FINDING YOUR CHEAPEST WAY TO A LOW CARBON FUTURE

The Danish Levelized Cost of Energy Calculator

Danish Energy Agency

Low carbon transition is a multifaceted challenge involving political, technical and economic elements. Denmark has developed economic models to optimize decision-making in our energy system, in order to secure continued competitiveness for Danish society.

Low carbon transition does not impede prosperity and wealth formation: Since 1990, Denmark has reduced energy consumption by 7% and CO2 emissions by over 30%, while the economy grew more than 40%.

Investments in new power generation and energy efficiency are important long-term decisions, locking in both public spending and climate impacts for decades. Low initial investments do not necessarily mean a cheap energy supply for society. Quality, security and externalities are of great importance. As a part of Denmark's international cooperation, the Danish Energy Agency (DEA) has developed a Levelized Cost of Energy Calculator - LCoE Calculator - to assess the average lifetime costs of providing one MWh for a range of power production technologies or power savings.

This tool will help compare and select the optimal technologies in the future national energy supply.

In order to facilitate sound long-term decisions in our partner countries, we are proud to present the LCoE Calculator that enables country specific comparisons of the average costs of conventional and new energy solutions. Focusing on not only project specific costs (investment, O&M, fuels, etc.), but also system and society costs, the model gives a holistic assessment of future costs for countries across the globe.

Morten Bæk

Director General
Danish Energy Agency

THE LCoE CALCULATOR

- a method to calculate the unit costs of electricity production from a societal perspective

The LCoE Calculator is a tool to estimate and compare the socio-economic electricity production or saving costs in a simplified manner using localized data and estimates. Based on internationally acknowledged methodology, the LCoE Calculator permits comparison of different electricity production technologies based on nuclear, fossil or renewable energy or energy efficiency.

The LCoE Calculator freely is available to everyone interested in investigating the costs of electricity production and saving.

The economy of difference energy investment such as new generation capacity or energy efficiency measures is quite complex involving both initial investment and future operational cost and interaction with existing supply and demand. Instead of mainly focusing on the initial price tag of different option Denmark has been focusing on analysis of future cost per energy unit supplied or saved. As an essential tool the Levelized Cost of Energy (LCoE) Calculator estimates the average lifetime cost of power production or saving per MWh for different options. The considered costs include both direct costs such as investment costs, fuel costs, operation and maintenance costs and indirect costs such as environmental externalities, system costs, and heat revenue for combined heat and power plants.

EASY TO USE AND ADAPT

The LCoE Calculator is built in Excel making it easy to understand and use. It can be modified to reflect the local conditions in a specific electricity system or a specific country. User instructions are provided for all input parameters to assist the users in adding their own data correctly.

It is an open source tool, without restrictions of use.

ALL DATA IS VISIBLE AND CAN BE MODIFIED

If the user wishes to explore the unit cost of energy for various power options, the LCoE Calculator has a number of predefined settings to choose between. This feature makes it easy for the user to explore the consequences of e.g. higher fuel prices, lower cost of plants or machinery, or higher productivity due to innovations and more effective equipment.

It is possible for the user to modify the default data and to add additional technologies, new fuel types and price scenarios, etc.

The calculations can be observed by the user in the Excel sheet and the results are shown in a diagram with the stacked values. Using the standard function available in Excel, the user can choose which technologies should be displayed in the graph.

DEFAULT DATA

Data for ten power production technologies relevant for the Danish power planning is based on the data from the official Danish Energy Agency's technology catalogue.

In addition seven different power production technologies not relevant in a Danish context based on international technical and financial data have been incorporated in the calculator. The data represents typical values for generic power production plants and are primarily based on the IEA publication "Projected cost of generating electricity 2015".

For energy efficiency (EE) a number of high-potential technologies is being presented with an option to add additional EE technologies or measures.

The default fuel and CO_2 prices are based on the projections from the IEA World Energy Outlook 2015, including the three main scenarios "Current Policy", "New Policy" and "450 ppm". The default costs of local environmental externalities are primarily based on European calculations and estimates, and the system integration cost reflects the experience from Denmark and Germany. All these inputs and parameters can be modified by the user.

The possibility for adjusting parameters is important to be able to mirror country specific circumstances as closely as possible. Fuel costs and access to natural resources are some of the parameters that will often differ between countries or regions.

SYSTEM COSTS AND ENVIRONMENTAL EXTERNALITIES

The LCoE Calculator includes the costs related to system integration and environmental externalities related to emissions.

System costs reflects the costs of new electrical infrastructure, costs of integrating technology specific production profile into the electricity system, and costs of balancing unpredictable power sources. These costs are especially relevant for non-dispatchable technologies such as wind power and solar power, but also nuclear power might cause system costs because of its large and inflexible nature. Dispatchable technologies will often be credited with a system benefit (i.e. a negative system cost). System costs are highly dependent on the configuration of the actual electricity system.

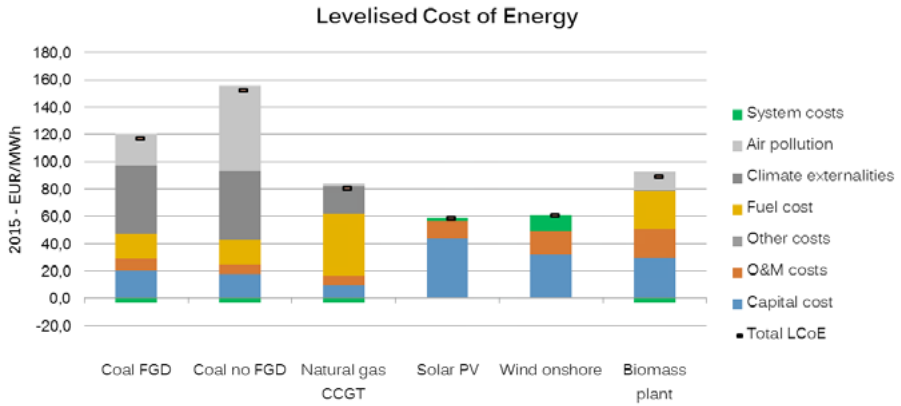
The costs of **environmental externalities** represent externalities from the generation of electricity, which often have no financial consequence for the owner of the power plant but are a cost for society due to e.g. health issues, lower productivity in the agriculture sector, and last but not least climate impact. The LCoE Calculator includes costs of greenhouse gas emissions (CO_2, CH_4, and N_2O) and human health effects due to emissions of SO_2, NO_x, $PM_{2.5}$, and radioactivity.

Cost elements in the calculation of levelized cost of energy

Capital cost: Investment cost of the plant and new or upgraded infrastructure if needed
Fixed operation and maintenance: Yearly costs which are independent of the production
Variable operation and maintenance: Dependent on the produced amount of electricity
Fuel cost: Projected costs of fuels according to IEA World Energy Outlook 2015
CO_2: Cost of CO_2 emission valued according to projected costs in IEA World Energy Outlook or a custom figure
CH_4: Cost of CH_4 emission converted to CO_2 equivalents and valued as such
N_2O: Cost of N_2O emission converted to CO_2 equivalents and valued as such
SO_2: Socio-economic cost of SO_2 emission
NO_x: Socio-economic cost of NO_x emission
$PM_{2.5}$: Socio-economic cost of $PM_{2.5}$ emission
System costs including: ■ **Balancing cost** – Costs of handling deviations from planned production ■ **Profile cost** – The value of electricity generation compared to a common benchmark, such as the average electricity market price ■ **Infrastructure** – Costs for expanding and adjusting the electricity infrastructure
Heat revenue: The earnings from heat sale (only applies to combined heat and power plants)

EXAMPLES OF RESULTS FROM THE LCoE CALCULATOR

The LCoE Calculator provides the following results for the seven key technologies using the default settings:



Key Assumptions. Technology data primarily from "Projected cost of generating electricity 2015" (IEA, 2015). Annual full-load hours for coal, gas and biomass technologies: 5,000, wind power: 3,000, solar PV: 1,700. Discount rate: 4% real. FGD: flue gas desulphurisation

Photovoltaic (PV) and onshore wind demonstrate the lowest LCoE, when all cost elements, including environmental costs and system cost, are considered. It is important to mention, that the costs of wind and solar power are very site specific as they depend on the available wind and solar resource. Moreover, the cost of system integration are very dependent on the penetration level and the flexibility of the surrounding the electricity system. In the example, the system costs are based on projections for Denmark. Denmark has a very high share of wind power (42 % in 2015), but also demonstrates a very flexible electricity system.

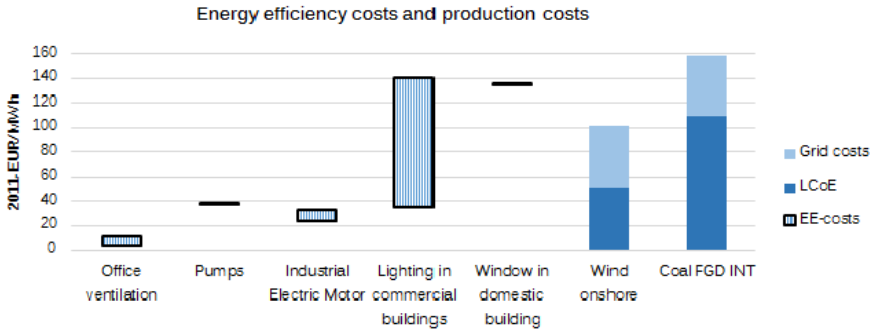
The cost of the biomass feedstock is an important factor for the cost of generating electricity from biomass.

If biomass residues are available at very low or no cost, biomass is close to being competitive with PV and wind power. With regard to coal based power production, the cost of local air pollution may turn out to be a determining factor for the LCoE.

The shown example investigates the LCoE of coal power with and without desulphurization equipment. The results show that the costs of increased air pollution by far exceeds the additional capital costs of the environmental installations. Climate abatement costs may be significant depending on the local regulation.The LCoE of natural gas fired power plant is in particularly sensitive to the price of fuel. Both capital costs and environmental costs are moderate.

Renewables such as PV and wind are considered to be at a relatively early stage of cost development compared to traditional fossil fuel technologies. Technological progress and economy of scale are expected to continue to decrease their cost.

For the ten Danish technologies, the user can generate results with future technical data expected for the years 2015, 2020, 2030, and 2050. The data for future years are estimates of the expected development of the different power production technologies.
As for energy efficiency the LCoE Calculator provides the following results for the five high potential EE technologies using the default settings:



For EE technologies the LCoE Calculator provides a cost range for saving one MWh due to the differences in the initial situation (how efficient is the current solution) and the level of EE measures introduced.

In order to make a fair comparison grid cost related to the power supply needs to be added to cost of generation when comparing cost of energy efficincy to cost of power supply.

As shown office ventilation and energy efficient industrial electrical motor offers the lowest LCoE well below any power generation technology.

WHERE TO FIND THE LCoE CALCULATOR

The LCoE Calculator has been developed for the Danish Energy Agency and can be downloaded from the homepage of the Danish Energy Agency: www.ens.dk/en

A report on the LCoE Calculator, including a user guide and a description of the methodology and key assumptions and can also be found here.

For further information please contact:

Henrik Breum
hebr@ens.dk
Phone: +45 3392 7812

This publication and the LCoE model was made in close cooperation with Ea Energy Analysis.

The Danish Energy Agency's Centre for Global Cooperation supports emerging economies to combine sustainable future energy supplies with economic growth. The initiative is based on four decades of Danish experience with renewable energy and energy efficiency, transforming the energy sectors to deploy increasingly more low-carbon technologies.

Learn more on our website:

www.ens.dk/

For further information, please contact:

Henrik Breum
hebr@ens.dk
Phone: +45 3392 7812

Danish Energy Agency

Danish Energy Agency,
Amaliegade 44, DK 1256 Copenhagen
Phone: +45 33 92 67 00
website: www.ens.dk/en