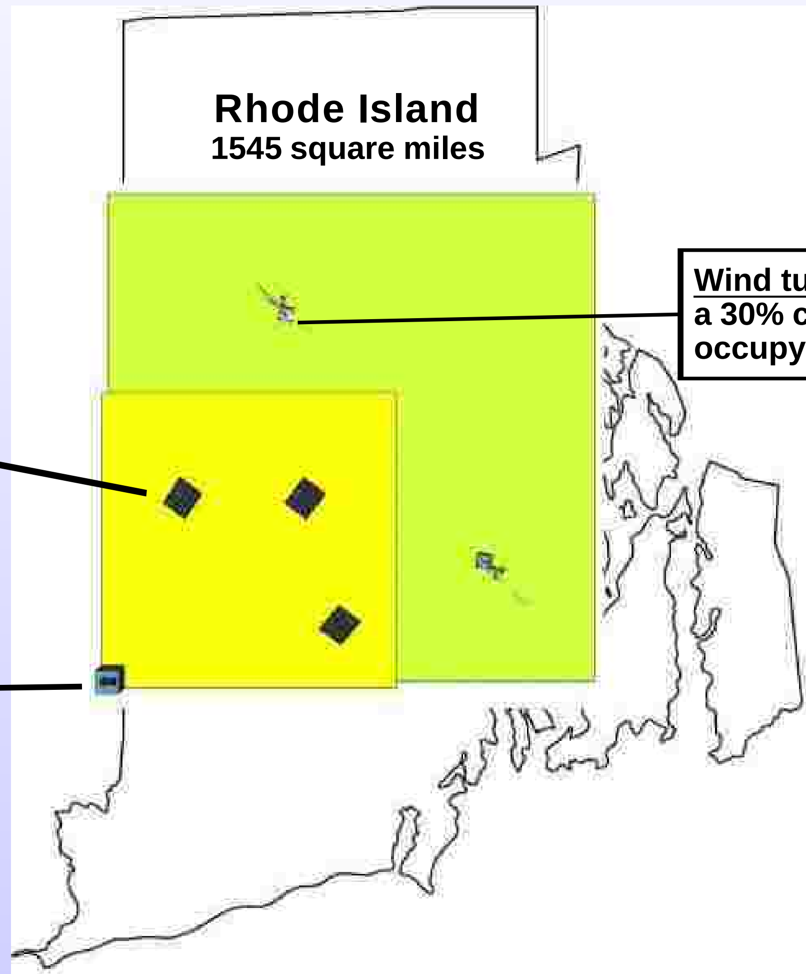
Comparisons of
Industrial Wind and Solar
with
Nuclear Energy

Table 1: Area of land or water impacted (in Maryland) by installations capable of generating 1440 MW annually or 1584 MW during summer afternoons						
	Annual			Summer Afternoons		
	Capacity Factor	# of units	Sq. miles	Capacity Factor	# of units	Sq. miles
Nuclear Reactor	90%	1	0.47	99%	1	0.47
Wind - onshore[1]	30%	2,400	13	13%	6,100	31
Wind - offshore[2]	40%	1,200	116	25%	2,100	194
Solar (PV)	14%	NA[4]	103	28%	NA[4]	52
Biomass	10[3]	NA[4]	2660	NA[4]		

[1]2 MW turbines. [2]3 MW turbines. [3]10 ton/ha/year crop yield (woody or herbacious). The typical range is from 5 to 15 tons/ha/year. [4]NA = Not applicable.

Area of land needed by nuclear reactor, solar collectors, or wind turbines to generate the same amount of electricity.



Wind turbines operating at a 30% capacity factor will occupy 832 square miles

Solar PV cells operating at a 19% capacity factor will occupy 292 square miles

2 - 1600 MW reactors operating at a 90% capacity factor will occupy 2 square miles

To grow biomass for a year's operation will require planting about 5,000 square miles, three times the area of the State.

http://www.cleanenergyinsight.org/energy-insights/what-does-renewable-energy-look-like/

Electrical Terms

! Generating Capacity: the amount of electricity that a device will make when operating under ideal conditions.
  ▸ This is often called the “nameplate capacity”

! Generation: the amount of electricity that was actually produced.

Two Critical Properties of Electricity Generators

! CAPACITY FACTOR (CF) = actual power divided by maximum (i.e., nameplate) power

! INTERMITTENCY = the unpredictable behavior of wind which leads to the necessity of maintaining fossil fuel plants for backup.

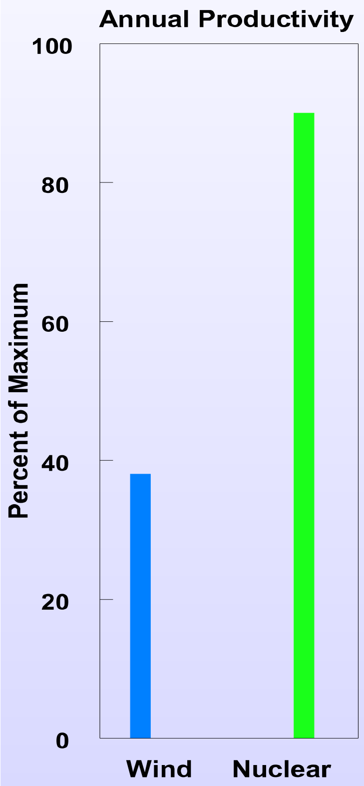
Some Capacity Factors

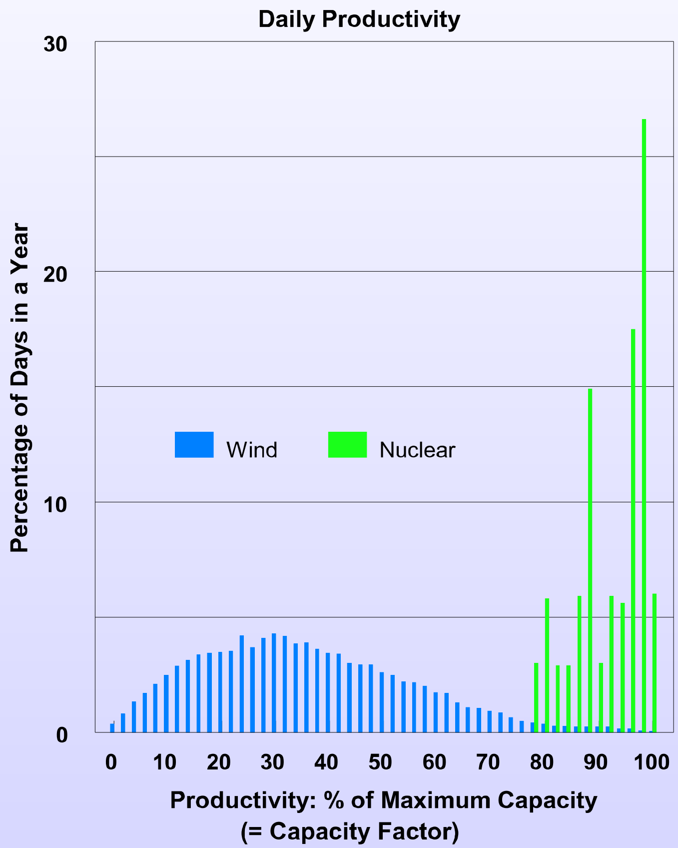
- Wind - land based - Maryland or global
  - Annual average ≈ 30%
  - During peak electricity demand in MD ≈ 13%
- Wind - offshore - Maryland or global
  - Annual average ≈ 40%
  - Summer ≈ 25%
- Solar - in Maryland
  - Annual average ≈ 14%
  - Summer ≈ 28%
- Solar - in desert regions
  - Annual average≈ 20%
- Nuclear - US
  - Annual ≈ 91%
  - Summer ≈ 99%

For additional information, see:
http://en.wikipedia.org/wiki/Capacity_factor#Typical_capacity_factors

Comparing the productivity of a very large array of offshore wind turbines with that of nuclear reactors with the same total capacity

(Showing that the high cost of building a reactor doesn't lead to more costly electricity)





Sources of data: WIND TURBINES - from Kempton, et al., 2010, *Proc. Natl. Acad. Sci.*, 107:7240-7245. Data from 5 years of actual wind measurements made from weather buoys located off the Atlantic Coast from the Florida Keys to Maine.
NUCLEAR REACTORS: Energy Information Administration, USDOE, Monthly Energy Review Jan, 2011 (http://www.eia.doe.gov/emeu/mer/pdf/pages/sec8_3.pdf). Monthly data from Jan. 2008 through Oct, 2010 on the production of the 104 reactors in the US.

LEFT GRAPH: The annual quantity of electricity expected from either 20,000 five MW turbines built offshore from the Florida Keys to Maine or from the 104 current U.S. nuclear reactors. These data show that the higher cost of building the reactors is completely offset by the lower annual productivity (lower annual Capacity Factor) of the wind turbines, because this necessitates building more turbines. The expected working life of the reactors (60 years) is longer than that of the turbines (25 years) which further reduces the relative construction cost of the reactors to significantly less (3-fold) than that of the turbines.

RIGHT GRAPH: An analysis more detailed in time than that in the Left Graph. These data show that turbines, even in large numbers and built over long distances, perform very erratically. It shows that they will produce at close to their maximum only a very small proportion of a year (this is called Intermittency). The reactors, on the other hand, never performed at less than 78% of their maximum capacity and they were at almost 100% for a significant proportion of the time. The erratic prooductivity of this geographically extensive array of turbines creates the need for fossil fuel, carbon dioxide producing, back-up plants which add further to the relative cost of the wind turbines.

Levelized Cost of Electricity LCOE

- Considered
  - Construction cost
  - Working life
  - Financing of construction
  - Operation and maintenance
  - Fuel
  - Decommissioning and storage (for nuclear reactors)
  - Capacity Factor and Intermittency
- Not considered
  - Governmental subsidies

Estimated (for 2016) Levelized Cost of New Generation Resources
and
Federal Financial Interventions and Subsidies in Energy Markets in 2007

Plant Type	Capacity Factor	Total System Levelized Cost ($ per megawatt-hour)	Subsidy and Support ($ per megawatt hour)
Advanced Nuclear	90%	$119	$1.59
Wind	34%	$149	$23.37
Wind -offshore	39%	$191	
Solar PV	21%	$396	$24.23

Sources: Energy Information Administration, Annual Energy Outlook 2010, December 2009, DOE/EIA-0383(2009); and Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels , U.S. Department of Energy, Washington, DC 20585

Levelized Cost to the Ratepayer and Amount of CO_2 Prevented by Five Alternative Scenarios for Maryland's Electricity Future

(analysis by Levitan and Associates for the MD PSC)

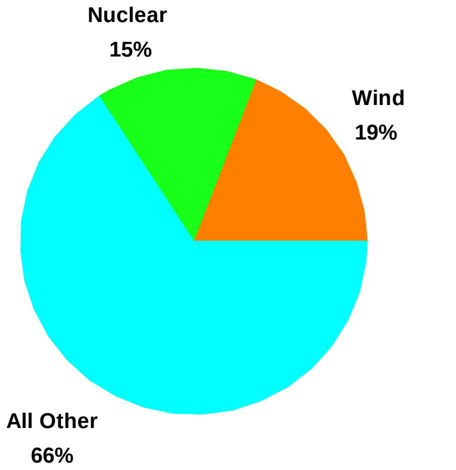
	Electric Power	Savings (loss) by year [1]	CO_2 emissions prevented [1,2]
Nuclear - Calvert Cliffs #3	1600 MW	$2.9 Billion by 2027	12 million tons per year
EmPower Maryland	NA	$2.3 Billion by 2027	3 million tons per year
Land-based Wind	200 MW	$0.3 Billion by 2038	0.4 million tons per year
Offshore Wind	500 MW	(-$0.2 Billion) by 2038	0.9 million tons per year
Rooftop Solar Photovoltaic	1,100 MW	(-$2.8 Billion) by 2038	0.7 million tons per year

[1] Data are from the Levitan Reports requested by the Maryland Public Service Commission (www.levitan.com). "Electric Power" is that which would be produced by installations of the size now being planned for Maryland, assuming that they function at 100% of full capacity.

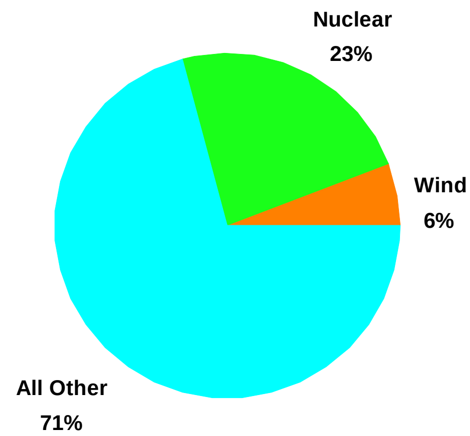
[2] By replacing coal plants ; replacing natural gas fired turbines will prevemt about one-half the emissions..

Nuclear compared to Wind in Germany

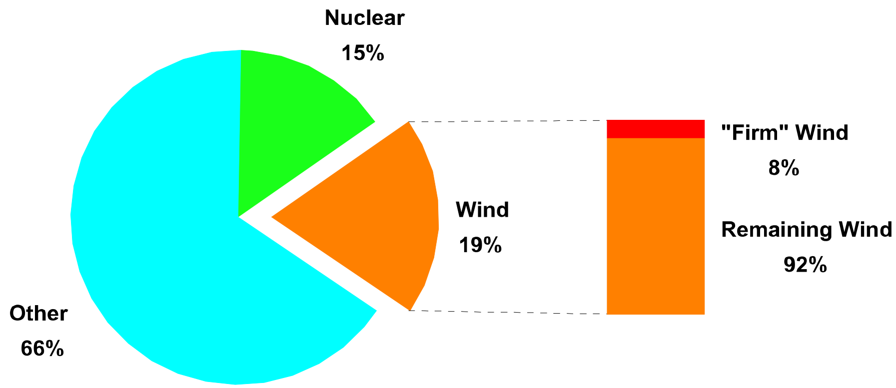
Both wind and nuclear have similar potential, but nuclear works more reliably.



Fraction of Total Generation Capacity



Fraction of Electricity Actually Produced



Only 8 % of wind capacity can replace coal

100% of nuclear capacity can replace coal

Fraction of Total Generation Capacity

Sources: U.S. Energy Information Administration - http://www.eia.doe.gov/countries/country-data.cfm?fips=GM#data;
Energy Information Agency, Paris;
Wikipedia - http://en.wikipedia.org/wiki/Wind_power_in_Germany and http://en.wikipedia.org/wiki/Nuclear_power_by_country
E.ON Netz – http://www.windaction.org/?module=uploads&func=download&fileId=232