DELAWARE RIVERKEEPER NETWORK

Natural Gas Versus Renewable Energy Alternatives

The natural gas industry claims that shale gas is an environmentally sound energy and argues that some of the impacts of renewable energy, such as solar and wind, are relatively high or higher than using natural gas. This is because life-cycle impacts can vary widely depending on the assumptions used in the analysis.

- Natural gas is mostly methane, a GHG that is 70 times more potent than CO_2. Large amounts of methane escape into the air during production, transmission, and distribution due to leaks. One study found that if as little as 3% of the methane that is taken out of ground escapes/ leaks, you might as well be burning coal (from a climate perspective).[1]
- Research is documenting that the 3% figure is being exceeded. It has been estimated that "during the life cycle of an average shale-gas well, 3.6 to 7.9% of the total production of the well is emitted to the atmosphere as methane." [2] Among the most recent scientific findings is that as much as 9% of the methane produced while drilling for gas is lost to the atmosphere.[3]
- Because shale gas is predicted to be plentiful and cheap, economic modeling suggests that the rapid expansion of shale gas will drive out most other sources of electricity, including renewables. Since power plants are designed to last decades, natural gas power plants built today will lock in our energy system for a significant time period.[4]
- Sufficient resources are available to power solar and wind technology. The capture of just 1% of the theoretically available solar power would supply more than the world's power needs. The wind power available in locations over land in the US is almost twice the current US energy consumption. Wind resources off the shallow Atlantic coast could supply a large portion of the entire US electric power.[5]
- Lifecycle analysis (LCA) looks at the impacts associated with a technology over the entire course of existence including resource extraction/ fabrication, construction, operation, and decommissioning. These analyses may differ depending on the assumptions used in the calculations. Furthermore, fully understanding the lifecycle impacts of renewable energy is necessary to create the most effective and safe energy options.
- Environmental measures that are considered in LCA analyses include GHG emissions, water consumption, land use impacts such as deforestation or forest degradation, impacts on wildlife and biodiversity, and health impacts including toxicity and carcinogen output. Solar power technologies have water use, land use, and hazardous material impacts, whereas wind power impacts include land use and wildlife.

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[1] Alvarez, R. A., Pacala, S. W., Winebrake, J. J., Chameides, W. L., & Hamburg, S. P. (2012). Greater focus needed on methane leakage from natural gas infrastructure. Proceedings of the National Academy of Sciences.

[2] Howarth, *supra note* 55.

[3] Methane Leaks Erode Green Credentials of Natural Gas, Nature International Weekly Journal of Science, Jan. 2, 2013. See also Howarth, *supra note* 56

[4] Jacoby, H. D., O'Sullivan, F. M., & Paltsev, S. (2011). The influence of shale gas on US energy and environmental policy. MIT Joint Program on the Science and Policy of Global Change.

[5] Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science, 2(2), 148-173.

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GHG emissions

- Wind and solar technology emit the most GHG during the extraction/ fabrication phase (71.5% and 71.3%, respectively) followed by construction (24.0% and 19.0 %) and operation (23.9 % and 13.0 %). Decommissioning of these technologies usually results in recycling materials into future production and therefore, lowers the GHG profile for these technologies (-19.4% and -3.3%).[6]
- Estimates of GHG emissions over the lifecycle of different energy technologies are lowest for wind and solar compared to natural gas and coal. The median values for all renewable energy technologies range from 4 to 46 g CO_2eq/kWh while those for fossil fuels range from 469 to 1,001 g CO_2eq/kWh (excluding land use change emissions).[7]

	Average (g CO_2eq/kWh)	Range (g CO_2eq/kWh)
Wind[a]	34.1	0.4 to 365
Solar[a]	49.9	1.0 to 218
Natural Gas[b]	469	272 to 907
Coal[b]	1,001	635 to 1,633

a. Nugent, D., & Sovacool, B. K. (2014). Assessing the lifecycle greenhouse gas emissions from solar PV and wind energy: A critical meta-survey. Energy Policy, 65, 229-244.
b. Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science, 2(2), 148-173.

- The timing between planning and operation of a new energy technology results in CO_2 and air pollution emission because it permits the longer operation of our current higher-carbon emitting power generation (opportunity costs). The overall planning-to-operation time for wind and solar is 2 to 5 years compared to 10 to 19 years for nuclear and 6 to 11 years for a standard coal plant with carbon capture and storage.[8] Technologies with longer lifetimes and short installation times have the lowest opportunity costs CO_2eq emissions.

Water Consumption

- CSP solar power requires heating water to produce steam. Although this process is a closed looped system where the water is not lost, the steam is typically cooled again and therefore, water is lost by evaporation. Water is also used to clean the mirrors. Dry cooling reduces water use by 90% but also reduces efficiency.
- Although PV solar and wind turbines do not consume water during operation, water is used in the manufacturing.
- Extracting NG from shales can use up to 25 times more water than conventional natural gas. The amount of water used during hydraulic fracturing differs among locations- Marcellus shale uses more water for extraction than any of the other shale regions.[9]

	Average (gal-H_20/kWh)
Wind[a]	0.001
Solar[a]	PV: 0.04 CSP: 0.74
Natural Gas[b]	0.25
Coal[b]	0.61

a. Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, & energy security. Energy Env. Sci, 2(2)148-173.
b. Grubert, E. A., Beach, F. C., & Webber, M. E. (2012). Can switching fuels save water? A life cycle quantification of freshwater consumption for Texas coal-and natural gas-fired electricity. Environmental research letters, 7(4), 045801.

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[6] Nugent, D., & Sovacool, B. K. (2014). Assessing the lifecycle greenhouse gas emissions from solar PV and wind energy: A critical meta-survey. Energy Policy, 65, 229-244.
[7] IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Prepared by Working Group III of the Intergovernmental Panel on Climate Change [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1075 pp.
[8] Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science, 2(2), 148-173.
[9] Meldrum, J., Nettles-Anderson, S., Heath, G., & Macknick, J. (2013). Life cycle water use for electricity generation: a review and harmonization of literature estimates. Environmental Research Letters, 8(1), 015031.

Land Use Impacts

- The footprint of wind energy on land is basically the tower area touching the ground (13 to 20 m^2 for one large 5MW turbine). The land in between turbines can be left as natural habitat, open space, farmland, ranch land, or used for solar energy devices.
- The footprint for utility-scale PV solar systems is larger than wind. However, solar panels can be sited at lower-quality locations such as abandoned mining land, existing transportation and transmission corridors, on homes or commercial buildings.[10] Currently 90% of installed PV is on rooftops.[11]
- The footprint for Natural gas includes the land transformed during the installation of an extraction site, the transmission pipeline, the roads created to access well sites and pipelines, and the footprint of the power plant. Well sites range from 0.25 to 5.0 acres. The average distance for domestic natural gas transmission is 604 miles (onshore). Assuming a 50 foot ROW, this equates to a total pipeline land area of over 3,000 acres. NG power plant facilities average 10 acres.[12]
- An average Marcellus well pad requires 3.1 acres of land with an additional 5.7 acres is required for associated access roads, gathering pipelines (19 acres), water storage impoundments. An estimated 21.2 acres of adjacent interior forest habitat is lost due to edge effects and fragmentation (estimated by creating 100 m buffer around new edges created by well pad and associated infrastructure).[13]
- US federal agencies estimate that the land-use requirements for NG power plants are 110 acres for a 1000 MWe plant with an additional 3,600 acres of additional land required for wells, collection stations, and pipelines.[14]

	Land Use
Wind[a]	Temporary disturbance: <1 acres/ MW Permanent disturbance: <3.5 acres/ MW
Solar[b]	PV: 3.5 to 10 acres/ MW CSP: 4 to 16.5 acres/ MW
Coal[c]	19 (+ mining land impacts) acres/ MW

a. Denholm, P., Hand, M., Jackson, M., & Ong, S. (2009). Land-Use Requirements of Modern Wind Power Plants in the United States. National Renewable Energy Laboratory (NREL) Technical Report NREL. TP-6A2-45834.
b. Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science, 2(2), 148-173.
c. http://energy.gov/eere/geothermal/geothermal-power-plants-minimizing-land-use-and-impact

Impacts on Wildlife and Biodiversity

- Energy technologies impact wildlife by destroying habitat, polluting air and water, and creating structure that they can collide with or are electrocuted on.
- Wind turbines are responsible for less than 0.003% of human caused bird death.[15] Estimates suggest that 80% are songbirds and 10% are birds of prey.[16]
- For comparison, communications towers in the US kill 5-50 million birds a year, collisions with windows kill 97.5 to 975 million birds a year, and hundreds of millions of birds are killed by cats.[17]

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[10] i.e. http://www.epa.gov/aml/revital/renewable.htm
[11] Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science, 2(2), 148-173.
[12] Skone, T.J. et al. (2014). Life cycle analysis of natural gas extraction and power generation. US Department of Energy, National Energy Technology Laboratory, http://energy.gov/sites/prod/files/2014/05/f16/Life%20Cycle%20GHG%20Perspective%20Report.pdf
[13] Johnson, N., Gagnolet, T., Ralls, R., Zimmerman, E., Eichelberger, B., Tracey, C., ... & Sargent, S. (2010). Pennsylvania Energy Impacts Assessment Report 1: Marcellus Shale Natural Gas and Wind. Harrisburg, PA, US: The Nature Conservancy-Pennsylvania Chapter. http://www.nature.org/media/pa/tnc_energy_analysis.pdf
[14] US Nuclear Regulatory Commission. Generic Environmental Impact Statement for License Renewal of Nuclear Plants (NUREG-1437 Vol. 1) http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1437/v1/part08.html#_1_190
[15] National Academy of Sciences (2007). Environmental impacts of wind-enery projects, http://books.nap.edu/catalog.php?record_id=11935-toc.
[16] Jacobson, M. Z. (2009). Review of solutions to global warming, air pollution, and energy security. Energy & Environmental Science, 2(2), 148-173.
[17] American Bird Conservancy (2008). www.abcbirds.org

- Oil and natural gas industries impact birds through gas flares, oil spills, tailing ponds, and habitat loss, degradation, and fragmentation.
- Oil spills have immediate disastrous effect on wildlife (i.e. 7000+ birds collected from the spill area of the Deepwater Horizon explosion, 375,000 to 435,000 birds killed from the Exxon-Valdez spill), but also a long-term and ongoing impacts (25 years after the Exxon-Valdez spill, oil with the same chemical components of the oils sampled immediate after the spill is still found on beaches in Prince William Sound).[18]
- Wastewater from oil and gas drilling which is stored in tanks or ponds can poison animals and can be a breeding ground for mosquitos which transit diseases to wildlife (i.e. West Nile Virus).
- Natural gas flares create a new and continuous artificial light source which attracts birds, can cause death, collisions, or disorientation. Although some mass deaths have been reported (7,500 songbirds were kills in 2013 at gas flare in New Brunswick, Canada[19]), a few dead birds a day at each facility would result a significant number given the amount of facilities that flare gas in the world. Just ten birds per facility per day equates to 3,650 dead birds per facility per year.

	Bird Death in US
Wind[a]	10,000 – 40,000 per year
Oil Spill- Exxon Valdez[b]	375,000 – 435,000
Oil Wastewater Pits[c]	500,000 – 1,000,000 per year
Fossil Fuel Power Plants[d]	512,000 – 23,960,000 per year
Communication Towers[e]	5,000,000 – 50,000,000 per year
Cars[f]	89,000,000 – 340,000,000 per year

a. National Academy of Sciences (2007). Environmental impacts of wind-energy projects, http://books.nap.edu/catalog.php?record_id=11935-toc.
b. https://ashleyhannah2.wordpress.com/2014/04/09/oil-and-natural-gas-extraction/
c. Trail, P. W. (2006). Avian mortality at oil pits in the United States: a review of the problem and efforts for its solution. Environmental management, 38(4), 532-544.
d. Sovacool, B. K. (2012). The avian and wildlife costs of fossil fuels and nuclear power. Journal of Integrative Environmental Sciences, 9(4), 255-278.
e. American Bird Conservancy (2008). www.abcbirds.org
f. http://www.usatoday.com/story/tech/2014/05/29/bird-deaths-car-crashes/9623931/

Metals and Toxins

- The addition of Carbon Capture and Storage (CCS) at fossil fuel power plants (gas or coal) will substantially increase the demand for nickel and molybdenum. CCS requires 10 to 30% more metals than the current electricity mix due to additional infrastructure and the reduced efficiency.[20]
- PV solar requires the use of tin, silver, aluminum, zinc, and copper, materials that can be sourced through recycling programs or come from mining operations that have environmental footprints (acid mine drainage, arsenic emissions, cyanide and mercury poisoning of waterways, energy intensive processes, human rights abuses and child labor exploitation).
- Solar requires the similar amounts of iron and nickel as NG plants with CCS, and the increases in mining of iron, tin, and zinc are relatively insignificant compared to current production.
- Renewable energy sources would increase the need for aluminum (1-15%), nickel (50 – 250%), molybdenum (30-100%) and silver (0-44%).[21]

[18] https://ashleyhannah2.wordpress.com/2014/04/09/oil-and-natural-gas-extraction/
[19] https://ashleyhannah2.wordpress.com/2014/04/09/oil-and-natural-gas-extraction/
[20] Kleijn, R., Van der Voet, E., Kramer, G. J., Van Oers, L., & Van der Giesen, C. (2011). Metal requirements of low-carbon power generation. Energy, 36(9), 5640-5648.
[21] Kleijn, R., Van der Voet, E., Kramer, G. J., Van Oers, L., & Van der Giesen, C. (2011). Metal requirements of low-carbon power generation. Energy, 36(9), 5640-5648.

- Material substitution may reduce the metal requirements- Silver can be replaced by other metals, PV solar cells can be made with FeS, Nickel and molybdenum containing steels can be replaced with other alloys, concrete can be used instead of steel towers for wind turbines, Aluminum can substitute copper as a conductor.
- Most of the rare earth metals needed for renewable energy technologies are also used in cell phones, computers, medical imaging, jet engines, defense technologies, catalytic converters, light bulbs, and TVs. EPA reported that more than 2 million tons of electronics are thrown out per year, but only 25% of these are recycled. Recycling e-waste can save the energy used in mining these resources and conserves the resources.
- Most renewable energy technology companies have a strong financial incentive to ensure that the rare and highly valuable materials are recycled. However, there isn't enough waste generated currently from these industry to warrant large scale recycling programs. As more renewable energy is put into production, waste accumulation and end-of-life recycling programs will start becoming a major issue (expected for solar around 2020 from systems installed in 1990s). First Solar, an Arizona-based firm, has an industrial-scale recycling facility at each plant which takes panels back at no cost to consumers. This process recovers all components of the panels, including 95% of semiconductor material and 90% of the glass. Furthermore, reusing silicon and cadmium telluride uses only 1/3rd as much energy as using raw materials.[22]
- In the Solar industry, cadmium telluride is being used more in place of silicon-based panels. Although Cadmium is a carcinogen listed as extremely toxic, it is a waste by-product of zinc refining and putting it into solar panels represents a safer alternative than storage or disposal in landfills. NREL indicates that CdTe solar panels do not present any risks to health and the environment.
- Other hazardous chemicals are used in the manufacturing of solar panels including hydrogen fluoride, nitric acid, sulfuric acid, and sodium hydroxide. Some these chemicals can be treated on-site, others must be disposed of properly off-site. Production safety and waste disposal from manufacturing is a pressing issue that needs to be addressed (especially given large increase in Chinese manufacturing where there is a lack of safety regulations).

<u>Definitions from Wikipedia:</u>

Concentrated **solar** power (also called **concentrating solar power**, concentrated **solar** thermal, and **CSP**) systems generate **solar** power by using mirrors or lenses to concentrate a large area of sunlight, or **solar** thermal energy, onto a small area.

A **photovoltaic** system, also **solar PV** power system, or **PV** system, is a power system designed to supply usable **solar** power by means of photovoltaics.

<u>Definition from Union of Concerned Scientists:</u>

Megawatts are used to measure the output of a power plant or the amount of electricity required by an entire city. One **megawatt** (MW) = 1,000 kilowatts = 1,000,000 watts. For example, a typical coal plant is about 600 MW in size.

[22] Nath, I. (2010). Cleaning Up After Clean Energy: Hazardous Waste in the Solar Industry. Stanford Journal of International Relations, 11(2), 6-15.