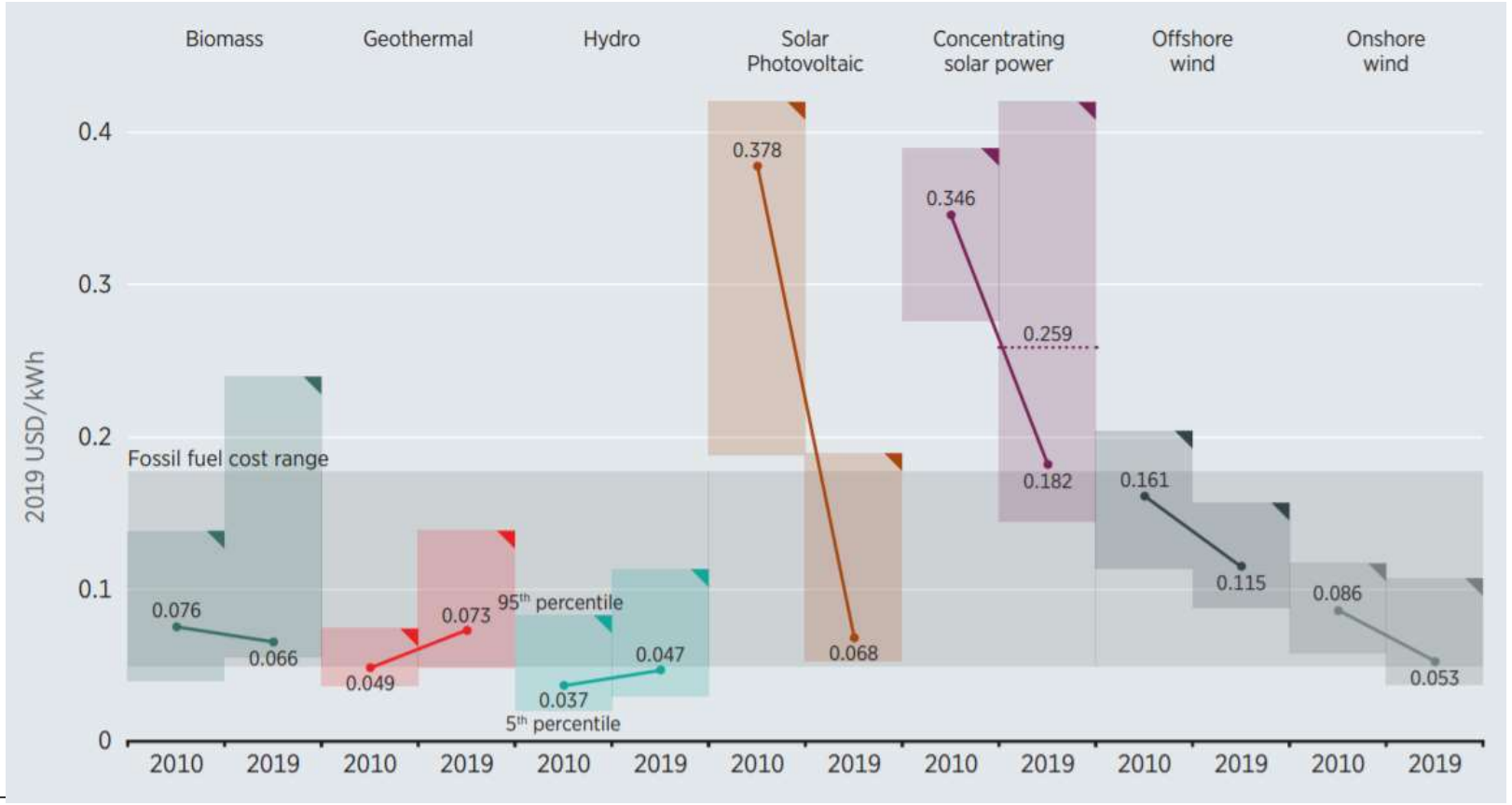




Typical use of LCOE and renewables

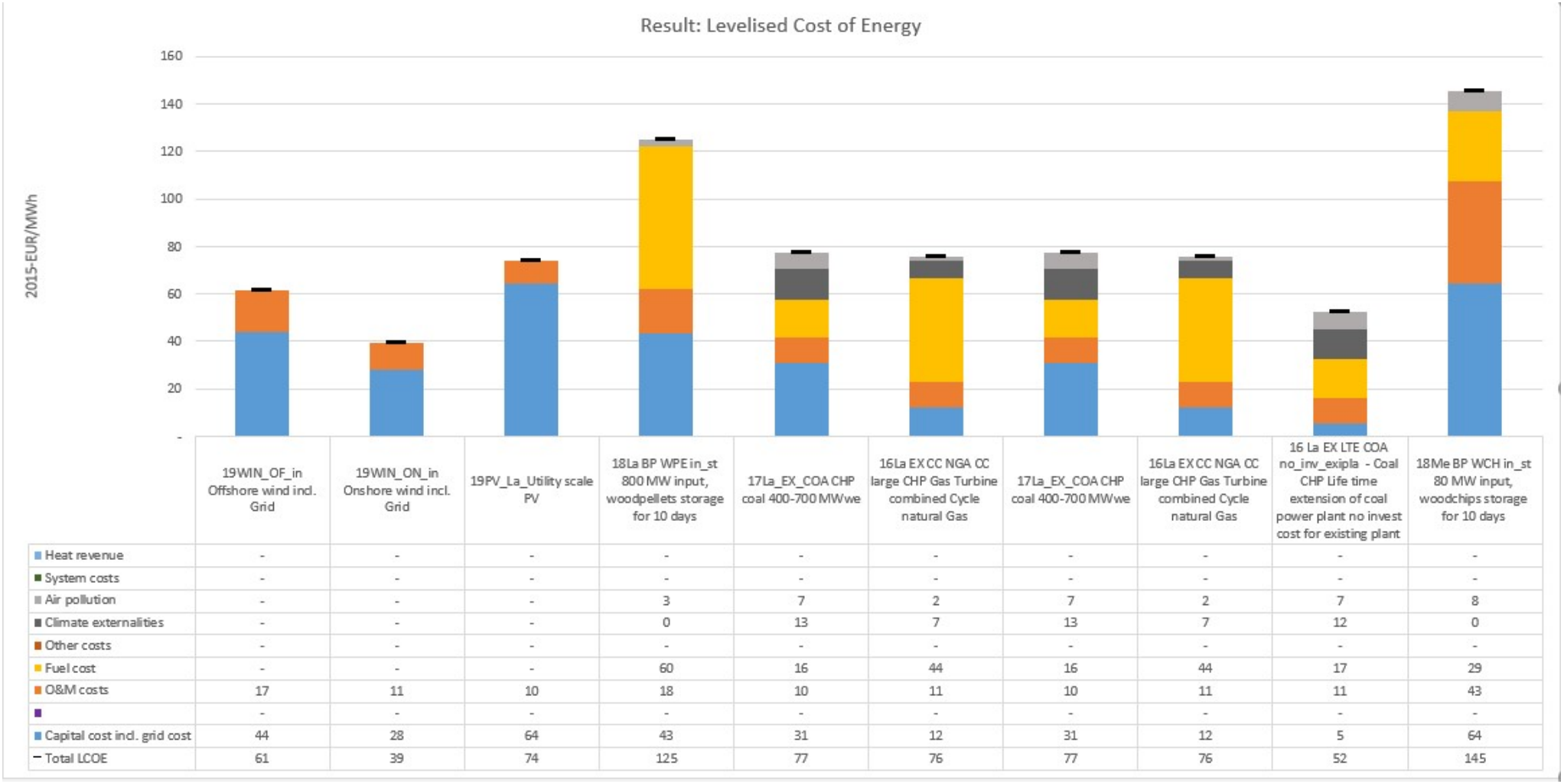
LCOE has for example been used to analyse the cost developments for renewable generation costs, such as by IRENA

% reduction over the last decades compared to fossil fuel technologies



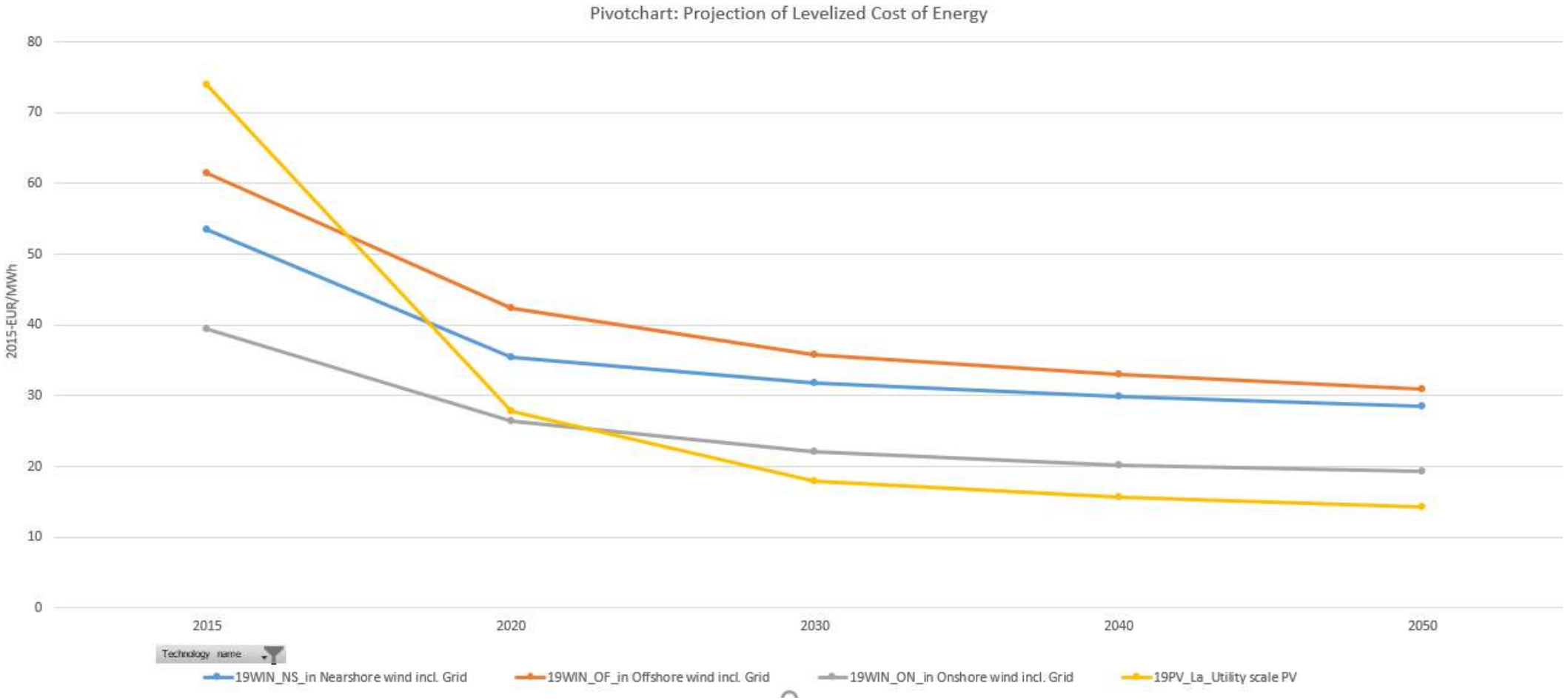
Source: IRENA (2020), Renewable Power Generation Costs in 2019

How it is used in Denmark (DEA)



	19WIN_OF_in Offshore wind incl. Grid	19WIN_ON_in Onshore wind incl. Grid	19PV_La_Utility scale PV	18La BP WPE in_st 800 MW input, woodpellets storage for 10 days	17La_EX_COA CHP coal 400-700 MWwe	16La EX CC NGA CC large CHP Gas Turbine combined Cycle natural Gas	17La_EX_COA CHP coal 400-700 MWwe	16La EX CC NGA CC large CHP Gas Turbine combined Cycle natural Gas	16 La EX LTE COA no_inv_exipla - Coal CHP Life time extension of coal power plant no invest cost for existing plant	18Me BP WCH in_st 80 MW input, woodchips storage for 10 days
Heat revenue	-	-	-	-	-	-	-	-	-	-
System costs	-	-	-	-	-	-	-	-	-	-
Air pollution	-	-	-	3	7	2	7	2	7	8
Climate externalities	-	-	-	0	13	7	13	7	12	0
Other costs	-	-	-	-	-	-	-	-	-	-
Fuel cost	-	-	-	60	16	44	16	44	17	29
O&M costs	17	11	10	18	10	11	10	11	11	43
	-	-	-	-	-	-	-	-	-	-
Capital cost incl. grid cost	44	28	64	43	31	12	31	12	5	64
Total LCOE	61	39	74	125	77	76	77	76	52	145

How it is used in Denmark (DEA)



How it is used in Denmark (DEA)

Applications in DEA:

- Quality assurance across different tools
- Investment assessments (e.g. PtX and across different countries)
- Policy decisions are based on the energy modelling studies (where LCOE can be an input)

Most influential factors for LCOE

The most influential evaluation factors for the societal LCOE costs are typically:

- the interest rate
- investment prices
- fuel prices

Differences between the LCOE method and the data inputs means that studies do not reach similar cost levels → important to consider this during decision making

It can therefore be complicated to compare technologies across different LCOE studies

Using other methods

- What other methods exist?

Limitations of LCOE method

Some limitations of the LCOE method:

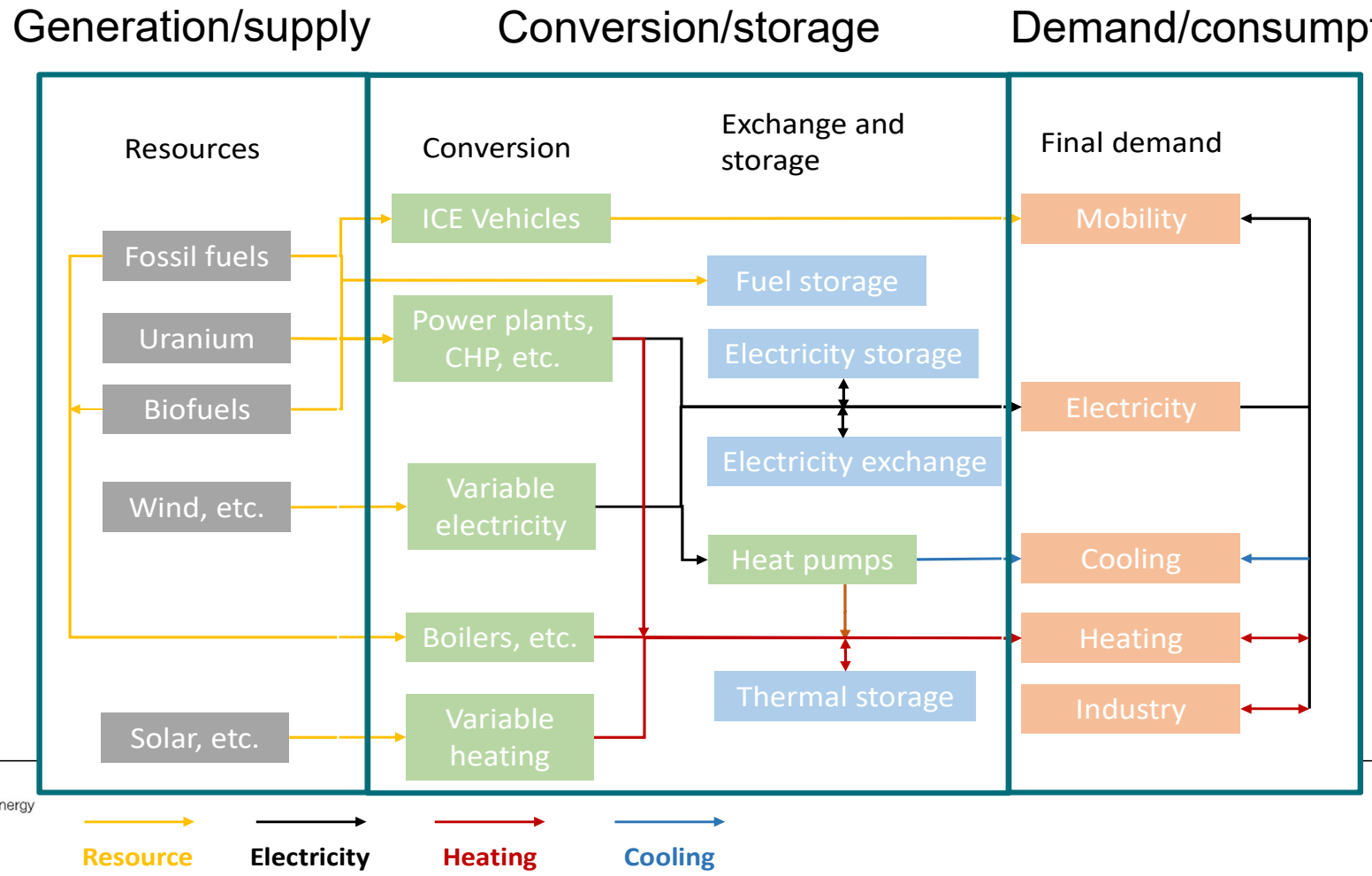
- The difference between the average lifetime cost of producing electricity from a technology and the **system cost** of a technology

- The lack of comparability between variable production and **dispatchable** generation technologies

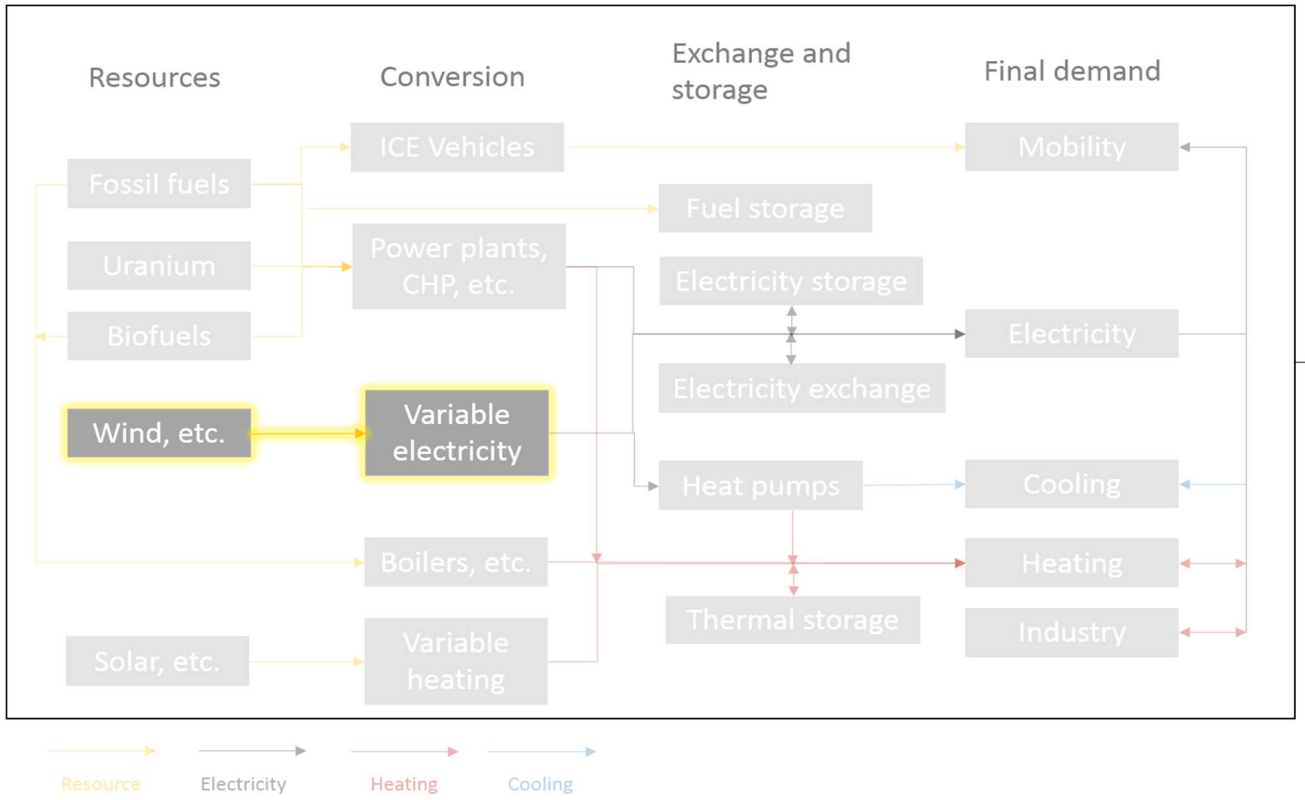
- No monetary value is assigned to the value of electricity in terms of **timing**, i.e. the possible mismatch between electricity production and demand. This is to a higher degree normally valued in electricity prices based on market conditions
    - "a static measure that looks at a snapshot in deriving the price per generated energy, while true market prices are dynamic"

Source: (Branker K, Pathak MJM, Pearce JM. A review of solar photovoltaic levelized cost of electricity. Renew Sustain Energy Rev 2011;15:4470–82)

Energy system perspective



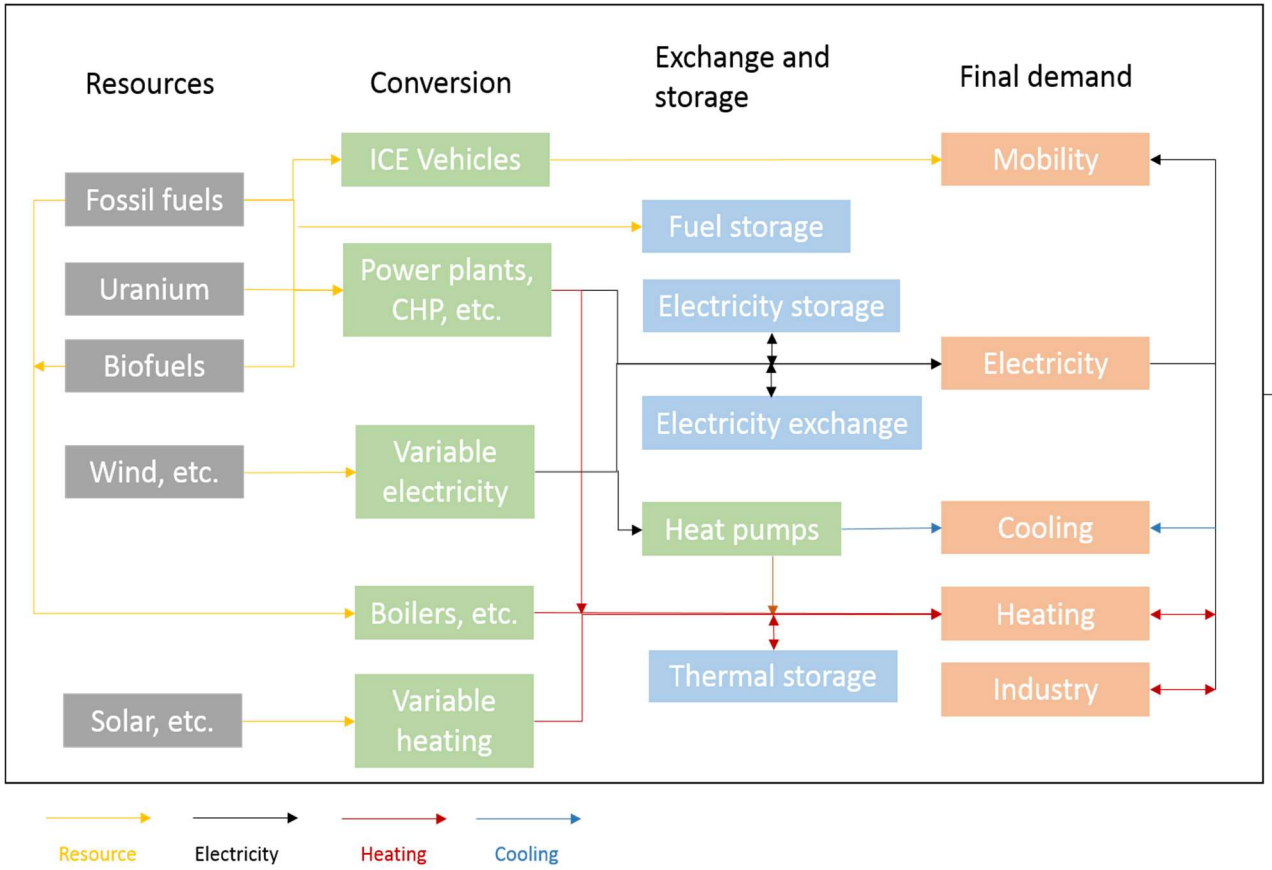
LCOE costs



- Levelized costs:
  - The cost of energy generation
  - Inputs are crucial

Levelized cost (€/MWh)

Energy systems costs



Energy system costs

- Temporality of entire system
- Investments, O&M, fuels, exchange, CO2, annualized over the lifetimes
- System operation and effects are crucial

Energy system cost (B€/year)

Recommendations for LCOE

- What should the LCOE method be used for?
- How is it used in the FIMOI project?

LCOE method

The LCOE method does therefore not autiomatically indicate which investments are best for society, but rather which generation technologies have the lowest cost.

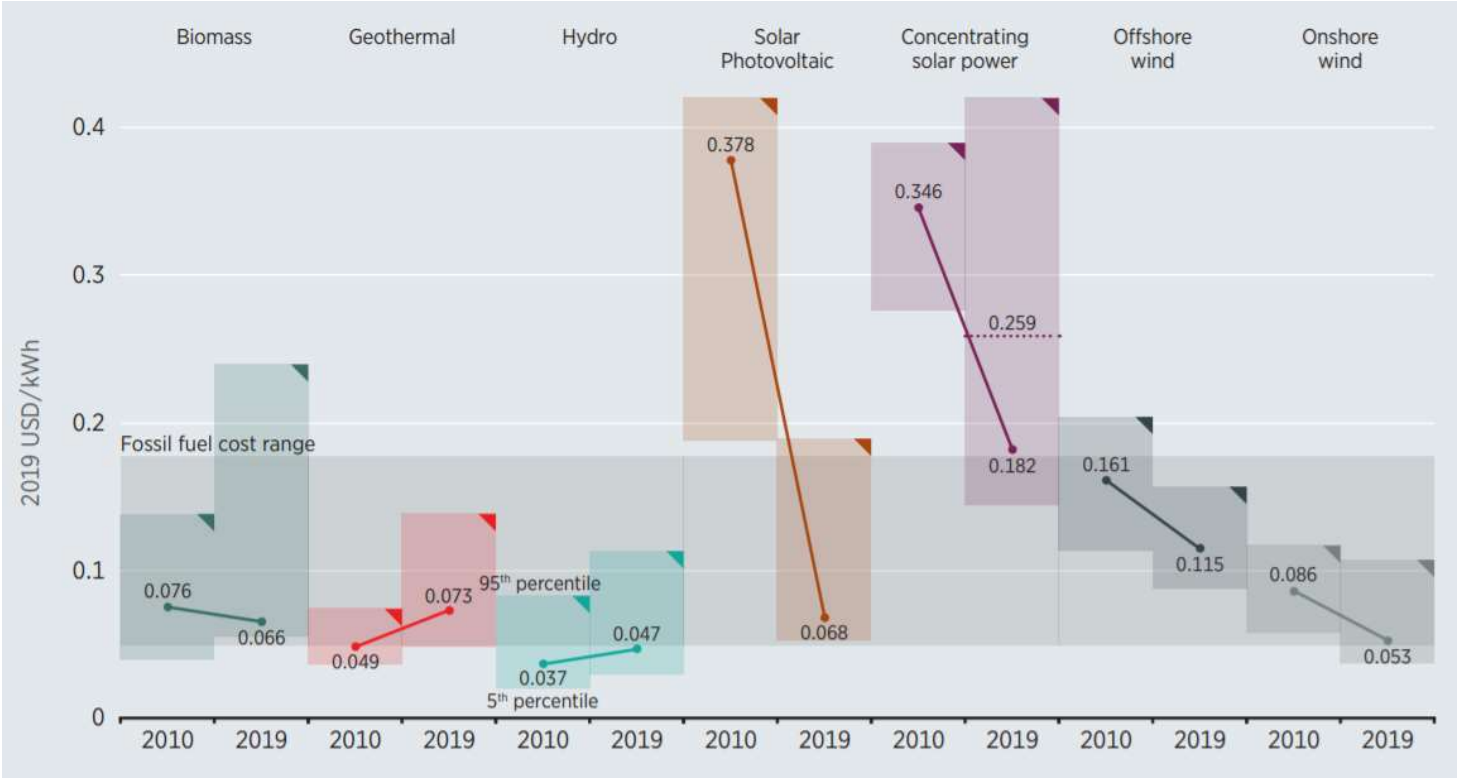
For example, LCOE estimates can highlight low cost trend developments for renewable energy generation technologies, but not the costs of integrating these into society and the value of dispatchable sources and storage.

Beyond the LCOE method other factors such as local availability, energy resource potentials, political ambitions and energy efficiency also impact the feasibility of installing a technology.

How LCOE can feed into decision making

Used for future trends and which technologies to prioritize

Not for designing the actual energy system



LCOE in FIMOI

LCOE in FIMOI from two perspectives:

- Societal perspective for benchmarking and priorities
- Developer perspective for expected costs for first offshore wind farms

Two perspectives means two different tools (session 5 & 6)

- LCOE is subsequently used for sensitivity analysis to analyse the most influential cost factors for offsore wind in India
- Analysis of how to reduce these cost factors to improve competitiveness of the offshore wind market in the long term
- Recommendations for how to achieve and implement these improvements from a government policy perspective

Power modelling in India

Ambition is to develop an Indian power sector technology catalogue to assist power modelling as part of MoP collaboration

Power modelling includes all the system costs and can propose concrete energy policies (investments, etc.)

LCOE can supplement power modelling in terms of trends and data

Next sessions

Upcoming in session 5 and 6:

- ***Introduction to the excel LCOE tool for energy technologies and socio-economic applications***
- ***Introduction to the excel LCOE tool for wind developer project applications***
- ***Examples of how to use these tools***

Q&A Session on Monday, June 15

Live online Q&A session discussing:

- Possible questions from presentations and the project
- The exercises
- Brief evaluation

If you have any questions or points that are worth discussing, please send the questions in advance to keha@ens.dk

They will be aggregated and answered by the DEA!

Exercise

Question 1:

Based on the previous application of the LCOE method, how could it potentially be used in an Indian government context?

Please provide concrete examples

Question 2:

Based on the previous application of the LCOE method, in which situations would it be preferable to use other methods than LCOE in an Indian government context?

Please provide concrete examples

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Thank you for listening!

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