Nuclear energy

Nuclear energy or nuclear power is produced in nuclear power plants using heat generated from a nuclear reaction (often nuclear fission) in a contained environment to convert water to steam. This powers generators to produce electricity. Besides nuclear fission, nuclear fusion is another technique which, however, is not yet being used to generate electricity for the mainstream consumers.

Nuclear power plants operate in most states of the US, in Japan, and across Europe. They produce about 20 percent of the USA’s power. Nearly 3 million Americans live within 10 miles (16 km) of an operating nuclear power plant. According to the most recent review article on the sustainability of nuclear power -- as currently practiced in the U.S., nuclear power generated from nuclear fission is not a sustainable energy source.[1]

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How it works

Nuclear power is a type of nuclear technology involving the controlled use of a nuclear reaction (i.e. nuclear fission) to release energy for work including propulsion, heat, chemical processes, pressure exchange, and the generation of electricity.

Nuclear power production makes use of nuclear fission reactions that release the binding energy of uranium atoms. In order to be used in the nuclear fuel cycle, uranium 235, which is found in natural uranium, must be concentrated. The primary type of nuclear power system used is a boiling water reactor.

"Too cheap to meter"

"Our children will enjoy in their homes electrical energy too cheap to meter," he declared. ... "It is not too much to expect that our children will know of great periodic regional famines in the world only as matters of history, will travel effortlessly over the seas and under them and through the air with a minimum of danger and at great speeds, and will experience a lifespan far longer than ours, as disease yields and man comes to understand what causes him to age." Lewis L. Strauss Speech to the National Association of Science Writers, New York City, September 16th, 1954 [New York Times, September 17, 1954].

This was the view of Lewis L. Strauss, chairman of the Atomic Energy Commission. This vision didn't happen for reasons such as each plant having to be tailored to fit the need of the surrounding area. New regulations (e.g. for reasons of safety) put constrains on construction. This hiked up costs of building.

The article "The Nuclear Cost Shell Game" explains how the full costs of nuclear power plant construction, operation, decommissioning and accidents are shoulerded by governments thereby disguising the real costs of nuclear power.

Recent publications from the U.S. Energy Information Administration state that nuclear power is expected to remain one of the more expensive energy sources for electrical power generation as the cost of conventional renewables falls.

Government subsidies

The UK government in 2010 declared that it would allow additional nuclear plants to be built, but would not support them through subsidies - this included a refusal to act as an insurer of last resort. This may effectively kill nuclear power as an option in Britain, especially considering the likelihood of increased insurance costs after the disaster in Japan in March 2011.

Nuclear disasters

From Natural disasters edit

Many releases of nuclear material have occurred around the world, but the threat posed to human health by those releases can be quantified. Quantitative analysis reveals that when evaluated on the basis of deaths per gigawatt-year of electrical power generation, nuclear power is safer than fossil fuel energy sources and nearly as safe (within 2 deaths per gigawatt-year) as the
conventional renewable energy sources. When expressed in terms of expected deaths per year at a national scale, nuclear reactors are many orders of magnitude safer than roadways and other widely accepted technologies. Advocates of nuclear power have argued that modern designs with proper safety considerations are failsafe[5] or at least extremely safe, without the fundamental flaws in design and operation of earlier plants, particularly the Chernobyl plant.

**Safe nuclear power**

*From Safe nuclear power  edit*

Nuclear energy is potentially low carbon energy, but many important questions need to be answered before claims of safe nuclear power can be made:

- Is the plant on a tectonic fault line, at risk of damage from earthquakes?
- Is the plant in a potential tsunami zone? (Add a large margin of error for the "unknown unknowns."")
- How can we be confident in the competence of the operators, including those running the plant in decades time... who may not even be born during the planning stages.
- Nuclear power plants are not able to be insured on the free market in any country without an artificial cap on their liability. Who is the insurer of last resort? This is always the government (tax payer) (additional info). The UK government's refusal to take this role effectively kills nuclear there. [verification needed] That makes sense - subsidized insurance for nuclear industry (corporate welfare) distorts the market. But of course, until there's a price on carbon, or until polluters are charged for the health and environmental damage- the market is already distorted.

**Types of Radiation**

- Alpha radiation
- Beta radiation
- Gamma radiation

**Advantages**

- Nuclear power plants produce less greenhouse gas emissions than fossil fuels
- Embodied carbon in the construction and operation of nuclear power plants is similar to that of wind and hydro and less than that of solar photovoltaic panels[6]
- A nuclear power plant's land area requirement per megawatt of electrical power generation is many orders of magnitude less than that of wind, solar, and hydro.[7]
- Nuclear reactors provide abundant heat cogeneration
- Nuclear power plants deliver more temporal reliability in electrical power generation than wind and solar, which have daily capacity fluctuations.[8]
- Nuclear reactor fluids provide pressures adequate to drive desalination processes.[9]
- Some nuclear reactor designs provide sufficient heat and chemical energy to convert biomass into liquid fuel as a sidestream process.[10]
- Nuclear power plants produce less uranium emissions than coal, which contains traces of radioactive material, released into the atmosphere when burnt.[11]
- Integral fast reactor will provide renewable fuel vis a vis uranium harvesting from oceanwater.[12]
Integral fast reactor will provide a means to dispose of the existing stockpile of spent nuclear fuel and weapons.\cite{13}

Disadvantages

Power generated from nuclear fission is not a sustainable energy source.\cite{14}

- Security issues:
  - Nuclear material cannot be, and has not been, kept safe from those who want it for violent and illegal purposes.\cite{verification needed} Having more radioactive material being transported, stored and handled, will inevitably increase that risk.\cite{verification needed}
  - Transport and power generation activities are targets for terrorist attacks.
  - Most contemporary reactor types require enriched uranium. Enriched uranium can also be used to produce nuclear weapons. There is currently a move towards using reactors that use low/non enriched uranium to circumvent this. Some types of nuclear reactors do not need it at all.

- Age issues:
  - Normally it is photovoltaics or wind turbines that get blamed for having too short expected productive life span. Current nuclear power plants are very old, built in 1970’s and 1980’s. And they should be dismantled (Decommissioning) out of safety reasons (material fatigue) after 35-40 years to be safe enough. Many European nuclear power plants are going through regular safety updates, which are expensive, to make them stay productive much longer.

- Environmental issues:
  - Accidents and emissions cannot be completely eliminated, at least not when using nuclear reactor designs that are not inherently safe. Examples are the Three Mile Island and the 2011 Japanese disaster. It is recommended that those that live in the area of a nuclear reactor keep supplies of Potassium Iodide.\cite{15}
  - Mining inevitably releases radioactive materials into the environment.
  - Decommissioning
  - Long-term loss of use of land due to contamination from radioactive material has consumed 1,000 square miles of the Chernobyl Exclusion Zone\cite{16} and 4,500 square miles at Fukushima.\cite{17}
  - Waste products from radioactive material
  - Depleted uranium is a by-product of the concentration process. This waste product would be completely eliminated with 4th generation power plants (see MYRRHA project, ..)

Liability issues and the indirect nuclear insurance subsidy

The potential liability from a nuclear accident/terrorist attack/natural disaster is so great that no nuclear power plant could be built if the owner had to pay for the full cost of liability insurance. Currently in the U.S. the liability is limited on liability for nuclear power plants under the Price Anderson Act (PAA). As former U.S. Vice-President Dick Cheney made clear when he was asked in 2001 whether the PAA should be renewed; he was quick to respond that without the PAA "nobody's going to invest in nuclear power plants".\cite{18} The U.S. Nuclear Regulatory Commission (USNRC) concluded the liability limits provided by nuclear insurance were significant as to constitute a subsidy, but a quantification of the amount was not attempted.\cite{19}

Shortly after this in 1990, Dubin and Rothwell were the first to estimate the value to the U.S. nuclear industry of the limitation on liability for nuclear power plants under the Price Anderson Act (PAA). Their underlying method was to extrapolate the premiums operators currently pay versus the full liability they would have to pay for full insurance in the absence of the PAA limits. The size of the estimated subsidy per reactor per year was $60 million prior to the 1982 amendments, and up to $22 million following the 1988 amendments.\cite{20} In a separate article in 2003, Anthony Heyes updates the 1988 estimate of $22
million per year to $33 million (2001 dollars),121 and also acknowledges that as he and Liston-Heyes simply corrected the methodology of Dubin and Rothwell's study and did not introduce new variables; the true subsidy estimates could actually be even higher. Heyes goes on to say: "Do Heyes and Liston-Heyes think that the true number might actually be 10 times bigger? Sure they do. Do they think that their number is closer to the truth than Dubin and Rothwell's number? No, they do not".22

In case of an accident, should claims exceed this primary liability, the PAA requires all licensees to additionally provide a maximum of $95.8 million into the accident pool - totaling roughly $10 billion if all reactors were required to pay the maximum. This is still not sufficient in the case of a serious accident, as the cost of damages could very likely exceed the $10 billion.232425 According to the PAA, should the costs of accident damages exceed the $10 billion pool, the remainder of the costs would be fully covered by the U.S. Government. In 1982, a Sandia National Laboratories study concluded that depending on the reactor size and 'unfavorable conditions' a serious nuclear accident could lead to property damages as high as $314 billion while fatalities could reach 50,000.26 A recent study found that if only this one relatively ignored indirect subsidy for nuclear power was diverted to photovoltaic manufacturing, it would result in more installed power and more energy produced by mid-century compared to the nuclear.27 The results clearly show that not only does the indirect insurance liability subsidy play a significant factor for the viability nuclear industry, but also how the transfer of such an indirect subsidy from the nuclear to photovoltaic industry would result in more energy and more financial returns over the life cycle of the technologies. The energy results alone indicate renewable alternatives are a more viable option, let alone when other shortcomings and risks of nuclear power are added to the list: high construction costs, security and proliferation risks as well as the problems with the long term nuclear waste management.28

- See also: Diverting indirect subsidies from the nuclear to the photovoltaic industry: Energy and financial returns.

**Criticism**

Although nuclear power is proposed as a partial solution to global warming, there is a general belief that this advantage outweighs its disadvantages, such as:

- Concerns about the life cycle of nuclear materials
- Concerns about safety, due to human error, terrorism and/or natural disasters
- There are technically superior solutions to climate change with renewable energy which both have less risk and lower costs than nuclear power.

**Addressing criticisms of nuclear energy**

**Note:** this section needs to be supported with references from the peer-reviewed literature - please help by editing it.

This is an attempt to engage with some of the issues, addressing some of the criticisms made of nuclear energy:

- Although in theory, renewable energy can meet the world's energy needs - e.g. see Beyond Zero Emissions, there is still the issue that most renewable energy production plants cannot generate power continuously. Storage of power is a partial solution, which can be coupled to load shifting, energy conservation, and smart grid policies. It should be noted that most options to store power also have an ecological impact (i.e. electrochemical (EC) batteries require chemicals to operate and need to be replaced every 5-7 years or so, depending on the type of EC battery).
- The idea that there is only 60 years of uranium left is geologically debatable. Further, it is possible to expand the supply of uranium through the use of breeder reactors and "fourth generation" nuclear reactors.29
Radioactive waste can be stored effectively, particularly using means like the Australian Synroc. Further, the radioactivity of the waste does not persist for hundreds of thousands of years - more like thousands - and claims about its radioactivity represent fundamental misunderstandings about the nature of radioactive decay.

It's unfair to claim that pro-nuclear people have vested interests. Some do. Some don't. Some anti-nuclear people are running solar cell firms, or have jobs which depend on their viewpoint. But logically you can be both right and have a vested interest. Accusations of vested interest should be made with care, lest they reflect back on you.

Construction - putting things in place, wiring them up and testing, is not a particularly CO2 intensive process. The mere fact that a nuclear power plant takes some time to construct does not mean its CO2 load is particularly high. Calculations do point to the CO2 effectiveness of power plants, and wind farms use more metal to fabricate than a nuclear plant able to generate the same power would need.[verification needed]

We do other things which generate CO2 than just produce energy, and nuclear plants do take some time to come online. Certainly, we should do other things to reduce global CO2. But that does not stop nuclear power from having a part to play.

Hot rocks and burning garbage are important potential energy sources. Just as we might point to nuclear power distracting us from other options, we can point to wind and solar distracting us from these other important renewable energy sources.

This page or section needs to be expanded. You can help Appropedia by adding information on this topic. Thanks! See the talk page for more details.

We do need to consider the steps needed to make a technology viable, be it fourth generation nuclear reactors, clean coal, wind, solar and other renewables, even fusion power.

The Australian political scene, with Howard promoting Nuclear Power, is more complex than would first appear. Howard did, for example, implement changes to the Building Code of Australia which controlled energy usage.

This page or section needs to be expanded. You can help Appropedia by adding information on this topic. Thanks! See the talk page for more details.

Nuclear reactors may be difficult to insure, but this could be because they are not standardised. Further, it is interesting that many anti-nuclear activists challenge market operation in other areas, but assume the insurance market is perfect at assessing risk.

If we (in Australia) were to export uranium and store the resultant nuclear waste, we could prevent weapon proliferation. [verification needed] Further, ethically it is strange to be happy to sell something with significant consequences in its use but take no responsibility for them.

This section includes ideas based on Thoughts on Nuclear Power by JohnAugust.

Types of nuclear reactor

Thorium

"I reckon we do need one small reactor on each continent to provide isotopes for diagnostics, but there are three main problems with conventional nuclear power: there's the risk of meltdown; the problem of radioactive waste … and reactors produce [nuclear] weapons fuel. 'I'm in favour of some types of nuclear power which don't have these problems. Unfortunately political leaders aren't interested in [these alternative designs, i.e. thorium] because they want the nuclear weapons." - Karl Kruszelnicki[30]
The Integral Fast Reactor (IFR) is a fast nuclear power reactor design developed from 1984 to 1994. The design includes both a new reactor and a new nuclear fuel cycle. The reactor is called the Advanced Liquid Metal Reactor (ALMR). The ALMR is a "fast" reactor—that is, the chain reactions between fissile material is maintained by high-energy unmoderated neutrons. The fuel cycle is distinguished by being closed; meaning that the fuel is produced, the power is generated, the fuel is reprocessed utilizing pyroprocessing, and the waste is managed all on site, reducing the risk of accidents during delivery and the risk of proliferation from theft of the nuclear material.

The funding, the scale, and the duration of the research project make it the largest energy research project in US history. Over the course of ten years of research over a billion dollars was allocated to the Argonne National Laboratory in order to develop a nuclear reactor which reduced the risk of proliferation, decreased the amount of nuclear waste, and increased the efficiency of the fuel cycle. The project was given ample funding and was progressing well, but then was canceled abruptly during the Clinton administration with the only reason given that "We will terminate unnecessary programs in advanced reactor development."

The project was not only canceled, it was also ordered to silence by the Department of Energy and all the progress that was made by the scientists over the decade of research was ordered to not reach the public ear.

Nuclear Energy vs. Renewable Energy

There are many costs to consider when choosing where and how to generate electricity. Such as the start up cost, availability of the fuel source, implementation cost and time, and operating costs. The graph below shows the range of capital costs for every different type of renewable energy except for biomass.

Cost

Capital Costs are the start up cost or the implementation cost to build renewable technology.

This graph below shows the operating costs of the different types of energy except for biomass.

This table shoes the different types of fuels in terms of specific energy.
Availability

Looking at the availability of a resource is just as important to determine if a renewable technology will be efficient or not. Biomass and water (varying in season) are practically everywhere on this planet and the current uranium on the planet can supply the world for 230 years. Hopefully in 230 years, we may switch to another fuel source, like thorium or start making nuclear fusion more feasible and cost effective.

On average the sun shines about 12 hours a day, meaning we can only generate electricity for half a day. The average wind speed varies from 6.64m/s over the ocean and 3.28m/s on land. Or 21.77ft/s over the ocean and 10.75ft/s over the land. Wind turbines can start generating electricity at wind speeds from 3-4m/s and the turbine shuts down if the wind speed is too high (25m/s).

Biomass

Some of the health hazards of Biomass include the following:

1. Spontaneous Auto-Ignition
   - There are three requirements for Spontaneous Auto-Ignition to occur; first is the presence of oxygen, second a type of fuel that can be ignited and third combustible dust or particles that air easily flammable. The presence of microorganisms may increase the temperature within the fuel source. Therefore which may lead to a spontaneous auto-ignition and turn the biomass power plant on.

2. Self Explosion
   - A Self Explosion can occur when there is the presence of five basic elements that are found at a biomass power plant; first is the presence of oxygen, second is the dispersion of dust particles, third if there is a dust cloud present, fourth the type of ignition source and fifth is the combustible dust availability. A Self Explosion is very similar to an Spontaneous Auto-Ignition, but the main difference between the two is that in an explosion, there are particles suspended in the air that are easily flammable. Therefore causing many health impacts because the reaction is not contained compared to the Spontaneous Auto-Ignition. There were two reports of serious explosion first occurring at the Inferno Wood Pellets Company in Rhode Island and second at Laxa pellets in Sweden.

3. Increase of Fungi
   - Fresh biomass piles have warm temperatures and high concentrations of humidity, thus causing fungi to thrive in those types of habitats. Aspergillus Fumigatus can cause eye, ear and sometimes lung infections in a human body. Some of the symptoms that are caused by Aspergillus Fumigatus include the following; Fever an chills, coughing, shortness of breath, chest of joint pain, headaches, nosebleeds and possibly facial swelling.

4. Increase in Carbon Oxide, Carbon Dioxide and Methane
   - These three gases are greenhouse gases and trap heat in the atmosphere. Also if an individual is exposed to these gases for a long period of time, they will be deprived of oxygen and cause many health effects. Even though Biomass Energy is considered to be net zero emissions when producing energy. It still has many cost effects and hazards that can be impact to species and the environment.

Hydroelectric

Some impacts that can arise from Hydroelectric projects include the following;

1. Decrease in Wildlife
   - Dams interrupt the migration of fish species throughout the year and also cause an increase in sedimentation after the dam. Therefore effect the health of the wildlife in the stream or river. A possible solution has been implemented in
dams and that's the idea of a fish ladder. Fish would essentially swim up this ladder to migrate around the dam. However recent studies found that fish ladders are not working. 

2. Increase in Global Warming Emissions
   - Depending on the size of hydroelectric plant, they can emit .01 to .06 pounds of carbon dioxide for every kilowatt-hour. Also the location of the hydroelectric plant if another factor that contributes to the total carbon dioxide the emit. For example in a more tropical area, the area can be flooded and produced more methane and carbon dioxide into the atmosphere compared to really dry areas.

3. Land Use
   - Building a hydroelectric reservoir has a huge environmental impact: it destroys what vegetation that existed there as well as the soil, it causes the animals using that habitat to move else where and it causes higher evaporation rates of water.

Geothermal

Some Environmental Impacts/Hazards that originates from Geothermal Energy:

1. Changes in Water Quality
   - Hot water that is pumped from underground reservoirs contain high levels of sulfur, salt and other minerals. After the pumped water spins the turbine, it gets pumped back into the ground which may contain small traces of steel and/or concrete. Also geothermal plants re-inject water into a reservoir to avoid contamination. However not all of the water makes it to the reservoir because it is loss as steam. Thus have to retrieve water from elsewhere to keep the same amount of water throughout the system, also known as a closed system. Geothermal plants may require from 1700 to 4000 gallons of fresh water to produce 1 megawatt hour. Therefore changing the water quality and the amount of fresh water present.

2. Air Emissions
   - The emissions that may be produced from geothermal power includes: hydrogen sulfide, carbon dioxide, ammonia, methane and boron. When hydrogen sulfide enters the atmosphere, it gets converted into sulfur dioxide. However geothermal plants produce 30x less sulfur dioxide then coal power plants. They also produce sulfur, vanadium, silica compounds, chlorides, arsenic, mercury, nickel and other heavy metals that are disposed at hazardous waste sites. For every 1 kilowatt produced, geothermal plants release 0.1 pounds of carbon dioxide equivalent into the atmosphere.

3. Changes in Land Use
   - Not only do geothermal plants take up a huge amount of land, they have higher levels of earthquake risk. Pumping water out of the ground has a similar effect has hydraulic fracking. Causing more earthquakes to happen because the absent of water in the ground to stabilize the landscape.

Wind

1. Noise
   - When wind turbines rotate, they make a lot of sound. As time progress, the later models of wind turbines are much quieter, but still produce some noise. Using the right design techniques and the most efficient insulation materials, the noise coming from the wind turbines can be minimal.

2. Visual Impacts
   - Some people do not like have a wind turbine in their "backyard" because they do not like the aesthetics of it. Therefore places that can have really high wind speeds could be an optimal place for wind turbines, but if people do not want them there, then they have to move else where.

3. Avian/Bat Mortality
   - Birds and Bats sometimes collide with wind turbines. The collision of birds/bats into wind turbines is a huge controversy in biology. To address these issues, there has been research where birds or animals have not been active.
in a specific areas and therefore can place their wind turbines there with careful site selection.

4. Other Concerns
   - There are some toxic products that can occur in wind turbines such as lubricating oils, hydraulic and insulating fluids. Therefore leading to a possibly on having these toxins leaching into the groundwater.
   - Or the generators in the wind turbines produce electric and magnetic fields, therefore can have the potential to interrupt radar and radiometric devices.\textsuperscript{[43]}

**Solar**

Some safety concerns about solar power include the following:

1. Greenhouse Gases
   - One common greenhouse gas that is involved to produce solar panels is nitrogen trifluoride, which is 17,000 times more potent than carbon dioxide. Also sulfur hexafluoride is emitted when building these panels and is the most potent greenhouse gas known.

2. Hazardous Byproducts
   - Solar panels also produce toxic byproducts and possibly polluted water. Every ton of polysilicon that is used in producing solar panels, four tons of silicon tetrachloride is created and it can make the topsoil uninhabitable for plant growth. A study at San Jose found that the creation of one solar panel on average causes a small amount of environmental degradation for 3 months to full recover.\textsuperscript{[44]}

3. Electrical Dangers
   - Depending on how you wire your solar panels (series or parallel), having a too big of a voltage drop could fry your circuit. Also in the event of the blackout, if a solar panel is wired to the grid it could possibly cause danger to the workers repairing the wires. If the entire grid is down, there would be no current flowing through the wires so it would be safe to work with. However if there was a current flowing through the wire without the workers knowing, it would cause some damage.

4. Installation Risks

Since the majority of solar panels are on top of houses, there is a risk of falling off of the house or carpentry work when screwing down the panel to the roof.

**Nuclear**

1. No long-term solution to waste
   - The primary components of nuclear waste include Uranium 235 and Plutonium. TerraPower is a nuclear energy technology company that was established in 2008 and is based our of the state of Washington. Their main fuel source to create energy from nuclear energy is depleted uranium or Uranium 235 which is the waste product instead of Uranium 238. With the abundance of depleted uranium, TerraPower's \textit{traveling wave reactor} will be able to produce power for decades using the depleted uranium.\textsuperscript{[45]}

2. Expensive start up cost, but are relatively cheap to operate. Therefore producing a relatively low LCOE (levelized cost of electricity)or also known as the total net cost over the time period that a specific energy resource was active. For example a solar panel can roughly run for 20 years and nuclear power plants can run for 50-70 years.

3. In the past there was not a lot of public support for Nuclear Power, but as time progresses people are starting to accept nuclear power since it is one of the two alternative energy sources that can be created on demand.\textsuperscript{[46]}

See the following content:

- \texttt{Indian Point Energy Center}\hyperlink{url}{[link]}
- \texttt{Sustainable Energy - Without the Hot Air}\hyperlink{url}{[link]}
Suggested projects

- How does nuclear energy compare with renewable energy sources for total financial cost to the community (i.e. if no subsidies or equal subsidies were given to all forms of energy production)? [expansion needed]

- How does nuclear energy compare with renewable energy sources for total greenhouse gas emission? All energy should be assessed, including energy used in accessing the raw materials (e.g. uranium for nuclear power and silica for solar cells) and making the energy producing devices (nuclear power plants, solar cell arrays, wind turbines). [expansion needed]

- How does modern nuclear power compare with coal for the release of radioactive material into the environment? Consider all aspects, including mining and power generation. [expansion needed]

See also

- Limitations of nuclear power as a sustainable energy source

Notes

2. Too Cheap to Meter?
4. Sustainable Energy - Without the Hot Air
5. Fail-Safe Nuclear Power
6. Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources
7. Sustainable Energy - Without Hot Air
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