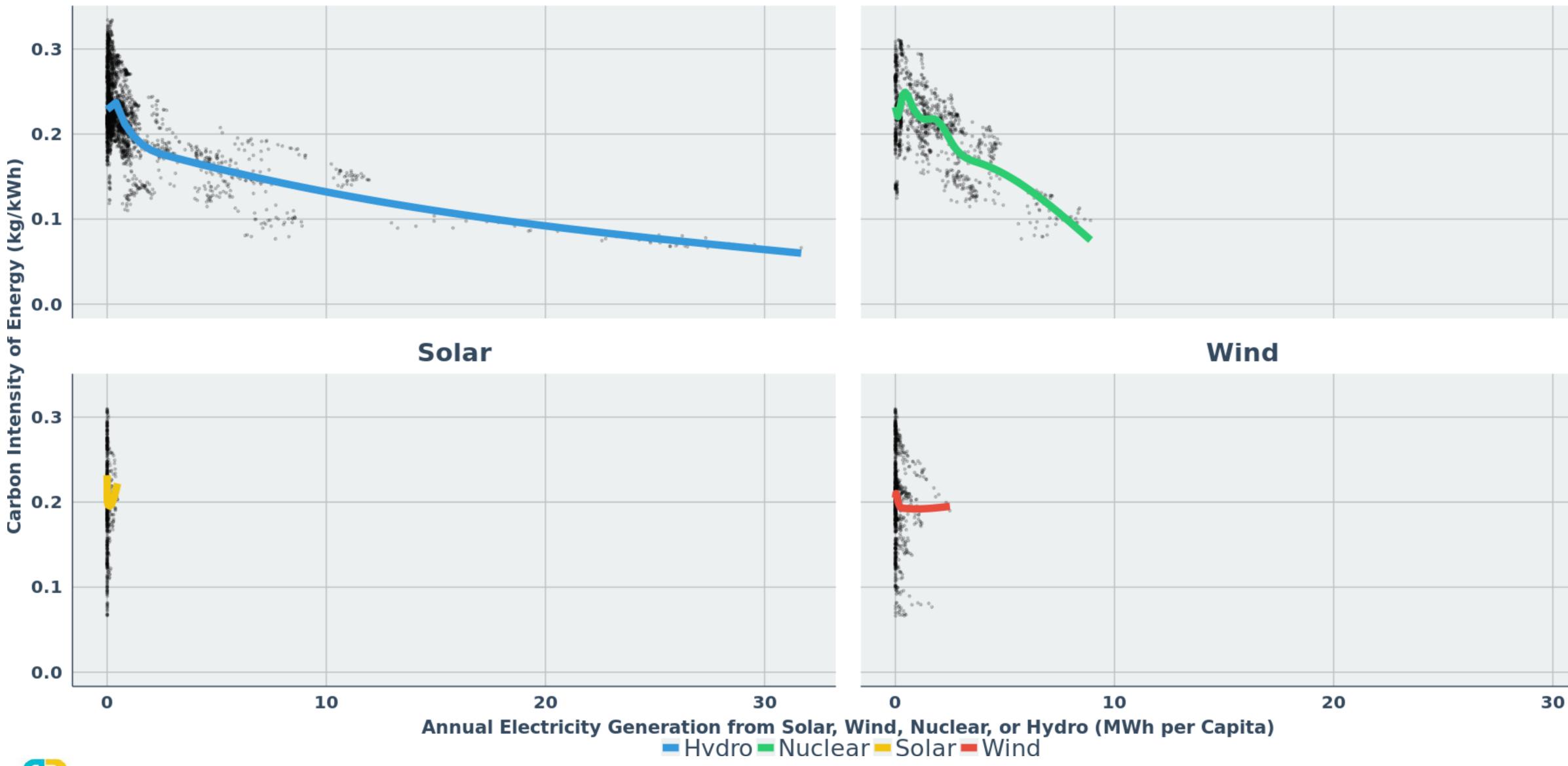
#### **Correlation between Low-Carbon Electricity Generation and Carbon Intensity of Energy** Nuclear Hydro





1	

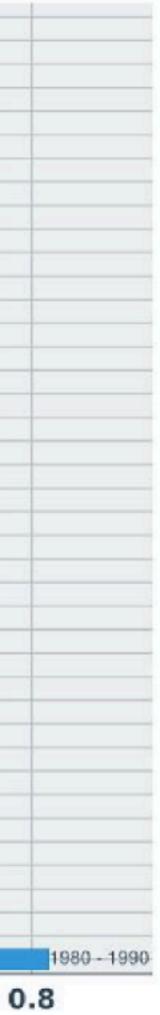


#### Largest 10-Year Deployments of Nuclear, Hydro, Wind and Solar Electricity

Germany Sola **Belgium Win** France Hydr China Hydr **Finland Win** United Kingdom Win United States Win Argentina Hydr Germany Win Portugal Hydr Slovakia Hydr Brazil Hydr Canada Win **Russian Federation Nuclea** United Kingdom Nuclea Spain Win Finland Hydr Portugal Win Ireland Win Spain Nuclea Denmark Win **United States Nuclea** Japan Nuclea **Ukraine Nuclea Hungary Nuclea Czech Republic Nuclea Bulgaria Nuclea Germany Nuclea** Sweden Win South Korea Nuclea Switzerland Hydr Canada Nuclea Sweden Hydr Slovakia Nuclea Switzerland Nuclea **Belgium Nuclea** Canada Hydr **Finland Nuclea** France Nuclea Sweden Nuclea Norway Hydr

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#### **LKARF22**



17

## Germany has invested \$222 billion in renewables since 2000

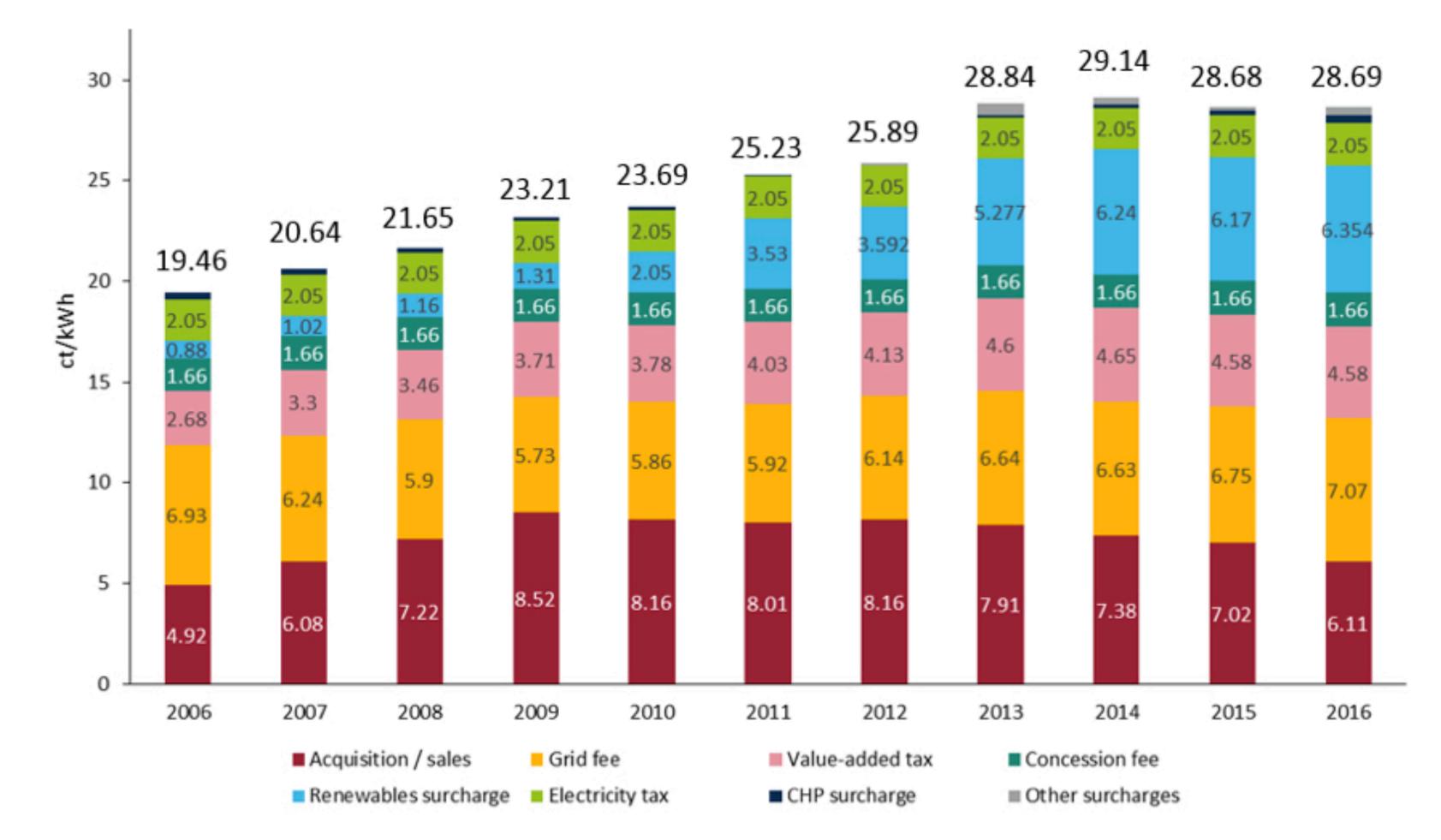


**Source**: Stanley Reed, "\$222 billion shift hits a snag," New York Times, October 3, 2017





# German electricity prices rose 47 percent from 2006 to 2016.

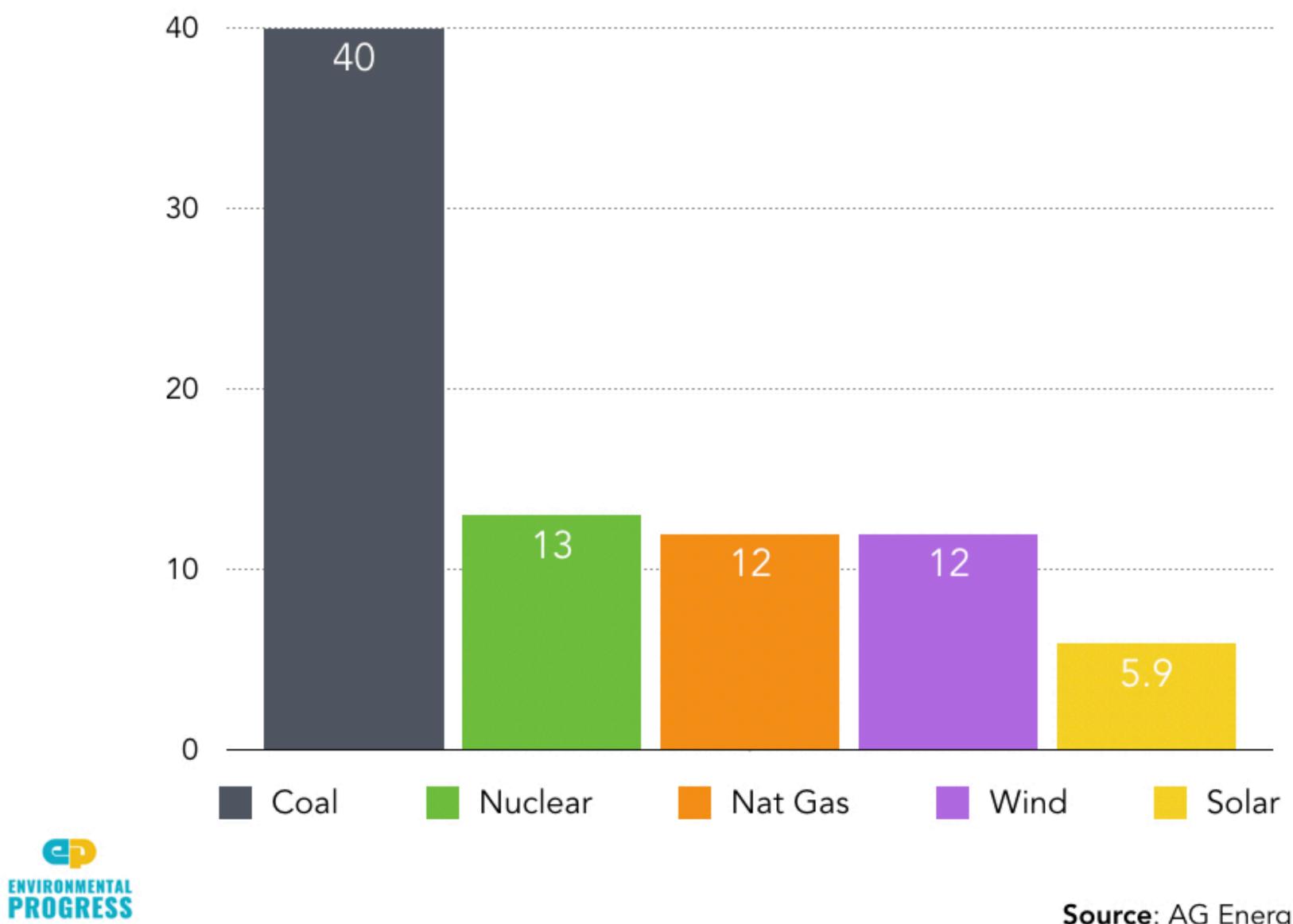




Composition of average power price in ct/kWh for an average household (3,500 kWh per year). Data source: BDEW, 2016.



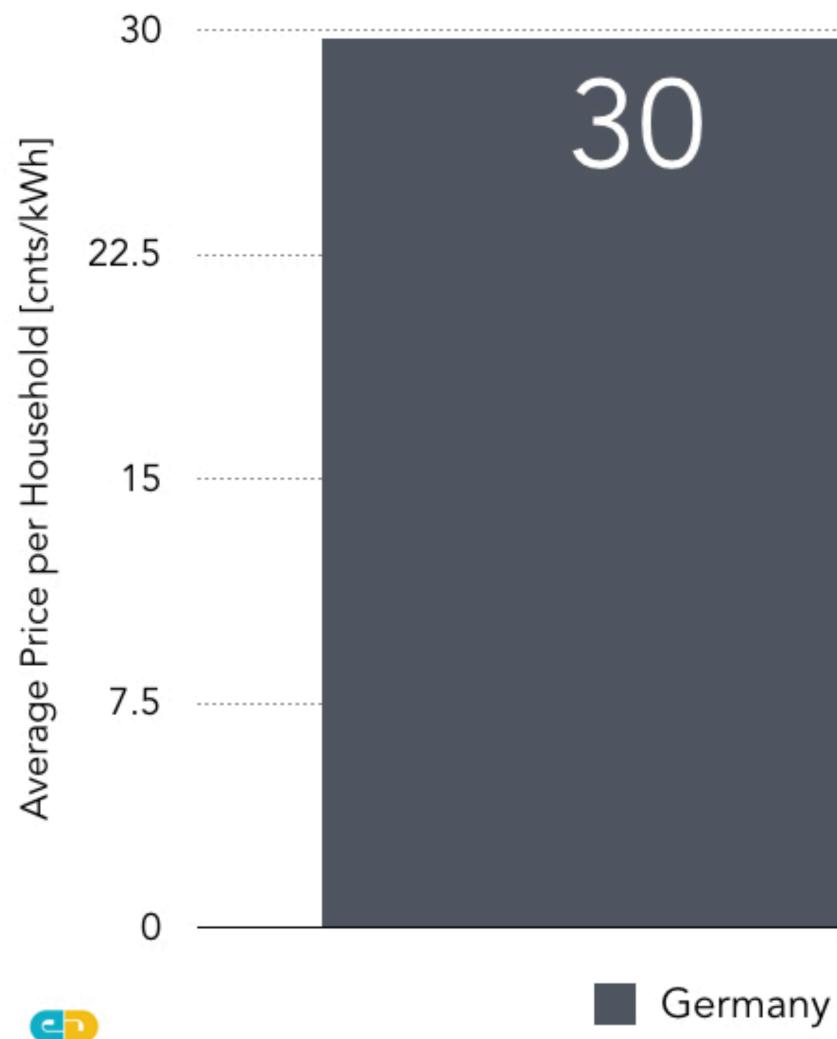
# Percent of German electricity in 2016 from coal, nuclear, natural gas, wind and solar



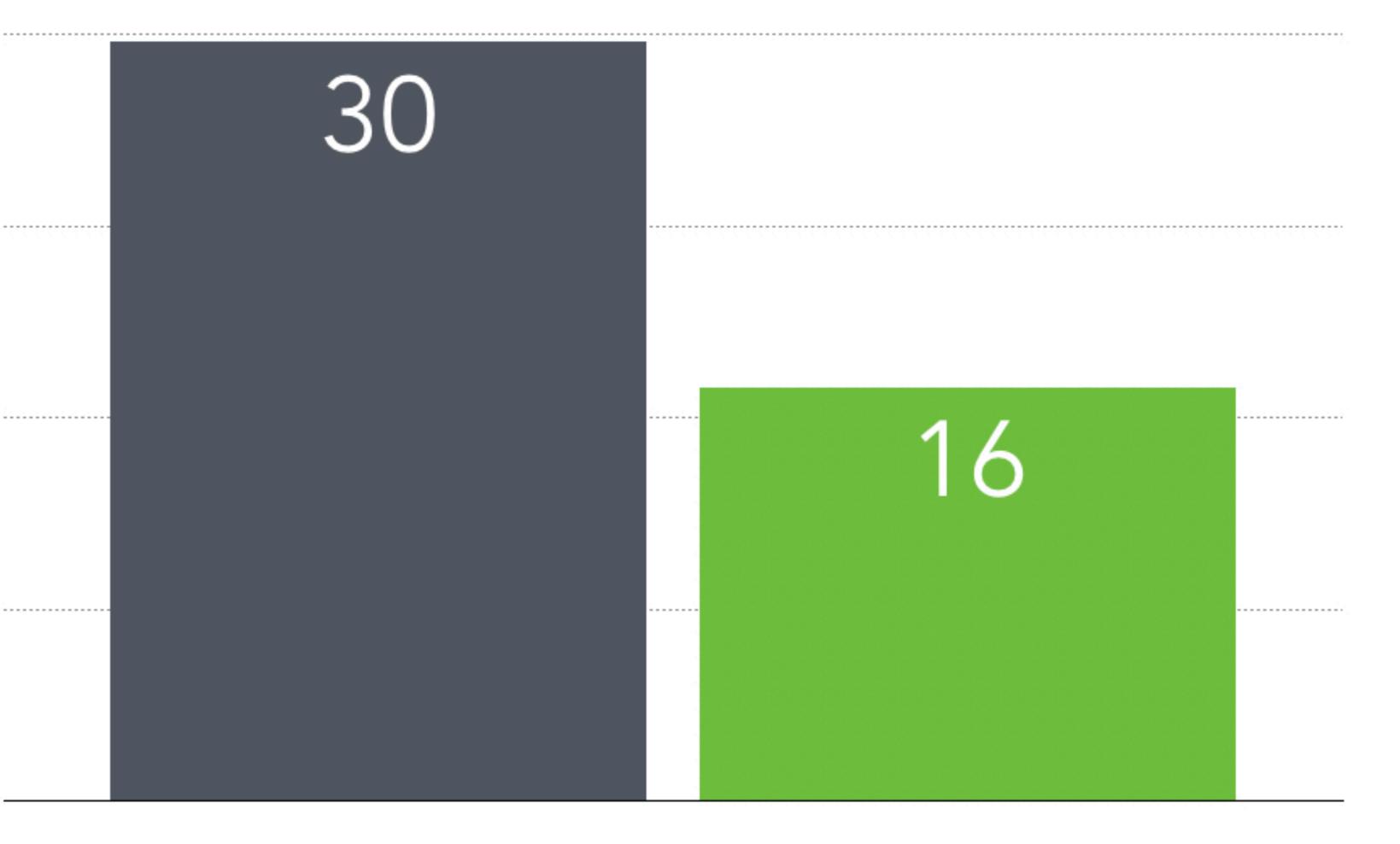
Source: AG Energiebilanzen, 2017



## German electricity is 2x more expensive than French electricity.





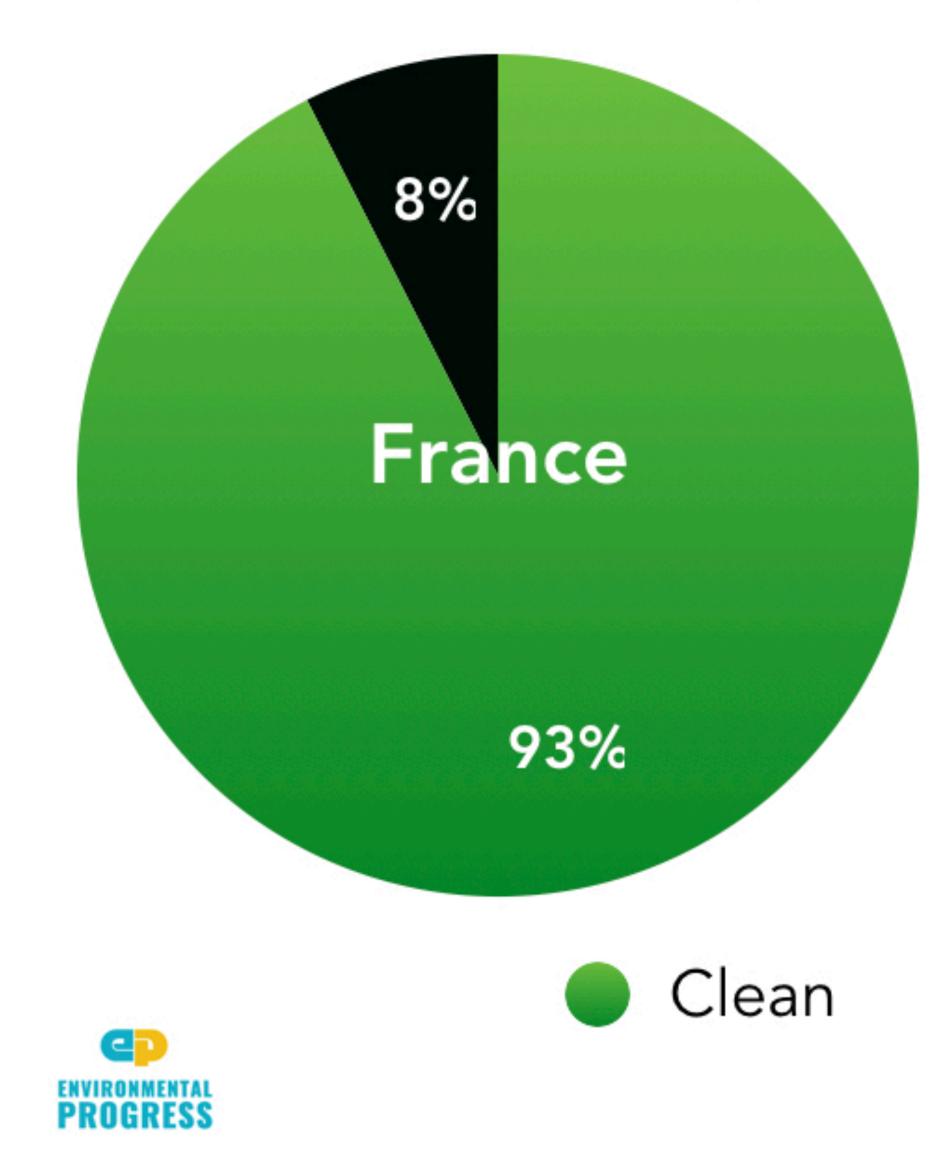


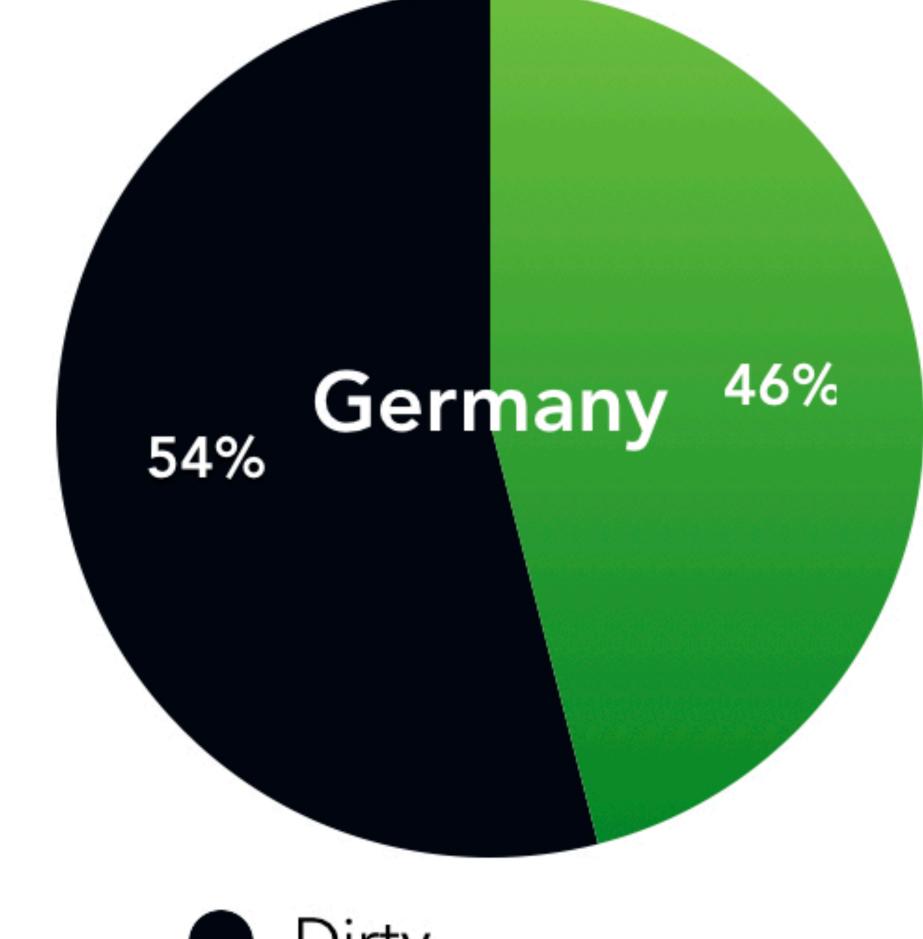


Source: Eurostat, 2015



# France generates 2x more electricity from clean energy sources than Germany.





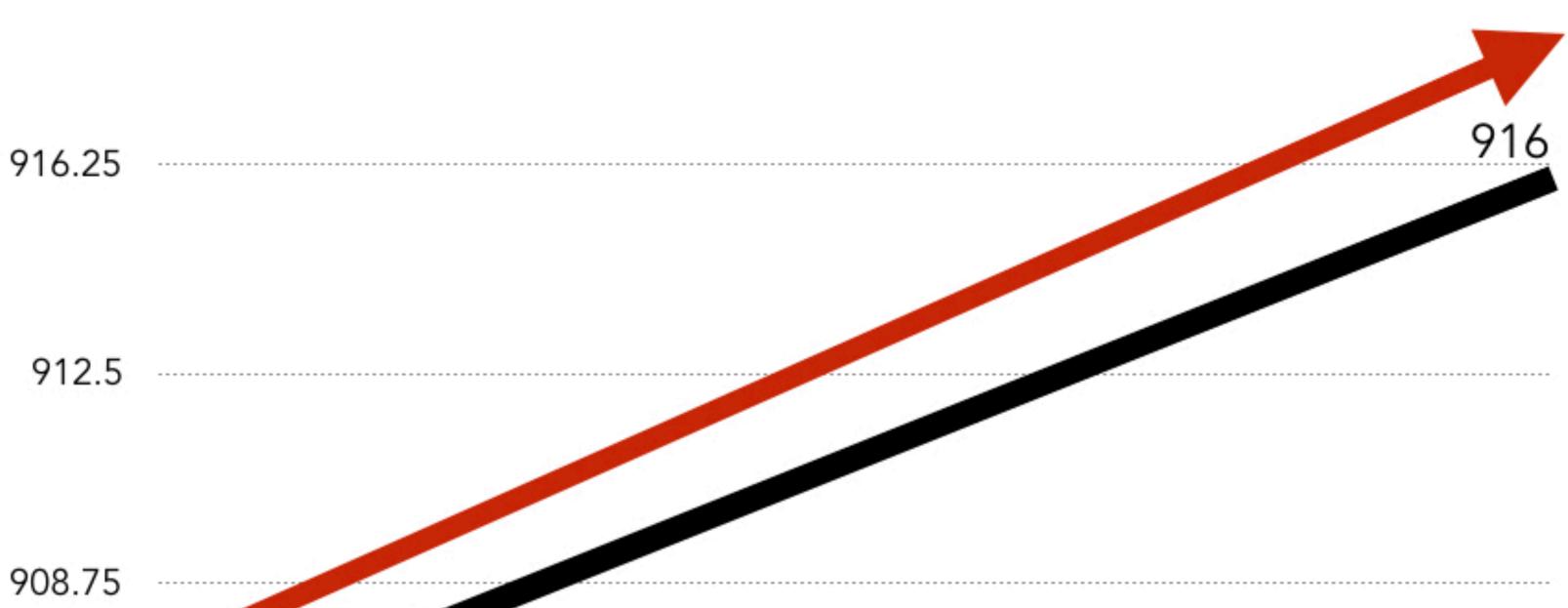


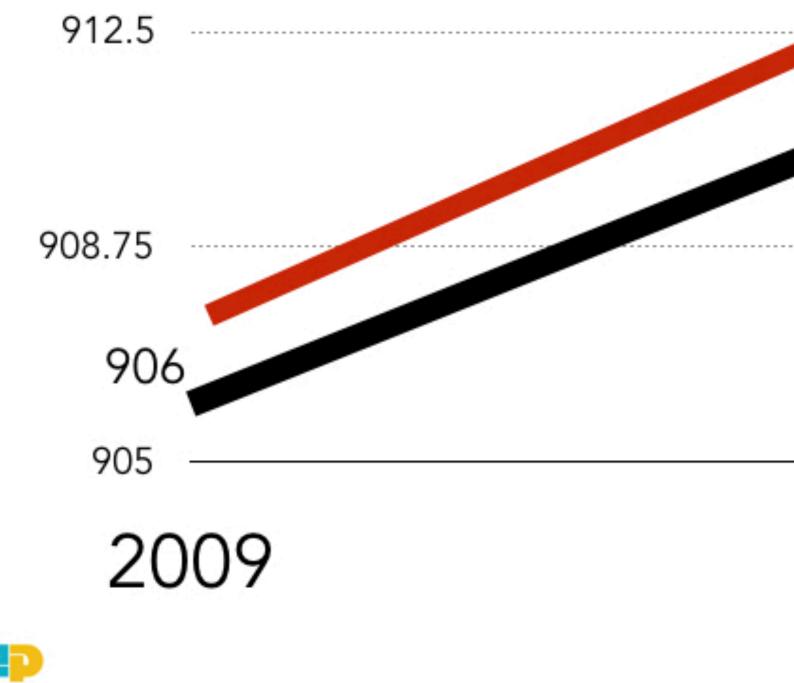
Source: BP Energy Outlook 2016



#### German emissions have been rising since 2009









#### 2016

**Source**: Agora Energiewende; Franhofer Institute; German Statistical Office Data



# Germany installed 4% *more* solar panels in 2016 – but generated 3% *less* electricity from solar.



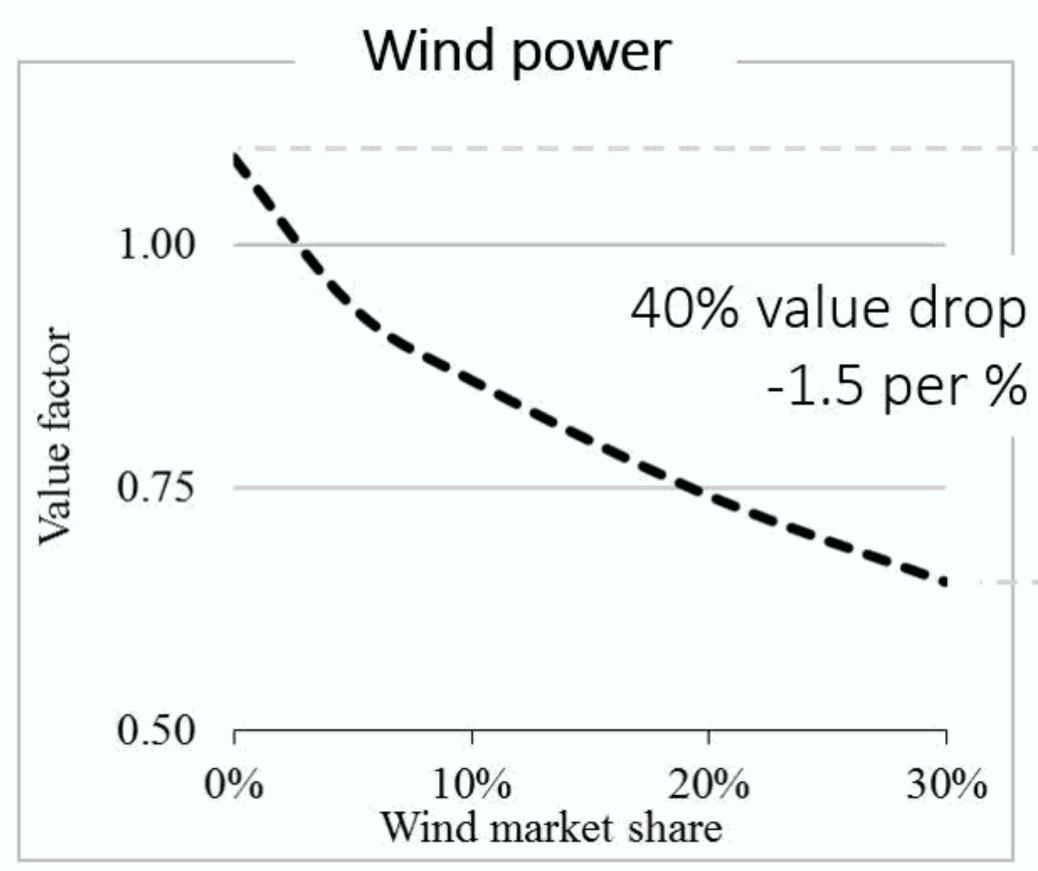


# less electricity from wind.



Germany installed 11% more wind turbines in 2016 – but generated 2%

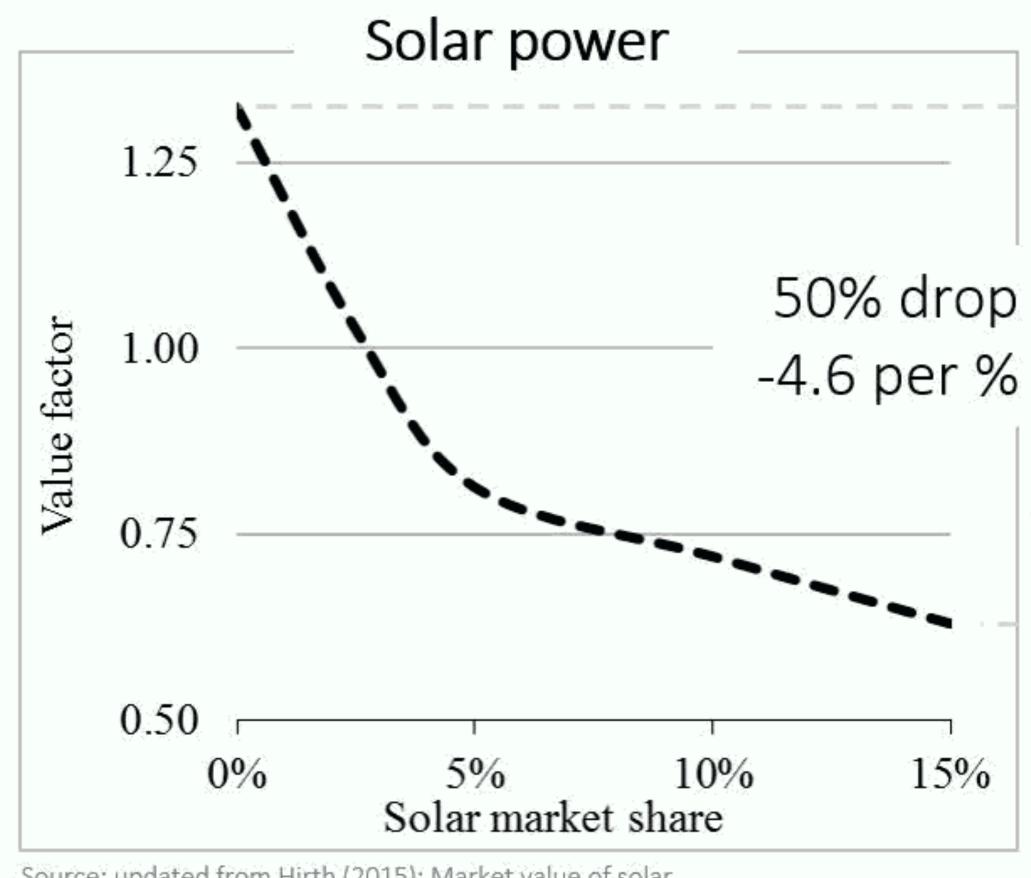




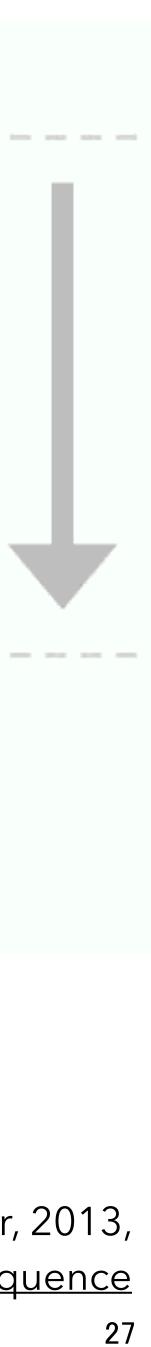
Source: updated from Hirth (2013): Market value



Source: Leon Hirth, "Market Value of Variable Renewables," EUI Working Paper, 2013, http://cadmus.eui.eu/bitstream/handle/1814/27135/RSCAS\_2013\_36.pdf?sequence



Source: updated from Hirth (2015): Market value of solar

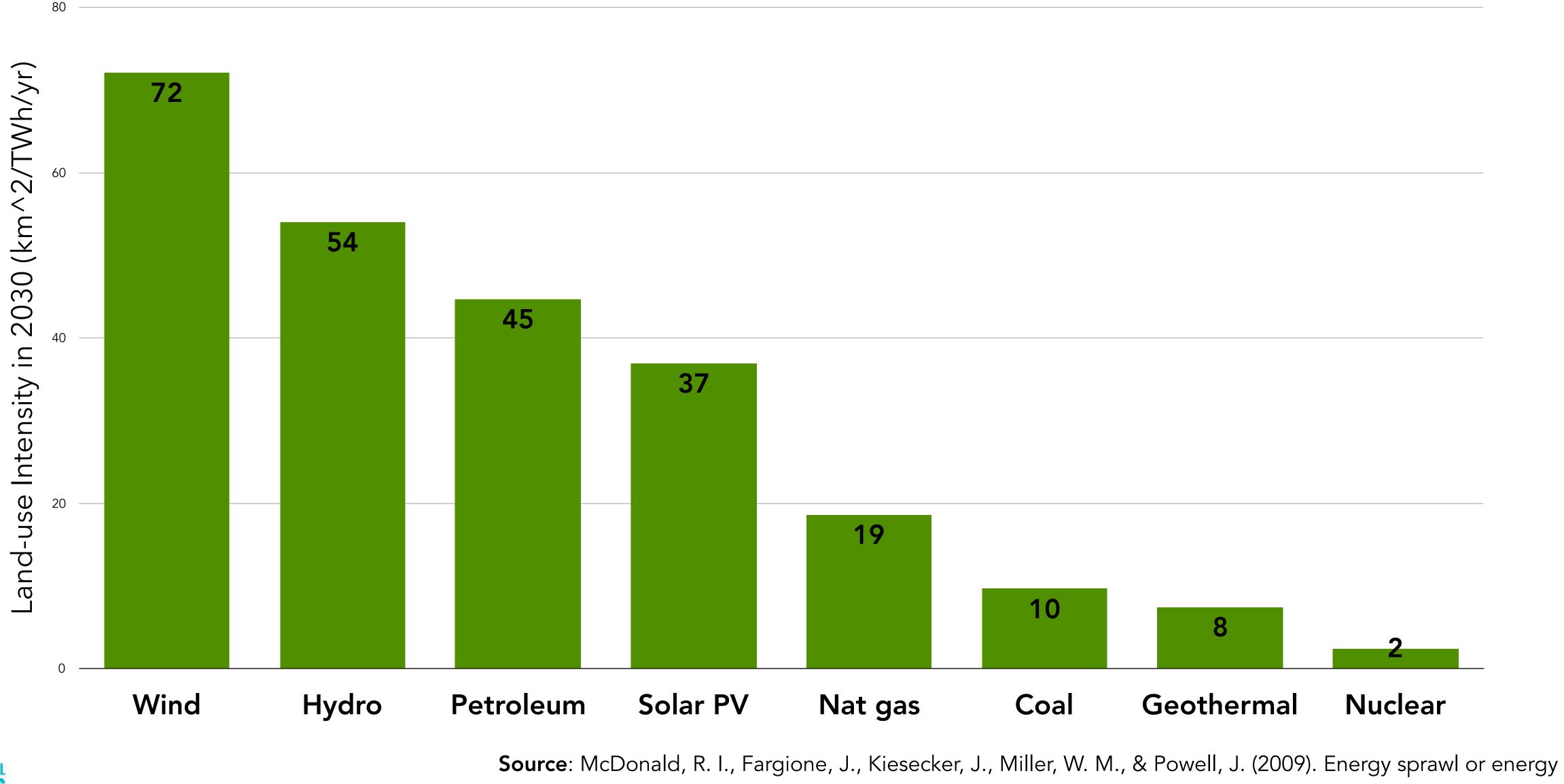


California has 23 minutes of electricity storage — if you used every car and truck in the state along with existing storage.





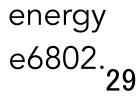
### Renewables require 17 - 35 times more land than nuclear



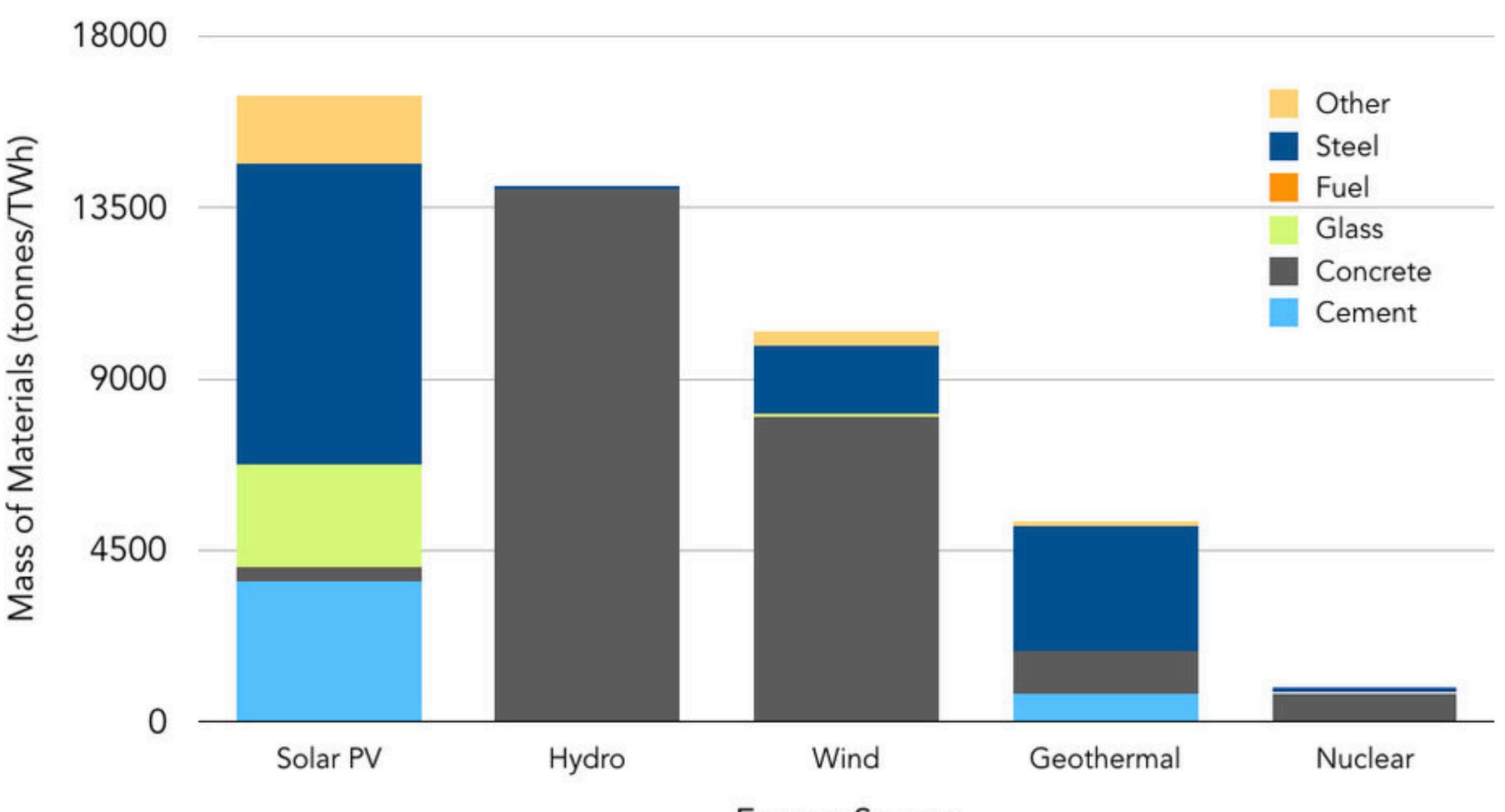
ENVIRONMENTAL PROGRESS

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efficiency: climate policy impacts on natural habitat for the United States of America. PLoS One, 4(8), e6802.29



## Materials throughput by type of energy source



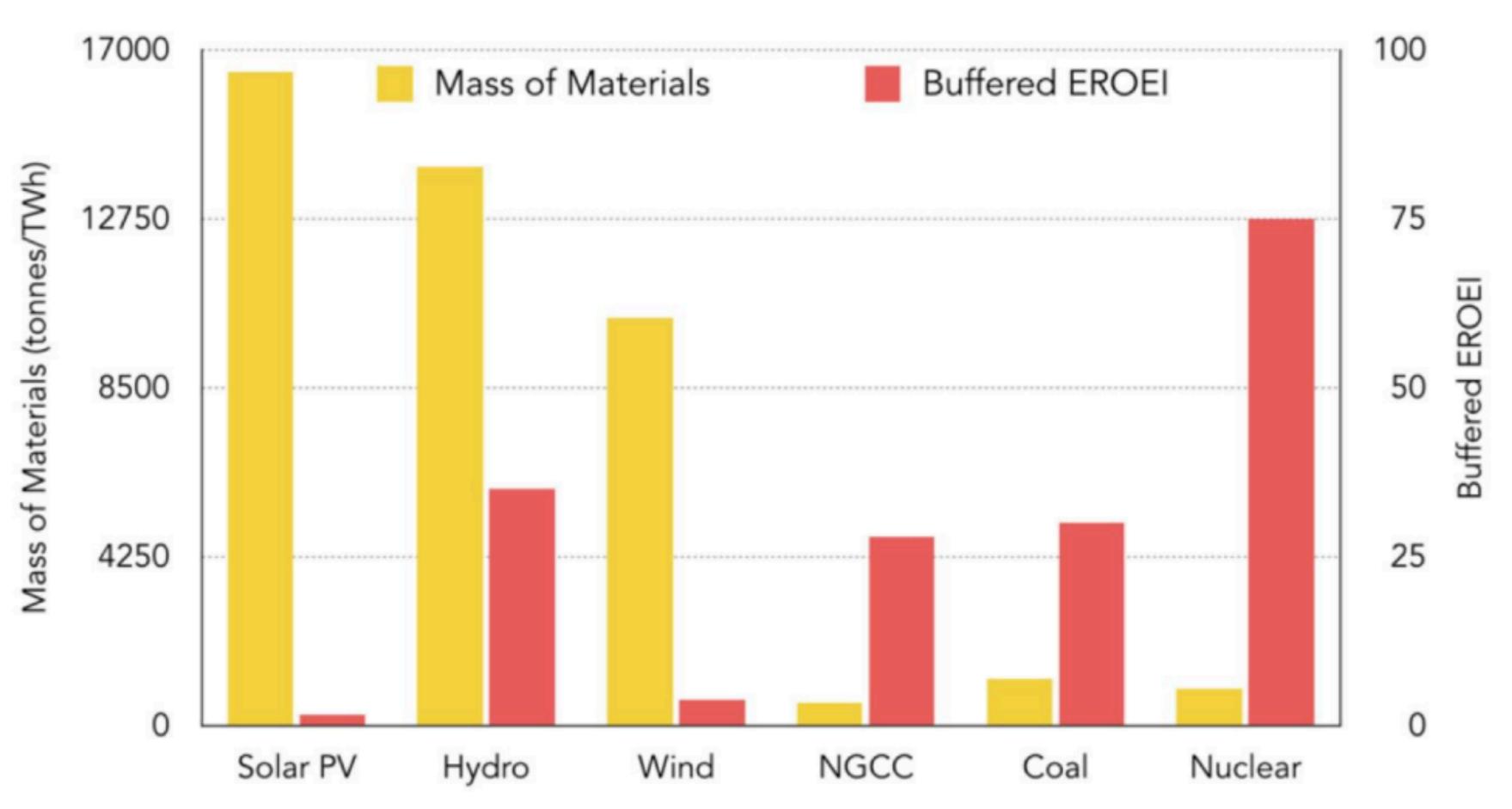


Sources: DOE Quadrennial Technology Review, Table 10. Murray, R.L. and Holbert, K.E. 2015. Nuclear energy: an introduction to the concepts, systems, and applications of nuclear processes (7th ed.). Elsevier.

**Energy Source** 



## Materials throughput and EROEI by type of energy source



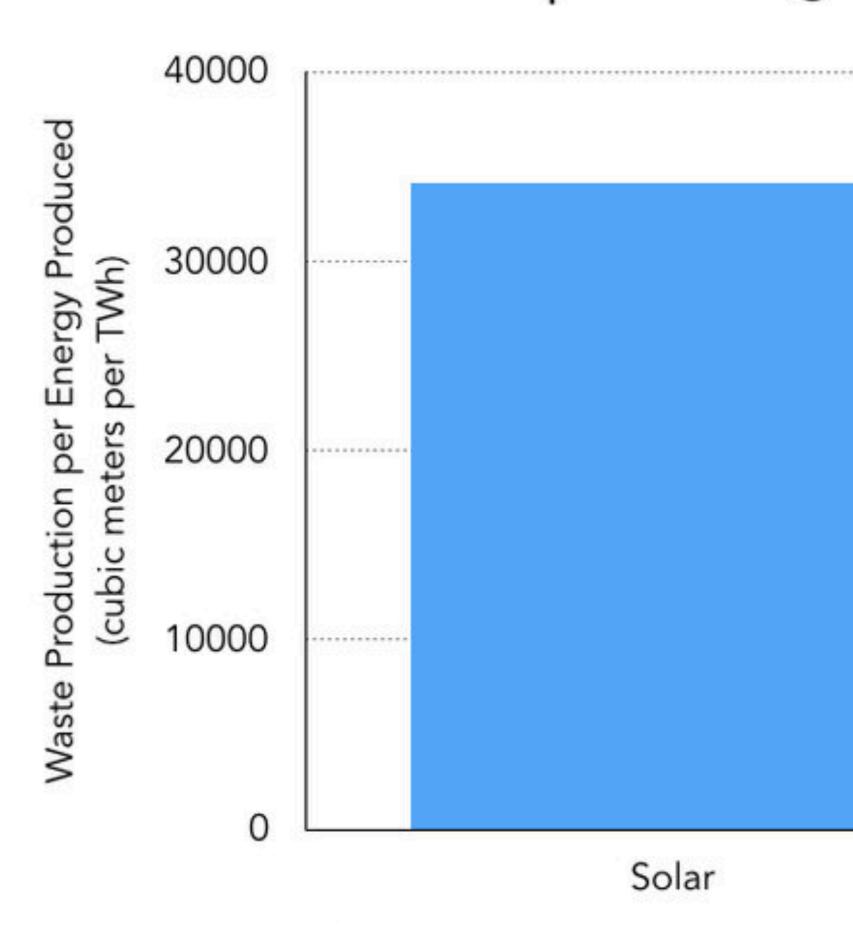


Sources: DOE Quadrennial Technology Review, Table 10. Murray, R.L. and Holbert, K.E. 2015. Nuclear energy: an introduction to the concepts, systems, and applications of nuclear processes (7th ed.). Elsevier.

Weißbacha, D., Ruprechta, G., Hukea, A., Czerskia, K., Gottlieba, S., & Husseina, A. Energy intensities, EROIs, and energy payback times of electricity generating power plants.



# Solar panels produce ~300x more waste than nuclear reactors when providing the same amount of energy.

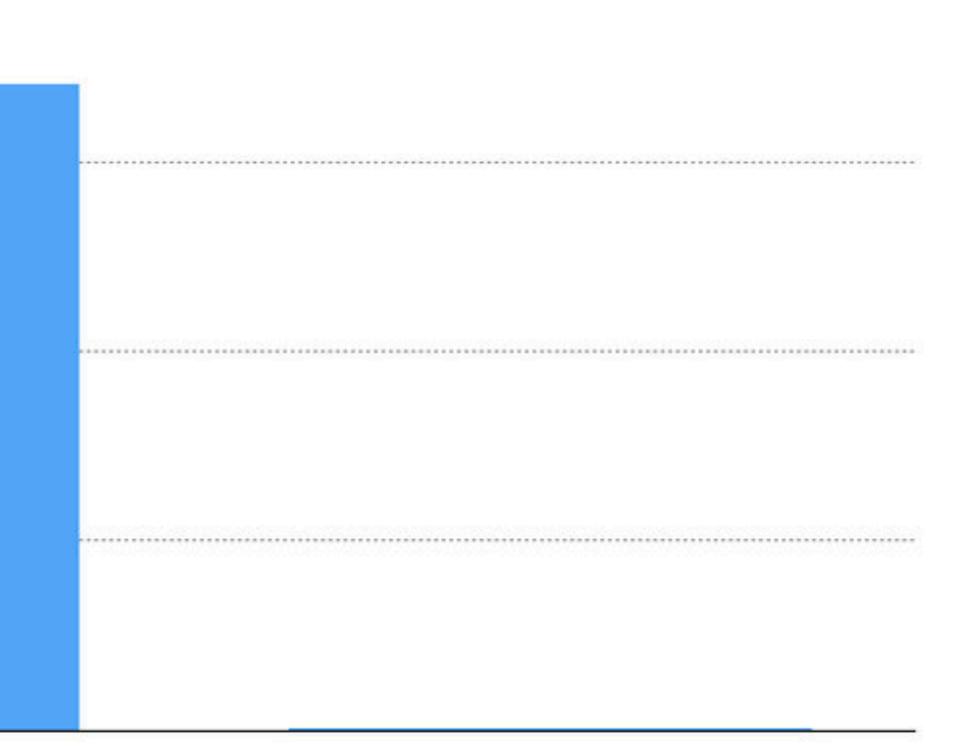


#### Sources and Notes:

US GAO, http://www.gao.gov/key\_issues/disposal\_of\_highlevel\_nuclear\_waste/issue\_summary World Nuclear Association, http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx http://www.world-nuclear.org/information-library/facts-and-figures/world-nuclear-power-reactors-archive/reactor-archive-december-2015.aspx IAEA, https://www.iaea.org/PRIS/home.aspx BP, http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

Solar panels specifications vary. Panel specifications were standardized according to TrinaSolar's Duomax Dual Glass 60-Cell Module: http://static.trinasolar.com/sites/default/files/PS-M-0474%20A%20Datasheet\_Duomax\_PEG5.XX\_US\_Feb\_2017\_A.pdf





#### Nuclear



Is there an alternative to nuclear for cheap, clean energy?

- Carbon capture and storage *must* be more expensive than coal or natural gas alone
- Intercontinental super-grid would be expensive undermine energy security
- Geo-engineering doesn't solve problems but creates new ones







# Chernobyl

- 28 deaths from acute radiation syndrome
- 15 deaths from thyroid cancer in 25 years
- 1% death rate overall predicted for thyroid cancer.
- 16,000 excess thyroid cancers in total predicted, thus 160 deaths predicted
- No effect on fertility, malformations or infant mortality - No conclusion on adverse pregnancy outcomes or still births
- liquidator cohorts)
- Heritable effects not seen and very unlikely at these doses – No proven increase in any other cancer (including





Source: www.unscear.org/docs/reports/2008/11-80076 Report 2008 Annex D.pdf



## Fukushima

- No radiation deaths
- Over 1,500 deaths from radiophonic panic, evacuation & stress
- Over 15,000 killed by in tsunami
- Unlikely to be any increase in thyroid cancer
- No impact on adverse pregnancy





Source: http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1710-ReportByTheDG-Web.pdf



# Living in big city increases risk of death more than putting out Chernobyl fire

Megacity versus small town living Passive smoking Exposure of 250mSv (Chernobyl Liquidator) Exposure of 100mSv (Chernobyl Liquidator)

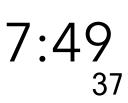
1.7% 1.0%

2.8%





Source: Smith J BMC Pubic Health 2007 7:49





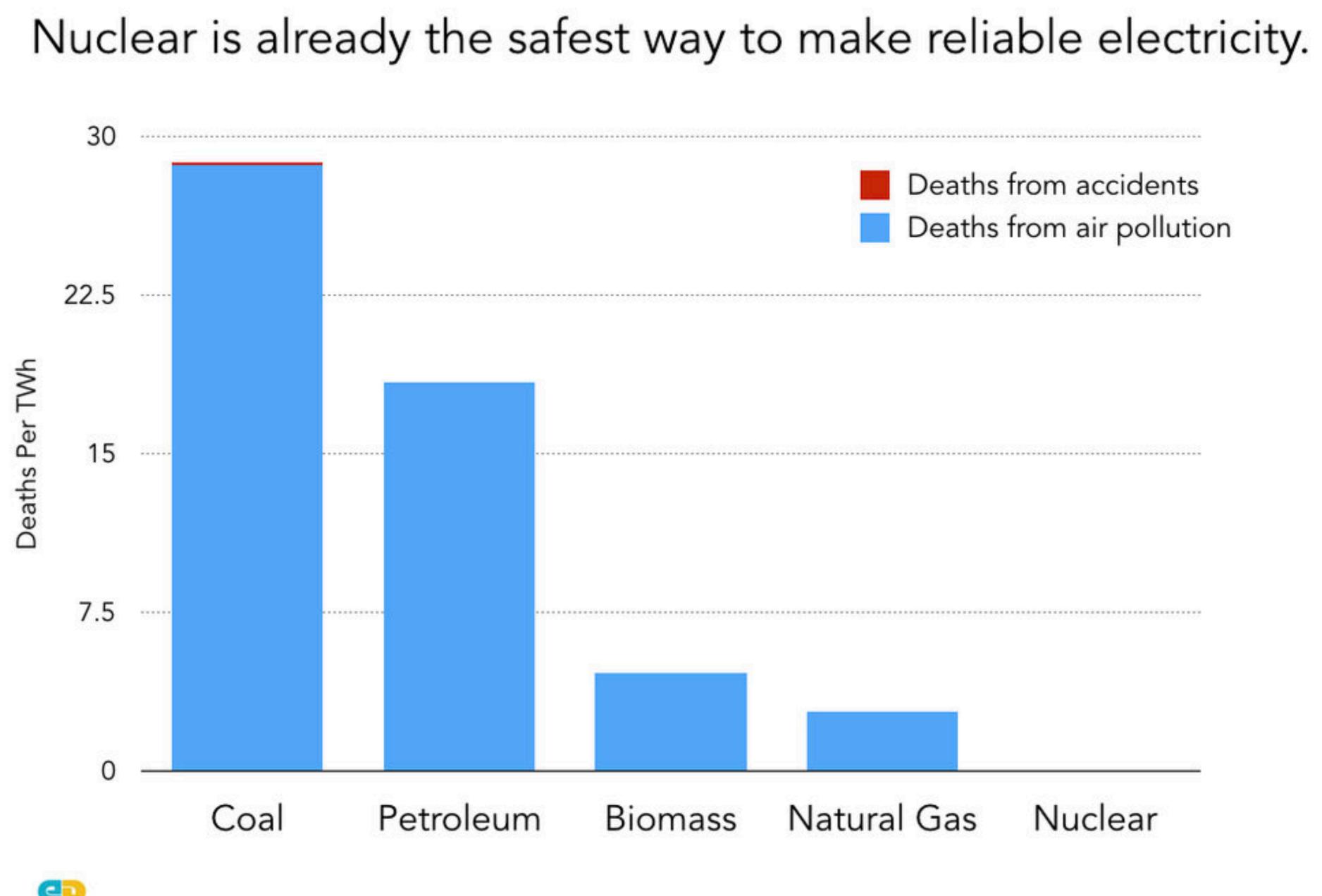


# 7 million die annually from air pollution

Source: World Health Organization, 2016. http://www.who.int/ mediacentre/news/releases/2016/air-pollution-estimates/en/









Source: Markandya, A., & Wilkinson, P. 2007. Electricity generation and health. The Lancet, 370(9591), 979-990.

