Energy Data Sources Used in Analysis

The list below provides notes and selected data sources used for an analysis of energy sources in the prior document on this website. Detailed Analysis of Energy Cost by Source.

Each entity that collects actual data on operating energy systems uses a different approach to develop an analysis. There are many different data points for the same metric on the same system. Most data points are not far from a median value. When data from multiple sources differs by a large percentage, it is important to determine the year when that data was collected. Some data may be collected one to four years before it was published. In many cases, energy analysis is performed on data that is one to as much as eight years old. The paper on this website Detailed Analysis of Energy Cost by Source, makes every effort to use consistent data or to update older data based on the most likely values from limited current data when reasonable.

Be aware that many reports use different units to specify energy generation sources. When comparing data from several sources it is frequently necessary to convert units from English to Metric or vice versa. Some sources complicate energy specifications further. Some use annual units based on a full calendar or fiscal year. Others prefer to use units per operating hour which are always different from units per calendar hours. Still others use data per watt or kilowatt or per kilowatt-hour, per system useful life, or horsepower, or joules/s.

- Dept. of Energy Costs https://www.eia.gov/electricity/generatorcosts/ https://www.eia.gov/tools/faqs/faq.php?id=487&t=3
- DoE Geothermal https://www.energy.gov/eere/geothermal/geothermal-faqs
- Science Direct https://www.sciencedirect.com/science/article/pii/S0301421516300106
- Average capacity factor used in this analysis is the simple ratio of actual annual KwHr output to KwHr output if a system generated nameplate power for all 8,760 hours per year.
- Actual costs per KwHr are the total costs to begin production of electricity from a greenfield start. Ongoing costs for energy sources include fuel and maintenance as well as replacements.
- There have been no recent US coal plants due to extra costs of carbon-capture and storage (CCS). A new coal plant in India has been built and started production in recent months without CCS at a total cost of 1313 per KW. EPA regs double total costs for US plants built without CCS. https://www.powermag.com/power-notebook-new-1600-mw-coal-plant-in-india-low-price-solar-deal-in-idaho/
- Values used for wind are based on actual DOE data for land-based systems installed in the US. There is limited data for US based offshore systems which indicate higher costs than land based.
- Solar energy production is the actual output of a solar system for 1 year divided by the nameplate output multiplied over 1 year. The value varies by location. NREL provides an accurate calculator to determine the actual energy output at a specific address. https://pvwatts.nrel.gov/ Output declines for solar PV as panels age. The US average generation of installed solar is 16.1% per NREL www.nrel.gov Data for some cities is noted in the article. https://news.energysage.com/10kw-solar-systems-compare-prices-installers/
- Data on nuclear plants in the US varies depending on year of completion. Plants built in the 1970s were built at less than $3,000 per Kw. The two recent plants at Vogtle, GA are projected to cost $9,000+ per Kw. A value of $10,000 per Kw is used in the analysis. Operational plants in Asia over the last few years have been built for about $2,000 per Kw. China is building two more plants using a Western Design (AP1000) expected to start producing power to the grid soon. These two US-style plants have been built for $3,800/Kw https://www.world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx

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Forbes collected data on US power plants and analyzed actual data available without subscription. https://www.forbes.com/sites/jamesconca/2015/04/20/the-ten-biggest-power-plants-in-america-not-what-everyone-claims/#777d3441a161

- Average useful working lifetime of industrial equipment is generally specified as the number of years after which the equipment is no longer economically viable. In many cases lifetime is determined by average time to total failure. Total failure is not the sole issue. Other factors that determine lifetime are reduced performance, reliability, product maintenance, and unacceptable safety risks.
- Nearly all US electric utilities jointly fund the Electric Power Research Institute (EPRI) www.epri.com EPRI performs research on most energy fields and funds research and development at companies. EPRI also published many useful reports on energy generation, transmission, and storage.
- Actual costs per KwHr are total costs to begin production of electricity from a greenfield start. There are ongoing costs for every energy source such as fuel and maintenance as well as system replacement.
- Maintenance does produce variable operating costs that are not included in fixed capital costs.
- Useful life for each energy source is the period of time when the rising cost of operations and maintenance makes a total replacement more economical than continuing to operate older equipment. In some cases, useful life is dominated by total failure. Total failure is the normal determination of useful life for deep water wind turbines; the cost to repair is too high to justify economically
- DOE tracks the energy output of each type of energy source over its useful life. That analysis uses a value for power output by each energy source at the mid-point of its useful life. Some energy types can maintain their full initial output with normal operations and maintenance that can include replacing turbine blades in hydro and natural gas plants.
- Lifetime capital is total capital required to enable a plant to achieve specified nameplate output for 100 years including total replacements at the end of each useful life and added capacity to compensate for reduced power output over time not corrected by normal operations and maintenance.
- Natural gas data is based on a nationwide average for a combination of old plants with boilers that generate steam to drive a turbine and newer plants that burn natural gas in a turbine adapted from an aircraft engine. DOE data also includes natural gas plants that were converted from coal to use natural gas to boil water instead of burning coal to produce heat.
- Values used for coal plants include the most recent values provided by DOE. These values use the nationwide average of old coal plants and newer coal plants that all use a boiler to produce pressurized steam that is sent to a steam turbine.
- The newest generation of deep-water ocean-based wind turbines have been failing long before their projected useful life of about 20 years. Failure analysis is not yet complete but preliminary results point to extreme loads on blades and bearings due to swaying and vibration in severe storms.
- Numerous recent very-large deep-water wind farms have been failing in less than 20-years.
- https://stopthesethings.com/2018/03/30/mass-blade-fail-means-early-retirement-for-hundreds-of-danish-wind-turbines/
- Nuclear plants and hydro plants have ongoing operations & maintenance costs that enable full power operation over their useful life that are not included in capital costs.
- High initial capital costs for nuclear plants only apply in the US and EU due to excessive regulatory factors and delays due to frequent changes in government requirements plus litigation from various groups. Capital costs for recent plants in developing countries have been as low as ¼ of US capital costs.
- US Energy Information Administration data https://www.eia.gov/electricity/data/eia923/

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- US Energy Information Administration data on Natural Gas Prices over time https://www.eia.gov/dnav/ng/hist/n3035us3m.htm
- Fuel consumption data for various energy production types and water consumption for various energy types including biomass. https://michaelbluejay.com/electricity/fuel.html
- Recent natural gas plants are more fuel efficient due to advances in turbines.
- Some data on solar, wind and natural gas was sourced from the National Renewable Energy Lab www.nrel.gov and from the Electric Power Research Institute https://www.epri.com/
- The capital cost for coal plants is based on the most recent DOE coal plant data at plants with scrubbers and other controls to limit NOx and SOx pollution. Newer plants are built to enable the addition of carbon capture and storage but do not include that feature. There are few recently built US coal plants. To get more recent estimates a portion of the coal plant capital costs were based on very recently constructed plants in India. The analysis on the prior document estimates a US plant costs about 2 times the costs in India.
- Cost data for wind farm use DOE data for land-based large turbines. The newest ocean-based wind turbines installed far from land in the EU have been failing long before 20 years, which was their projected useful life. https://www.sciencedirect.com/science/article/pii/S0029801818319474
- Nuclear fuel costs used are actual costs per DOE. Costs are dominated by a relatively low cost of nuclear fuel from Zambia. Fuel costs could double to triple if there were a US based fuel recycling operation that recovers 90% of the remaining fuel from "spent fuel rods" similar to that used in France. https://atomicinsights.com/nuclear-energy-is-cheap-and-disruptive-controlling-the-initial-cost-of-nuclear-power-plants-is-a-solvable-problem/
- Geothermal steam turbine maintenance factors and costs. https://asmedigitalcollection.asme.org/POWER/proceedings-abstract/POWER2013/56055/V001T05A005/279197
- Hydropower data sourced from the International Renewable Energy Agency (IRENA). https://irena.org/ Larger hydro facilities have been retrofitted with improved water turbines
- Operation and maintenance costs by fuel. https://www.power-technology.com/features/featurepower-plant-om-how-does-the-industry-stack-up-on-cost-4417756/
- Actual costs per KwHr are the total costs to begin production of electricity from a greenfield start. There are ongoing costs for every energy source such as fuel and maintenance as well as system replacement.
- Numerous recent very-large deep-water wind farms have been failing in less than 20-years.
- These high capital costs only apply in the US and EU due to excessive regulatory factors and delays due to frequent changes in government requirements plus litigation from anti-nuclear groups. Capital costs for some plants in developing countries have been as low as ¼ of US capital costs.
- https://askwonder.com/research/power-plant-costs-operation-and-maintenance-us-xl8xy2abp 3
- https://asmedigitalcollection.asme.org/POWER/proceedings-abstract/POWER2013/56055/V001T05A005/279197
- Nuclear plant cost https://atomicinsights.com/nuclear-energy-is-cheap-and-disruptive-controlling-the-initial-cost-of-nuclear-power-plants-is-a-solvable-problem/
- China nuclear power https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/china-nuclear-power.aspx
- Economics of Nuclear Power https://www.world-nuclear.org/information-library/economic-aspects/economics-of-nuclear-power.aspx
- Dept. of Energy Costs https://www.eia.gov/electricity/generatorcosts/
- DoE Geothermal https://www.energy.gov/eere/geothermal/geothermal-faqs
  Science Direct https://www.sciencedirect.com/science/article/pii/S0301421516300106
- https://markets.businessinsider.com/commodities/coal-price

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- Failure Mode of Offshore Wind Turbines https://www.sciencedirect.com/science/article/pii/S0029801818319474
- Life Cycle Reliability and Maintenance Analyses of Wind Turbines https://www.sciencedirect.com/science/article/pii/S1876610217301789
- The DOE National Renewable Energy Lab provides a web-based calculator to determine the energy generated by any type of solar installation based on the physical location and physical properties. https://pvwatts.nrel.gov/
- Solar installers collect data and provide that data back to NREL to adjust the model. https://news.energysage.com/10kw-solar-systems-compare-prices-installers/