

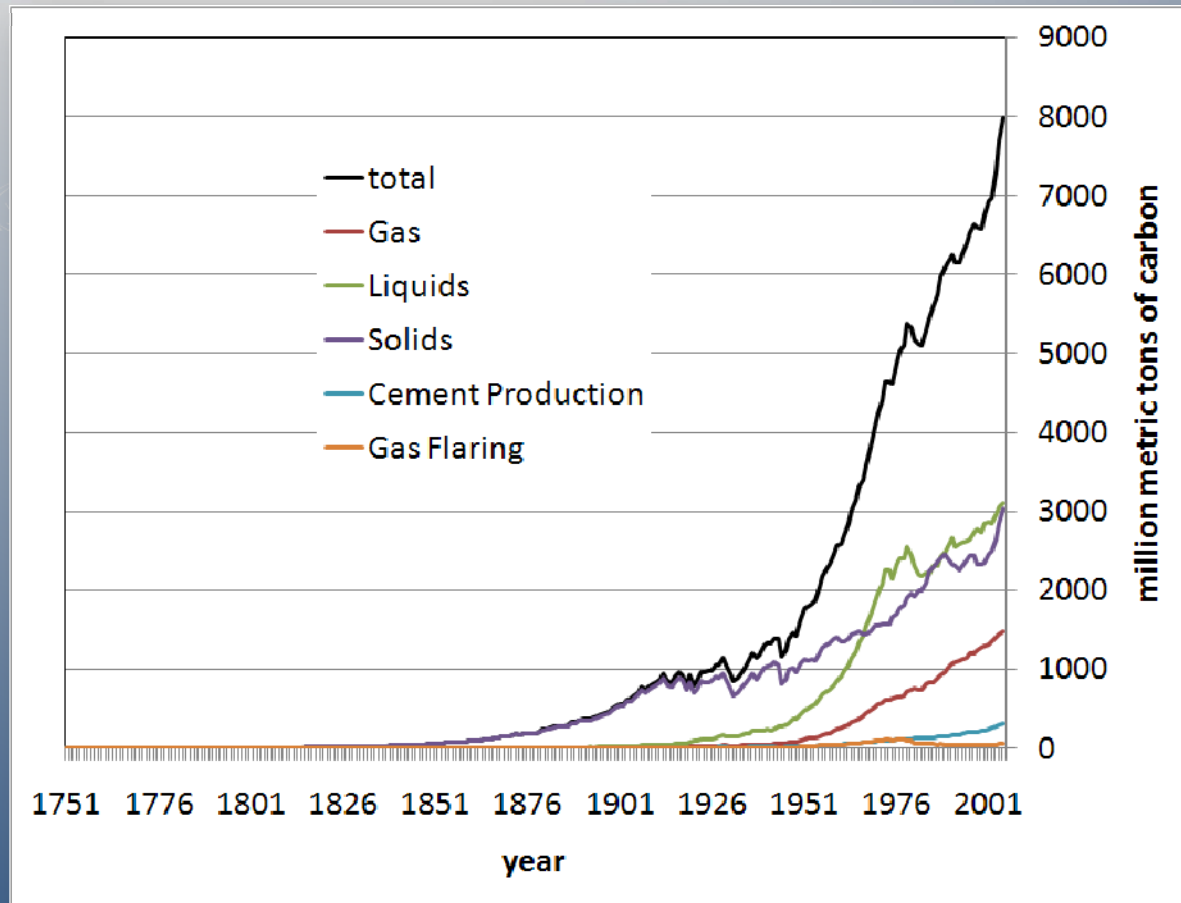
Prospects for a Low Carbon Energy Future

Michael B. McElroy

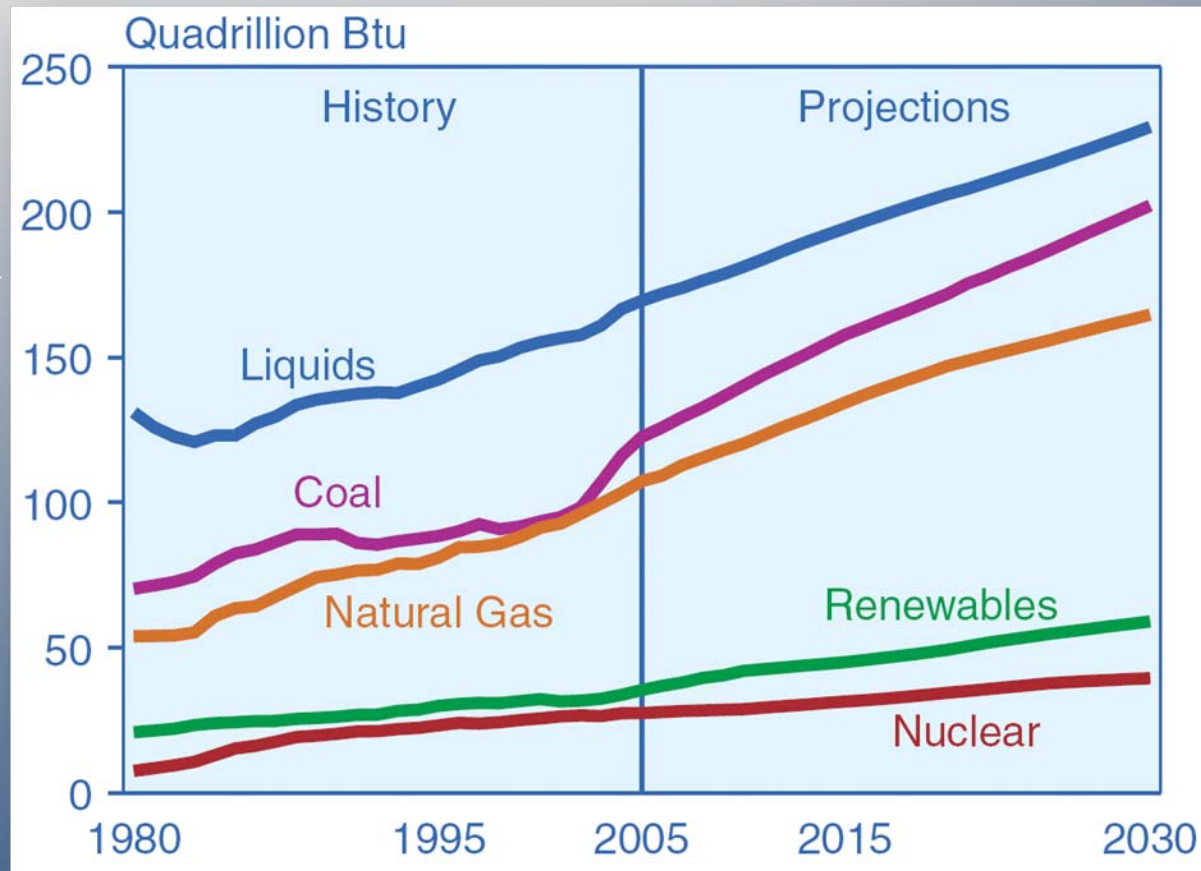
Harvard University

May 13, 2009

Global CO₂ Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2005



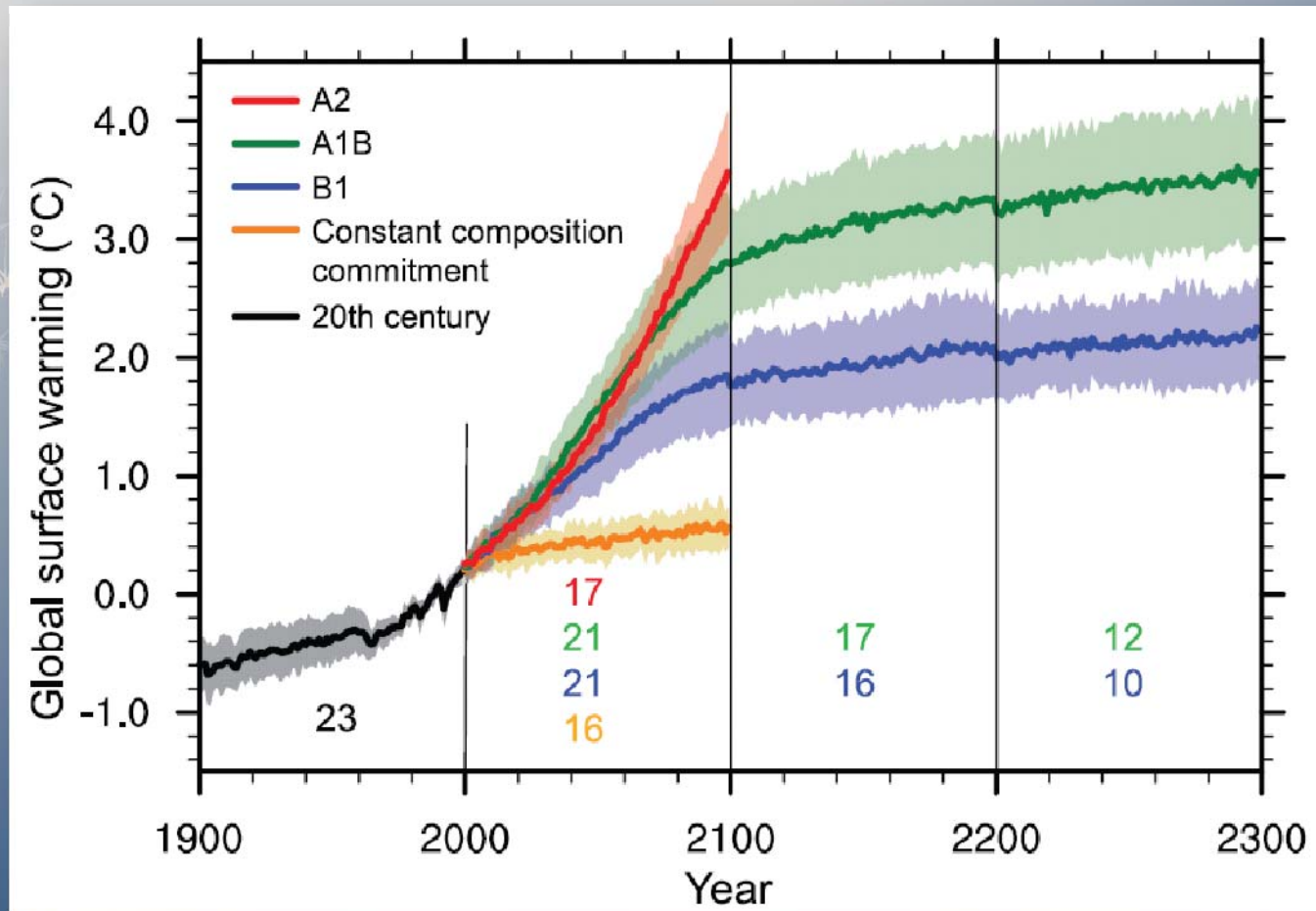
World Energy Use by Fuel Type, 1980-2030



(International Energy Outlook, EIA 2008)

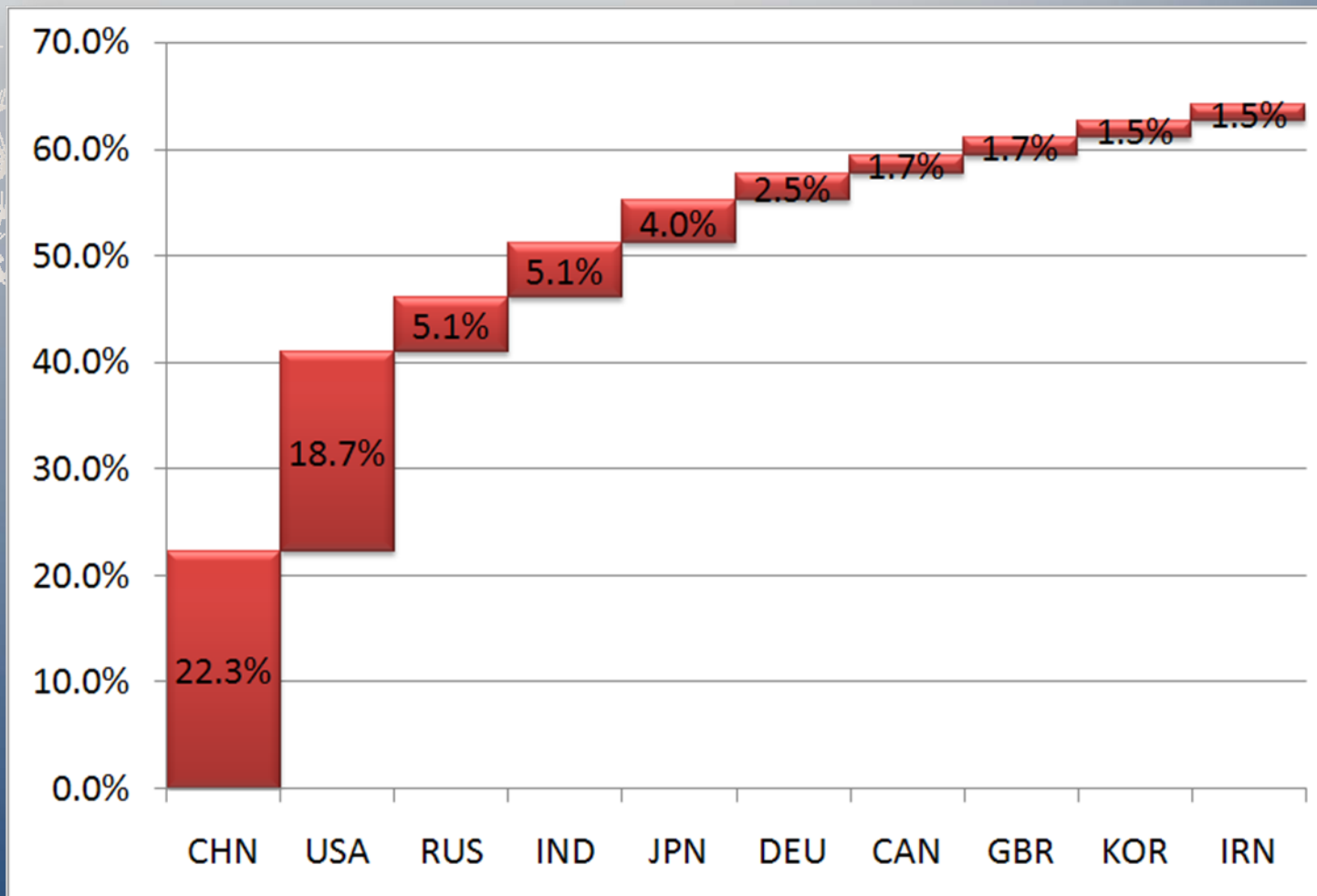
1 Quadrillion Btu \approx 1.055 EJ \approx 293.07 TWh

Global Surface Warming

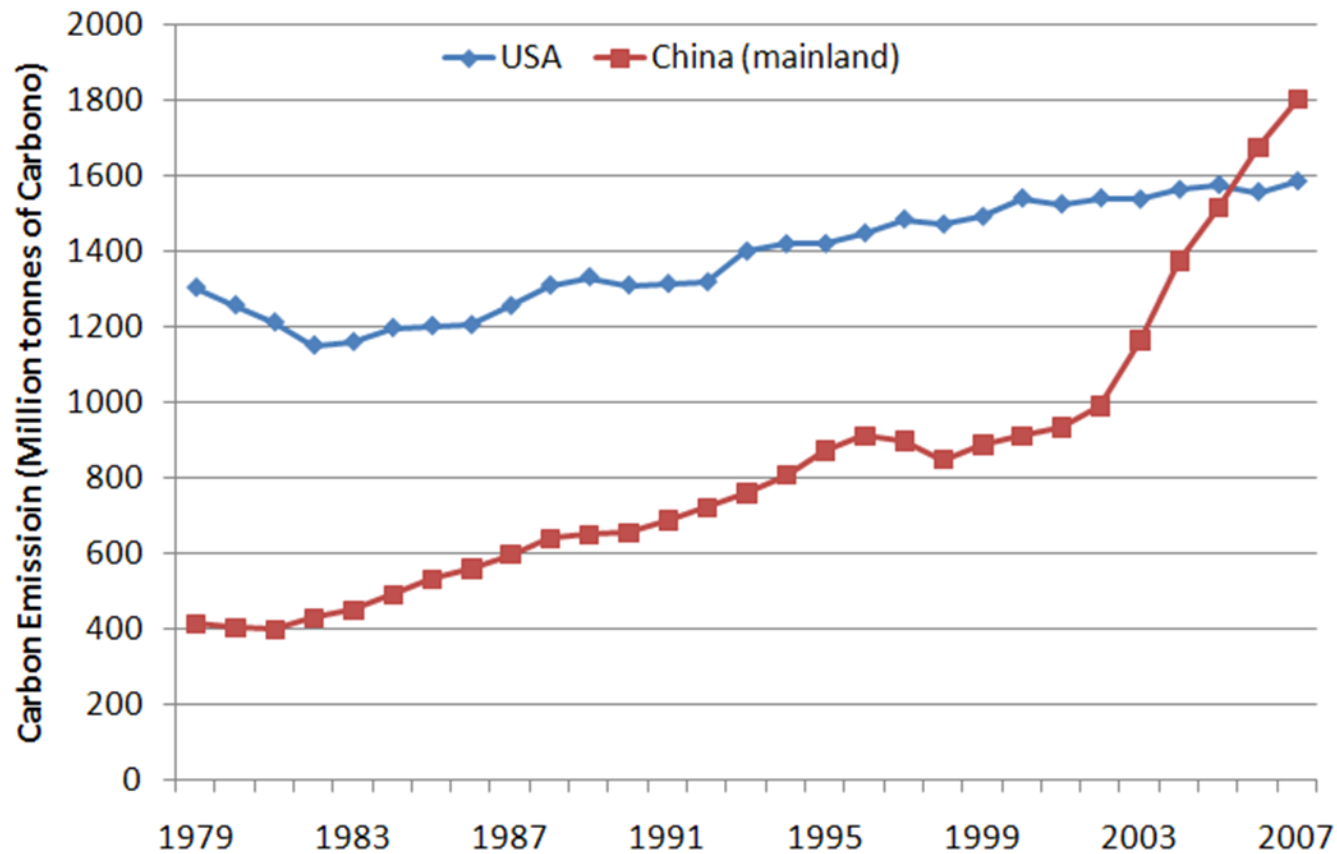


Source: IPCC 2007, Climate Change, the Physical Science Basis

Cumulative CO₂ Emission: Top 10 Countries in 2007

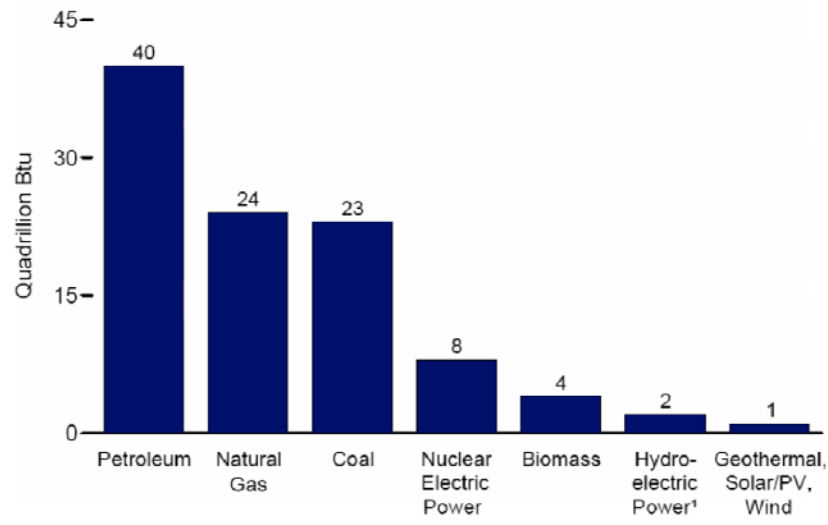


CO₂ Emission from the USA and China, 1979-2007



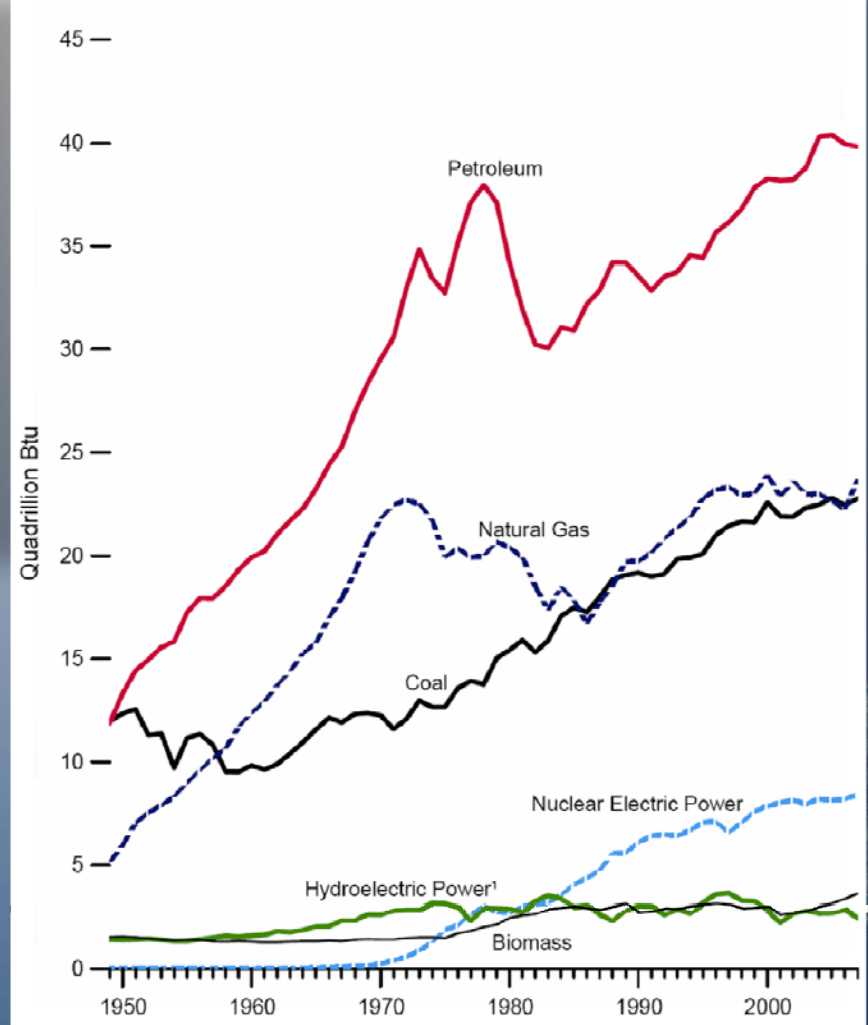
Primary Energy Consumption by Source in the US

By Source, 2007



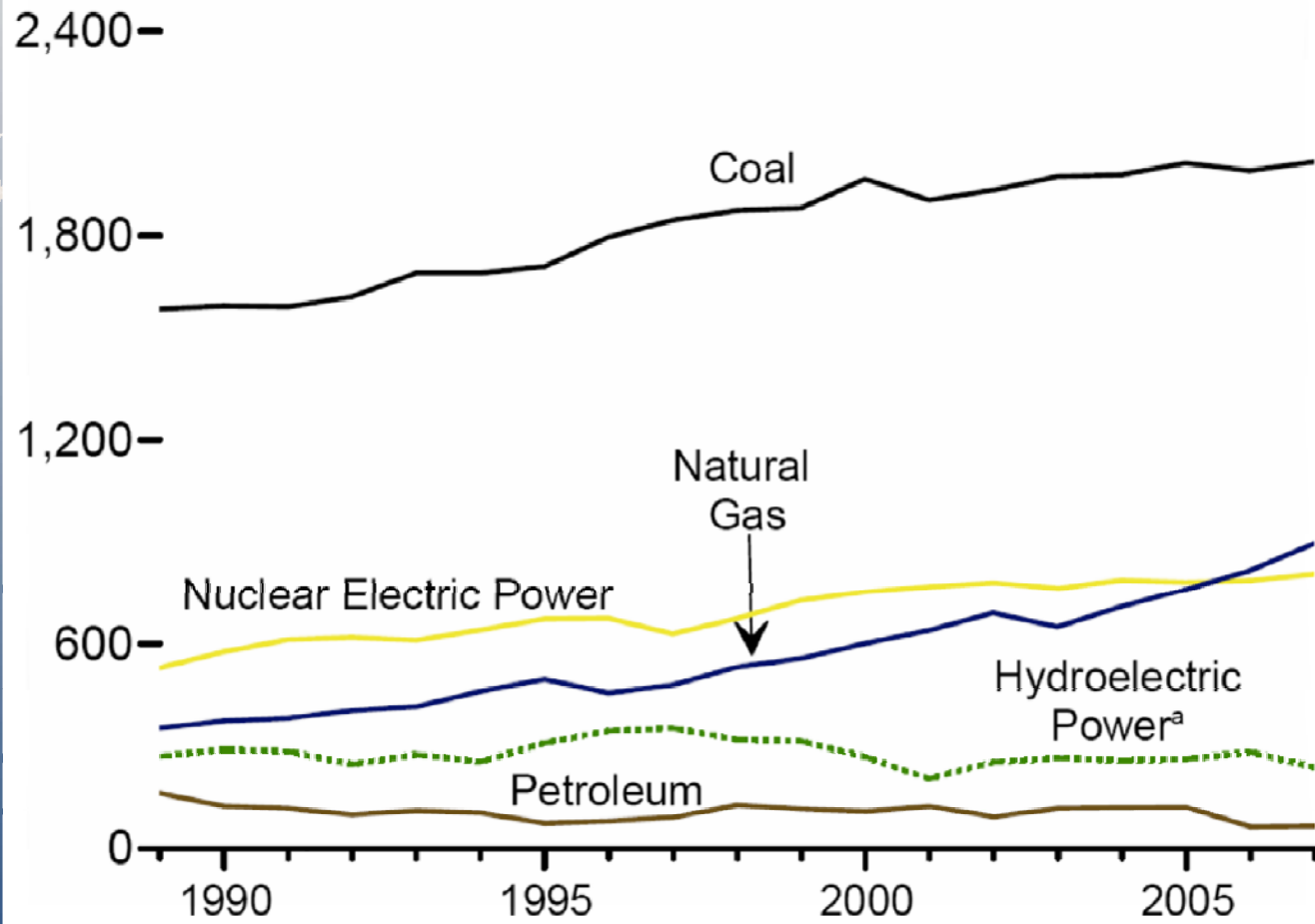
Source: EIA

By Major Source, 1949-2007



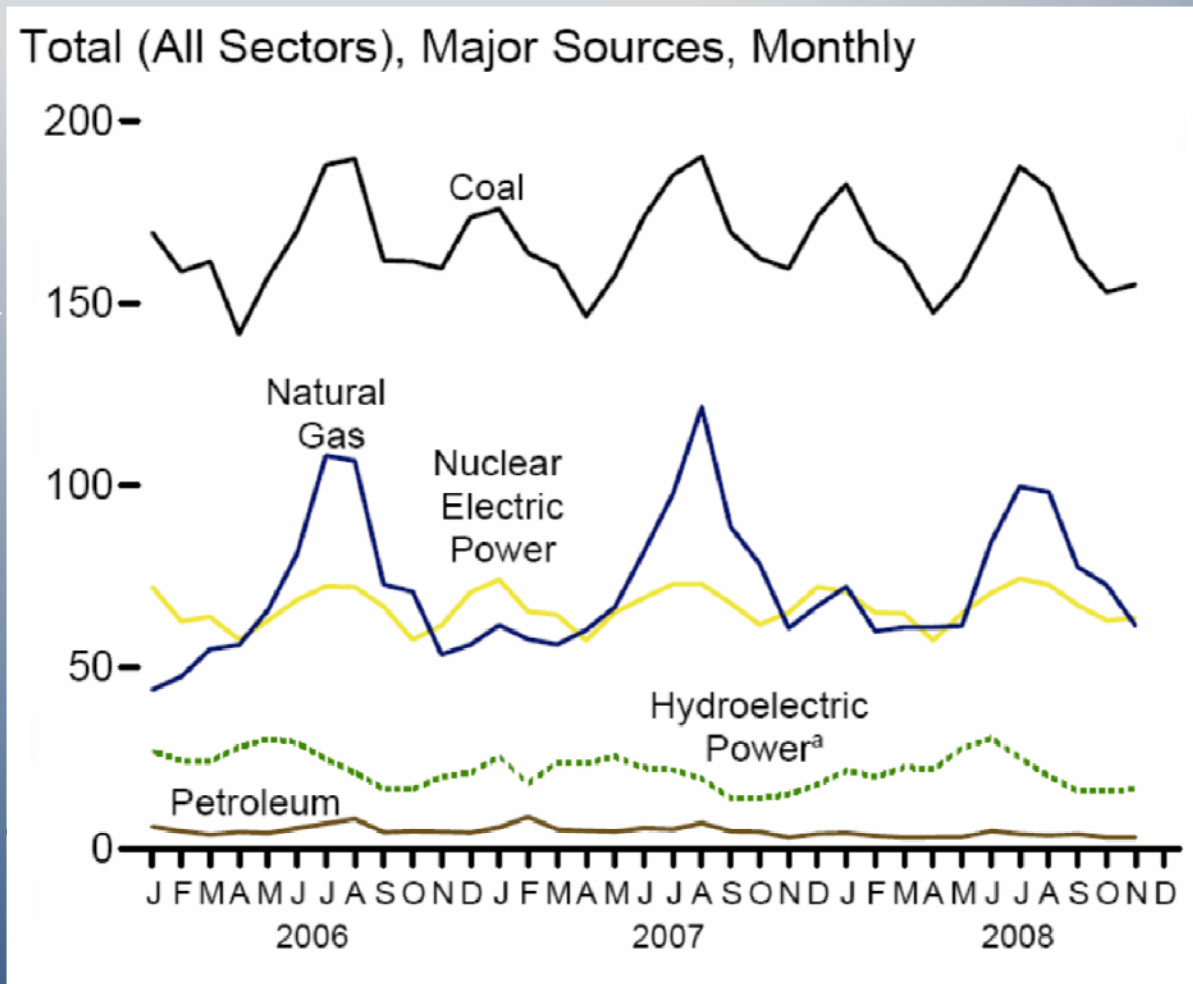
Electricity Net Generation (TWh)

Total (All Sectors), Major Sources, 1989-2007



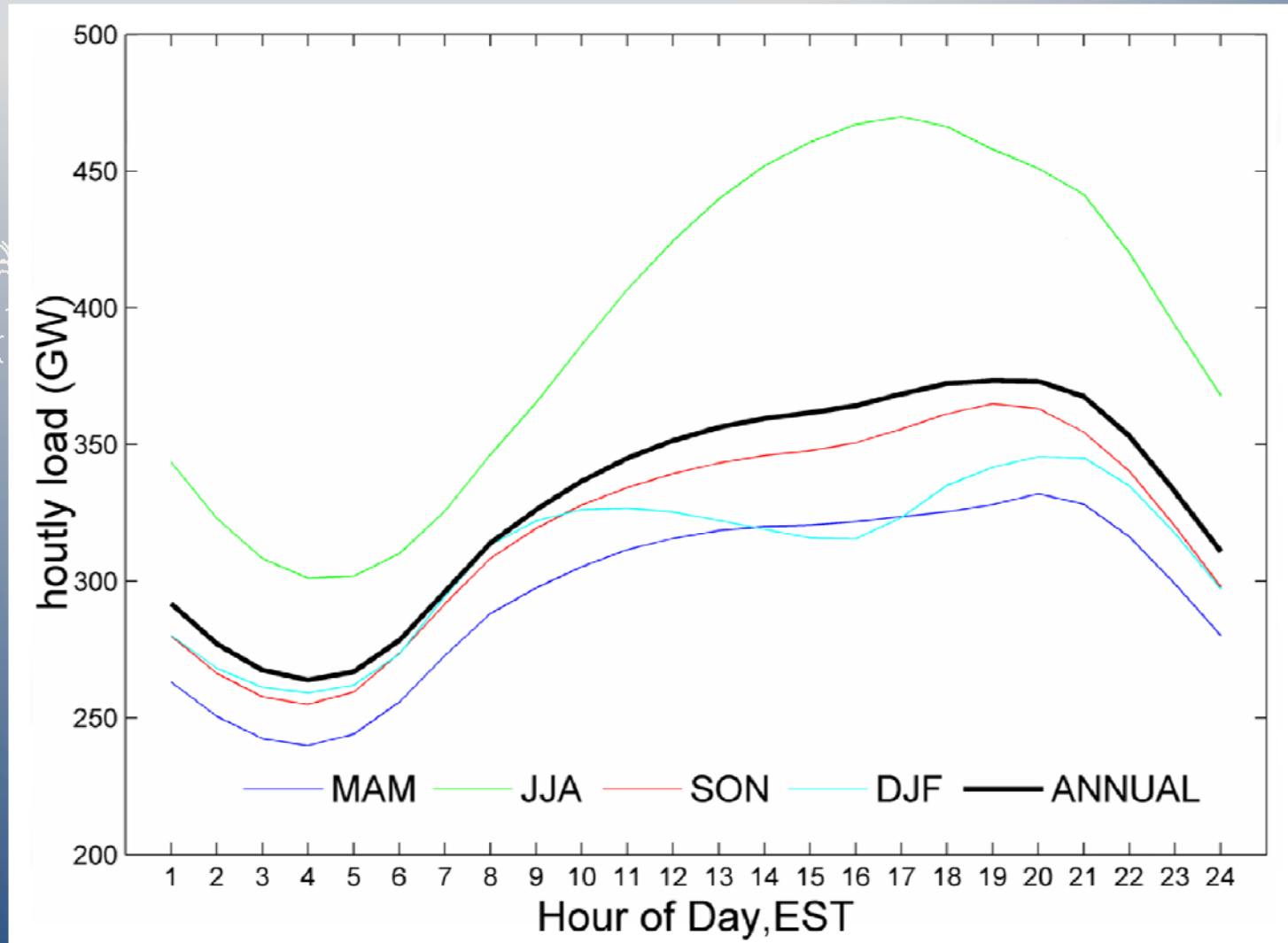
Source: EIA

Monthly Electricity Net Generation (TWh)

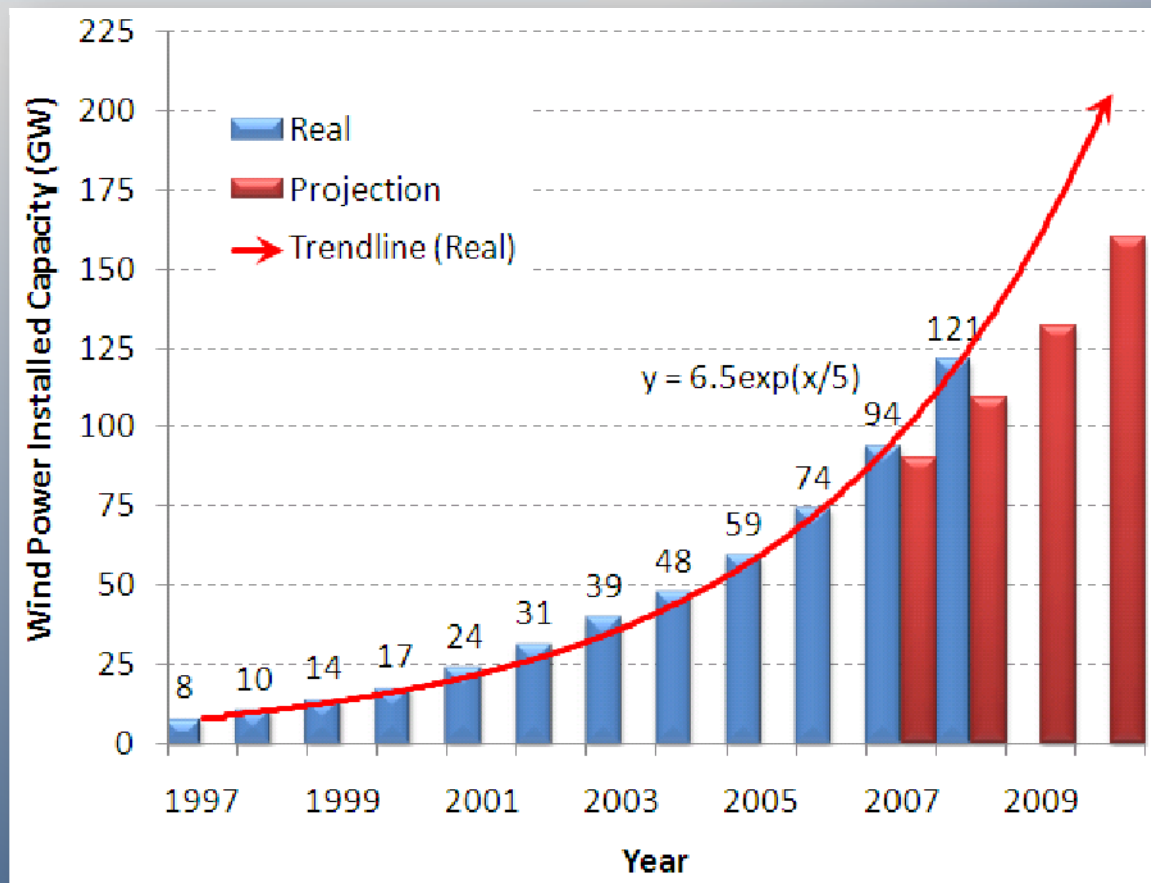


Source: EIA

US load diurnal variation, 2006



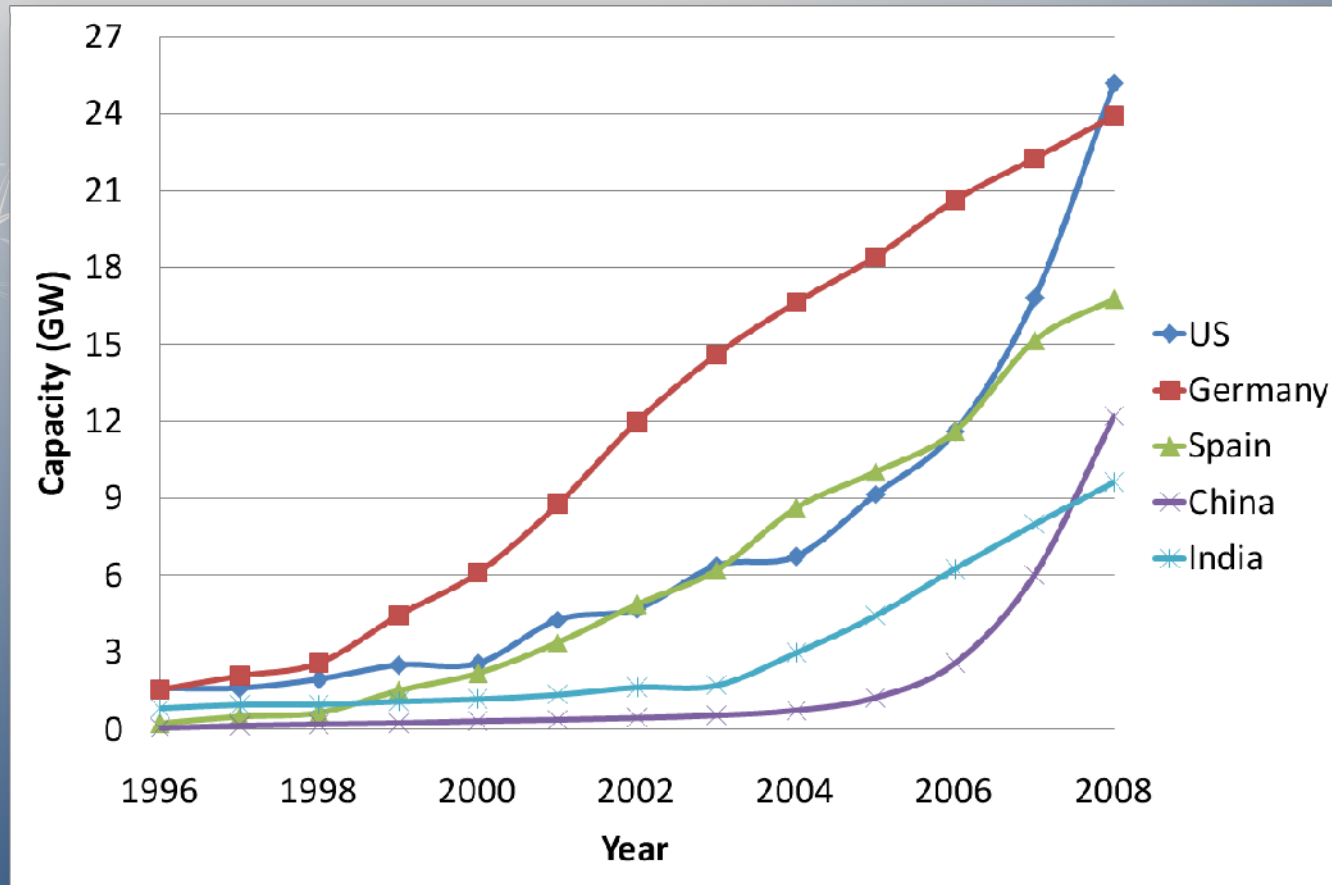
Growth of Wind Power Installed Capacity Worldwide



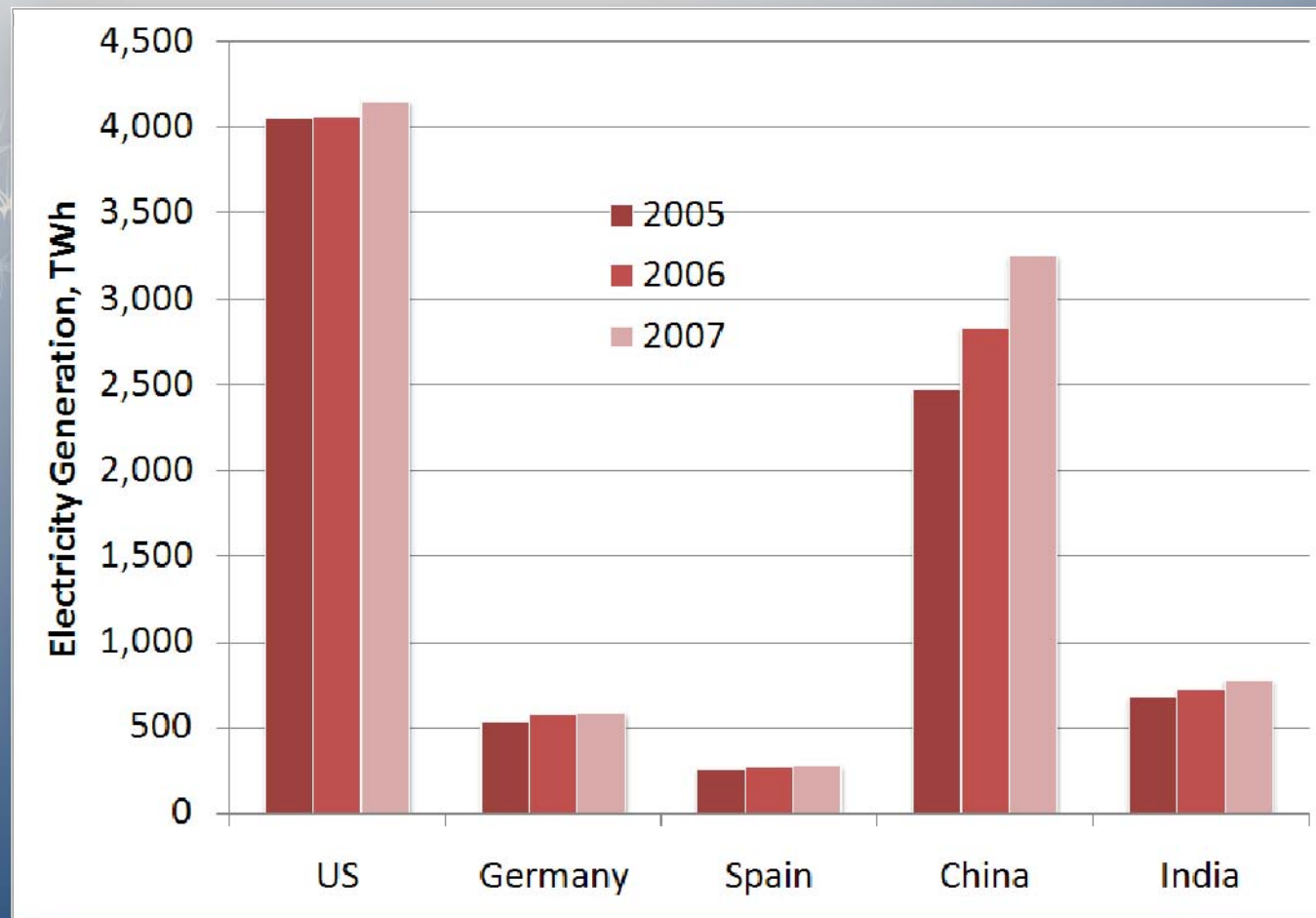
(WWEA, 2007)

IEA in its 2007 alternative Policy Scenario projected the possibility of an **18-fold** increase in wind electricity generation globally by 2030.

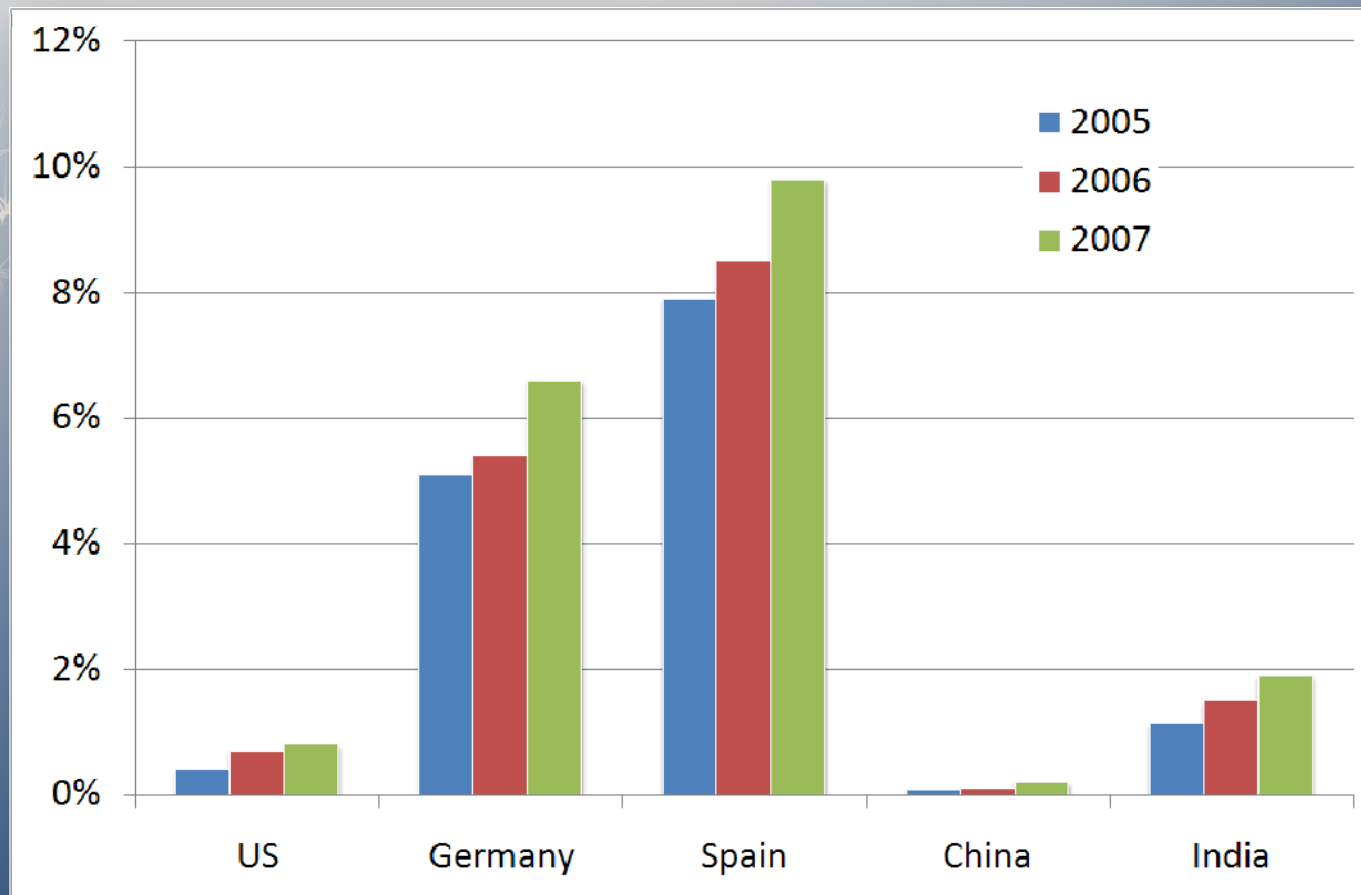
Installed Wind Capacity for the Top 5 Countries, 1996-2008



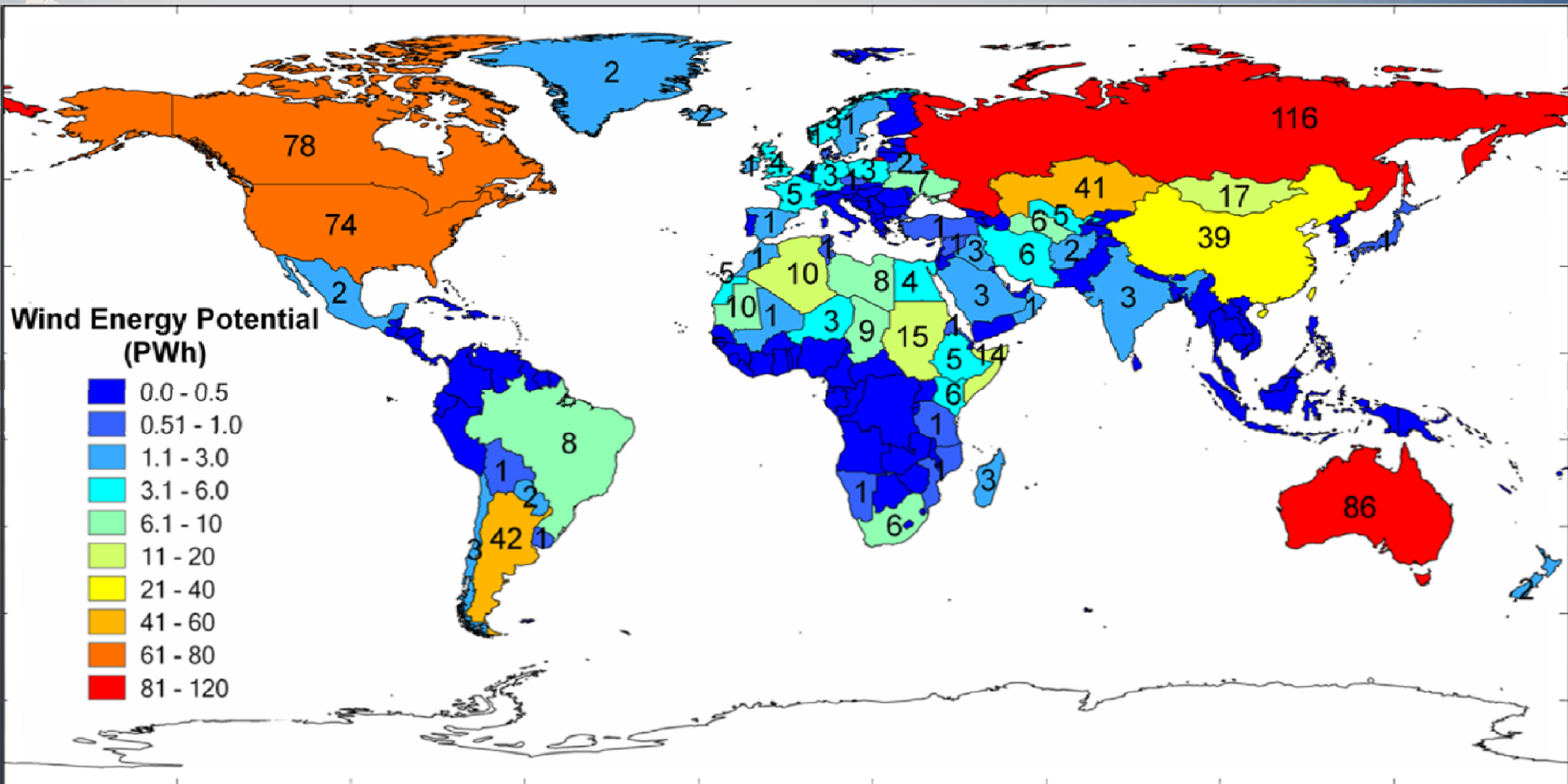
Electricity Generation for Top 5 Wind Power Countries, 2005-2007



Percentage of Wind Electricity in the Total Electricity Generation for Top 5 Wind Power Countries, 2005-2007



Annual Onshore Wind Energy Potential Country by Country, 2006

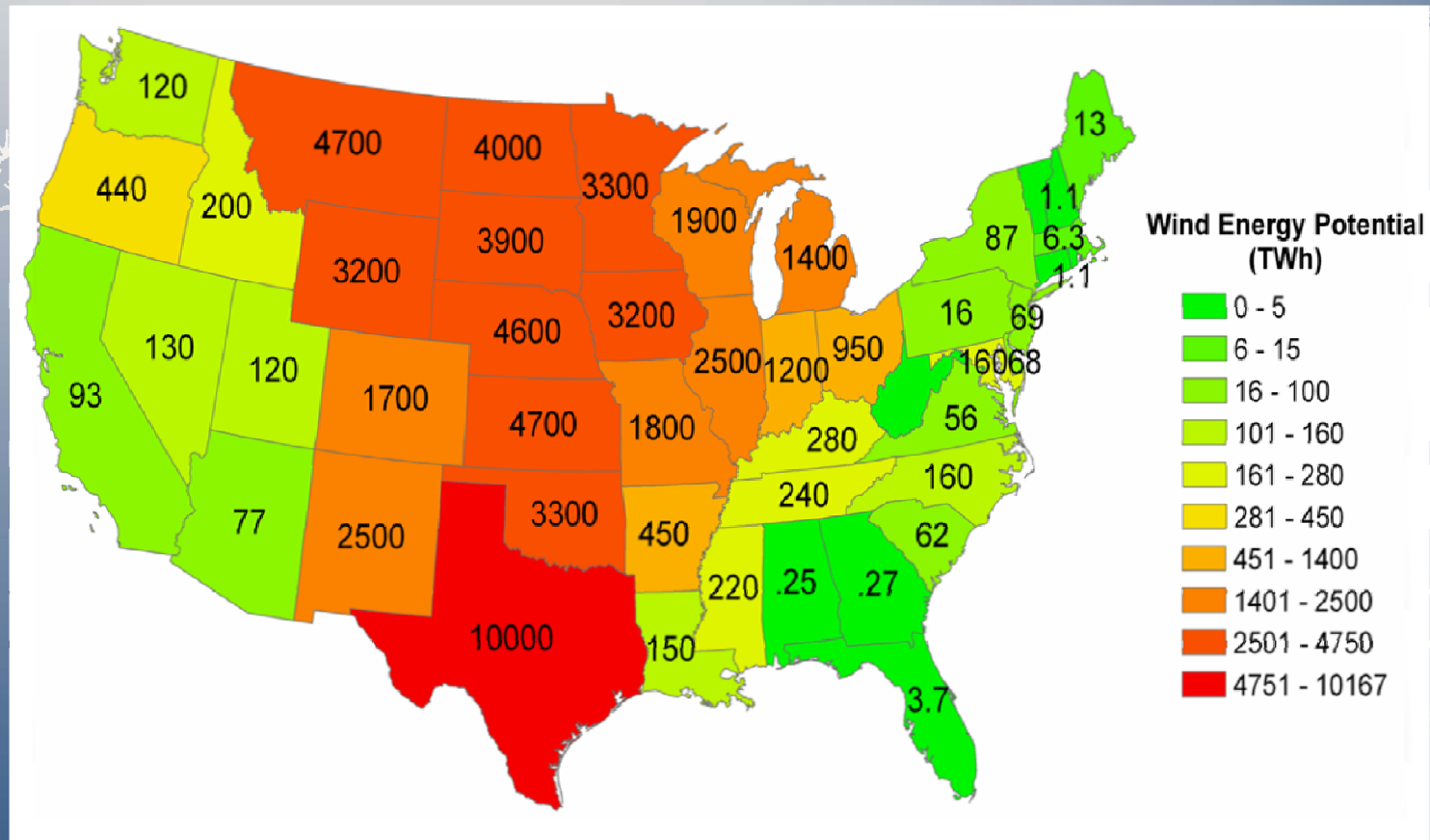


Annual Wind Potential, CO₂ Emission, and Current Electricity Consumption for Top 10 CO₂ Emitting Countries

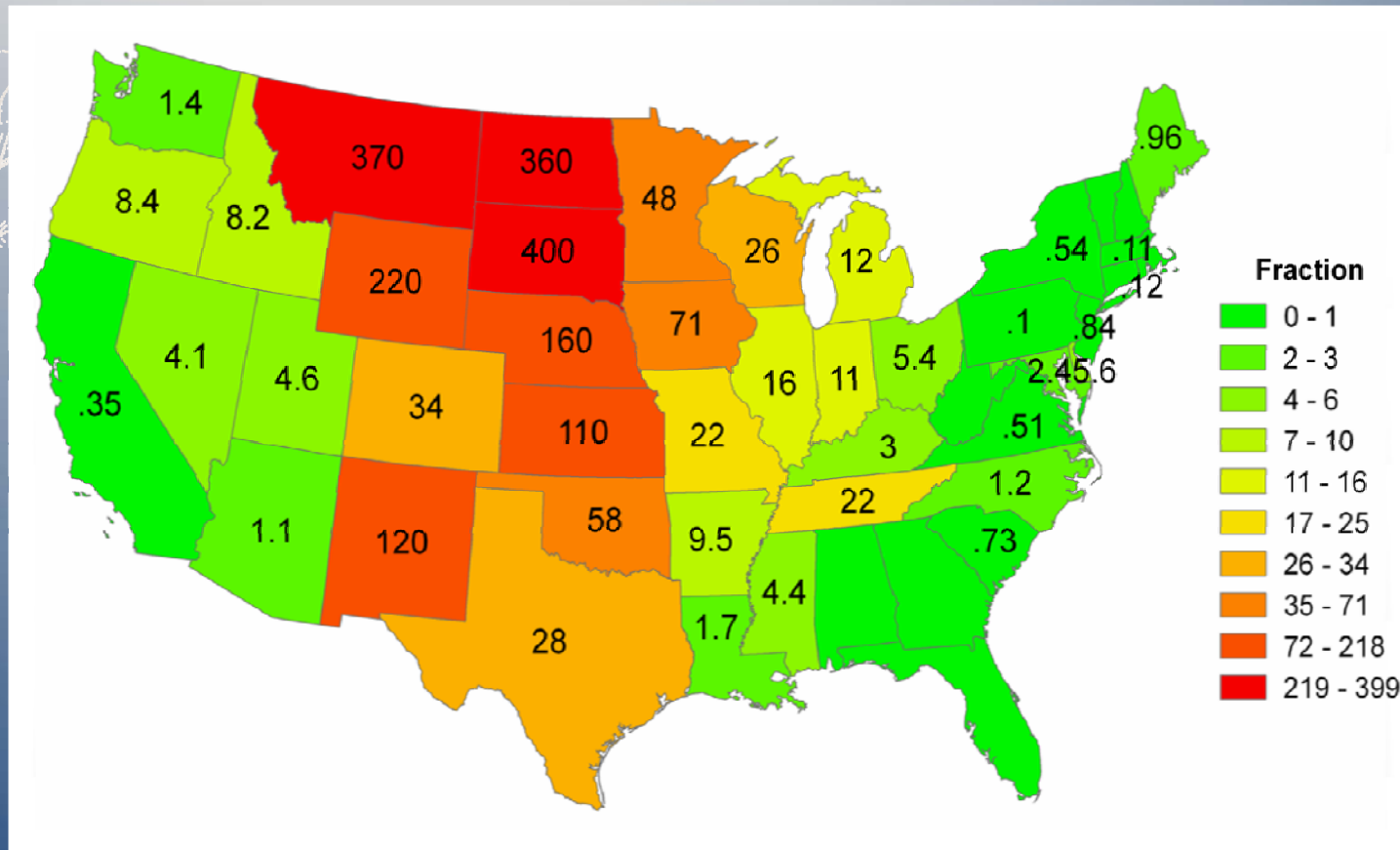
No	Country	CO ₂ emission (million tonnes carbon)	Elec. Consumption (TWh)	Potential Wind Energy (TWh)		
				Onshore	Offshore	Total
1	China	1885	2398.5	39000	4600	44000
2	United States	1586	3815.9	74000	14000	89000
3	Russia	432	779.6	120000	23000	140000
4	India	430	488.8	2900	1100	4000
5	Japan	337	974.1	570	2700	3200
6	Germany	210	545.7	3200	940	4100
7	Canada	145	540.5	78000	21000	99000
8	United Kingdom	145	348.6	4400	6200	11000
9	South Korea	130	352.2	130	990	1100
10	Iran	130	307.5	6100	130	6230

Carbon emission: CDIAC , 2007; Electricity Consumption : EIA, 2005

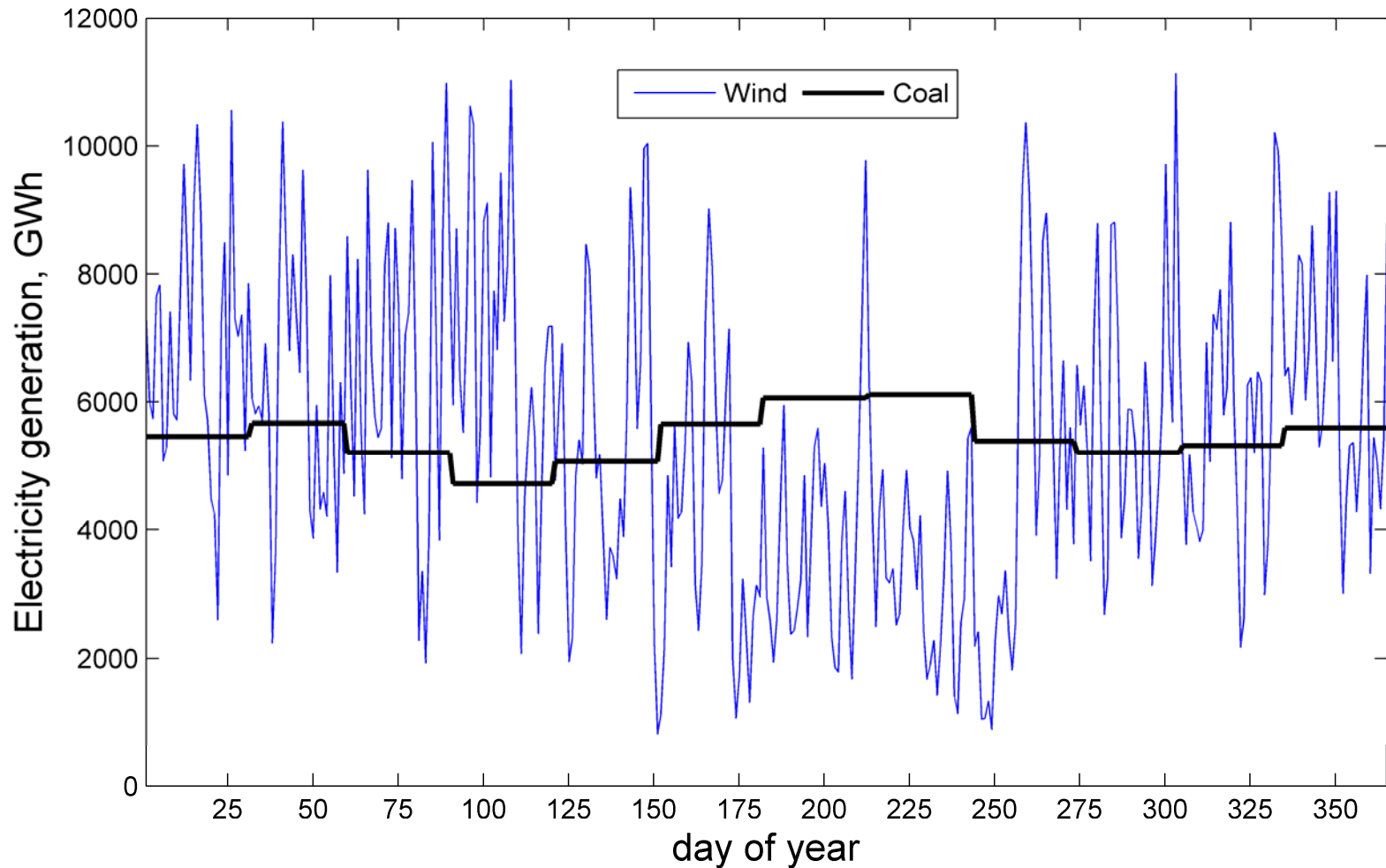
Annual Onshore Wind Energy Potential on a State-by-State Basis for the Contiguous US , 2006



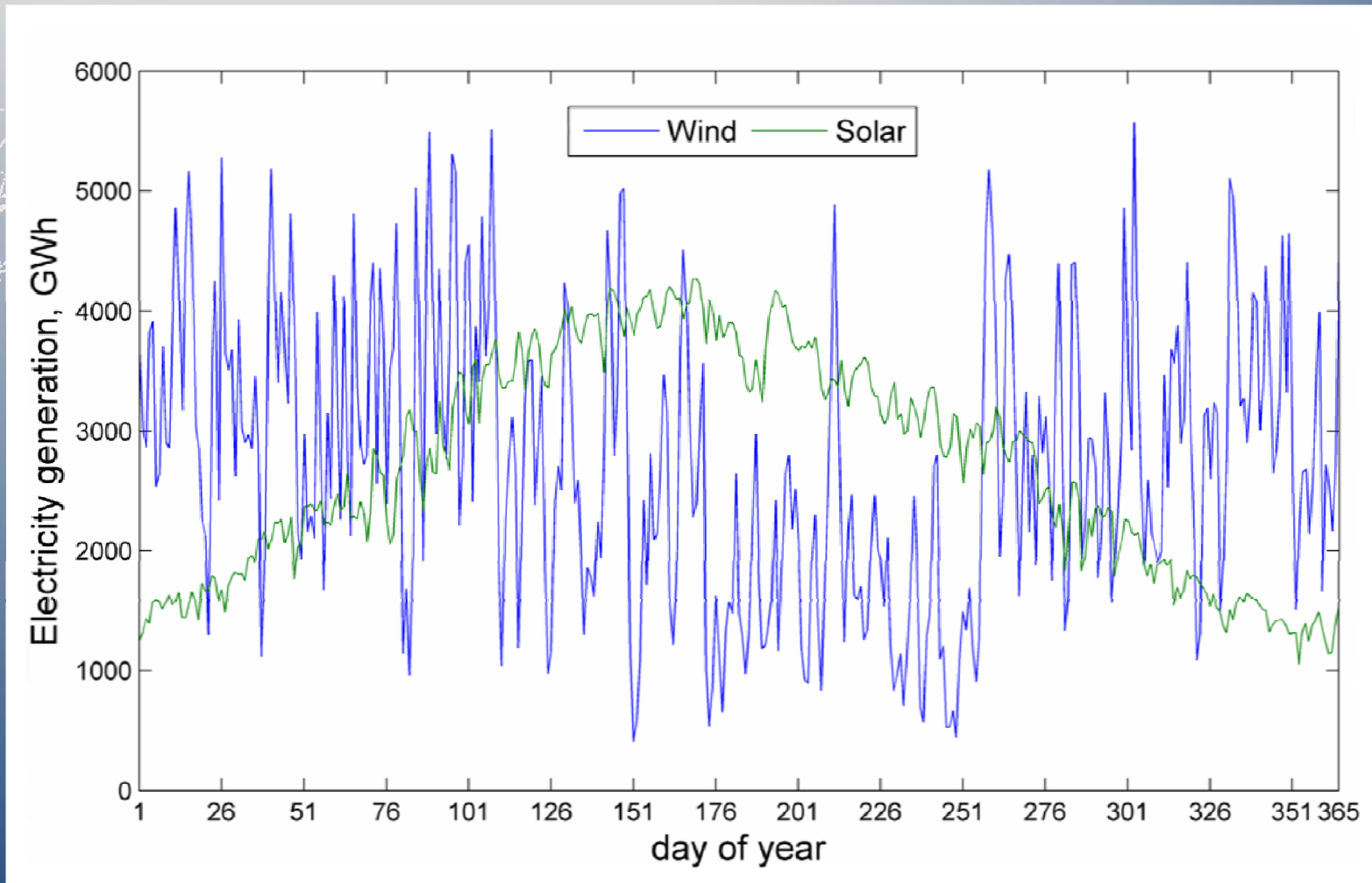
Annual Potential Wind Electricity on a State-by-State Basis for the Contiguous U.S. Expressed as Fraction of Total Electricity Retail Sales in the State, 2006



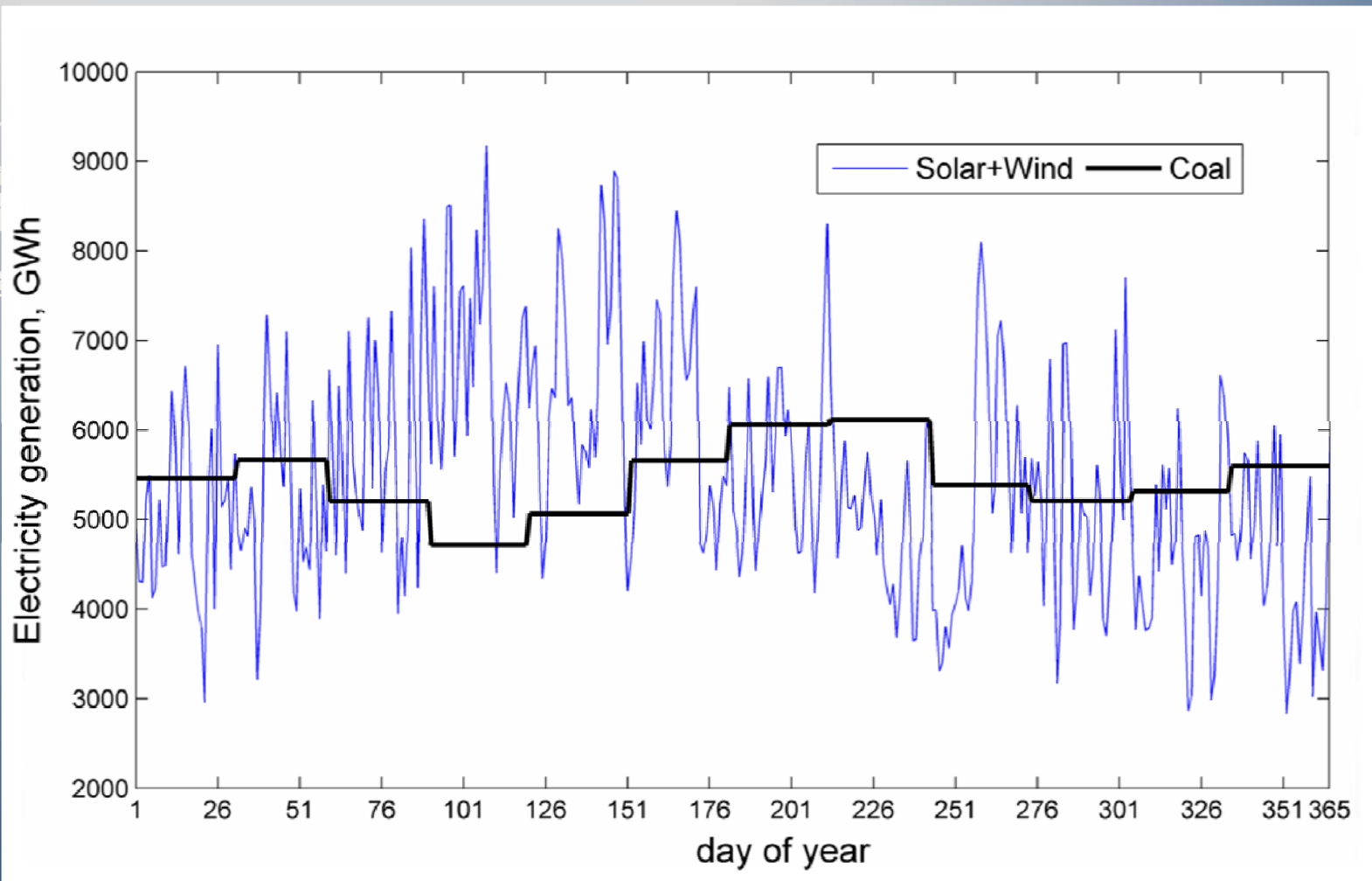
Use wind power only to replace the coal electricity in the US



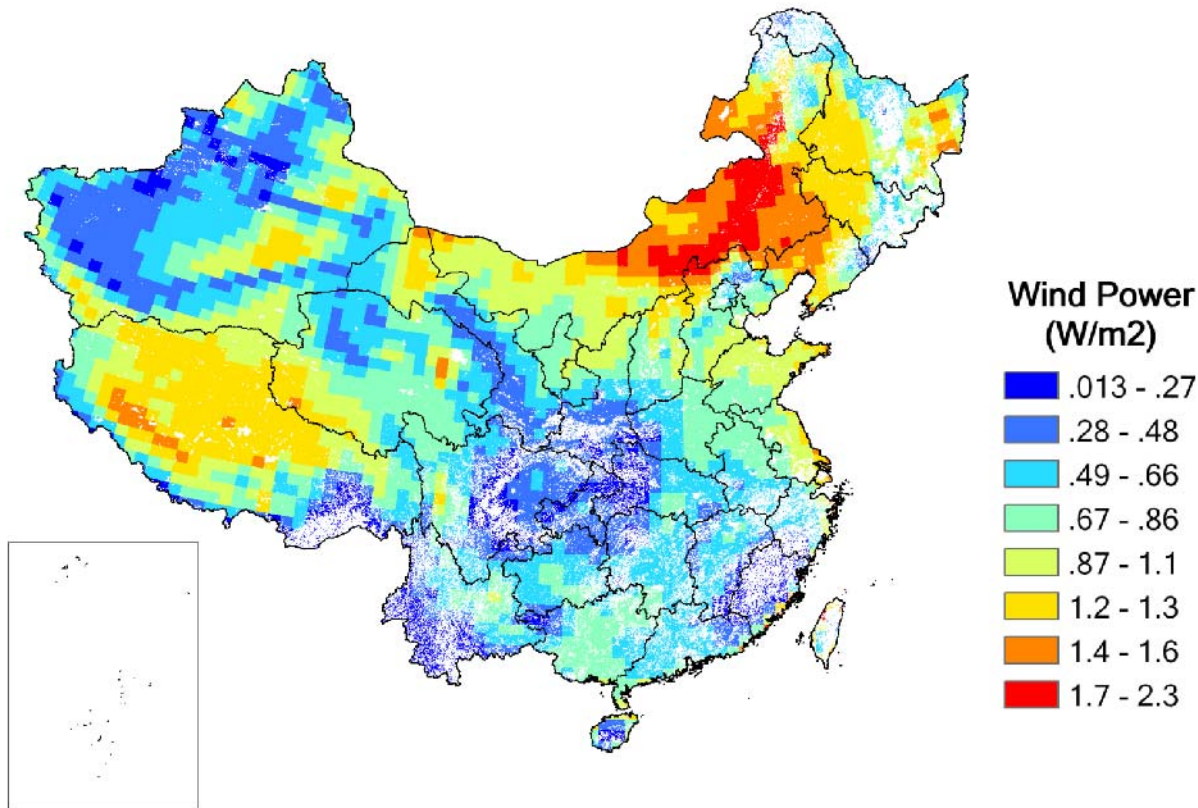
Use wind power and solar power to replace respectively 50% of the coal electricity in the US



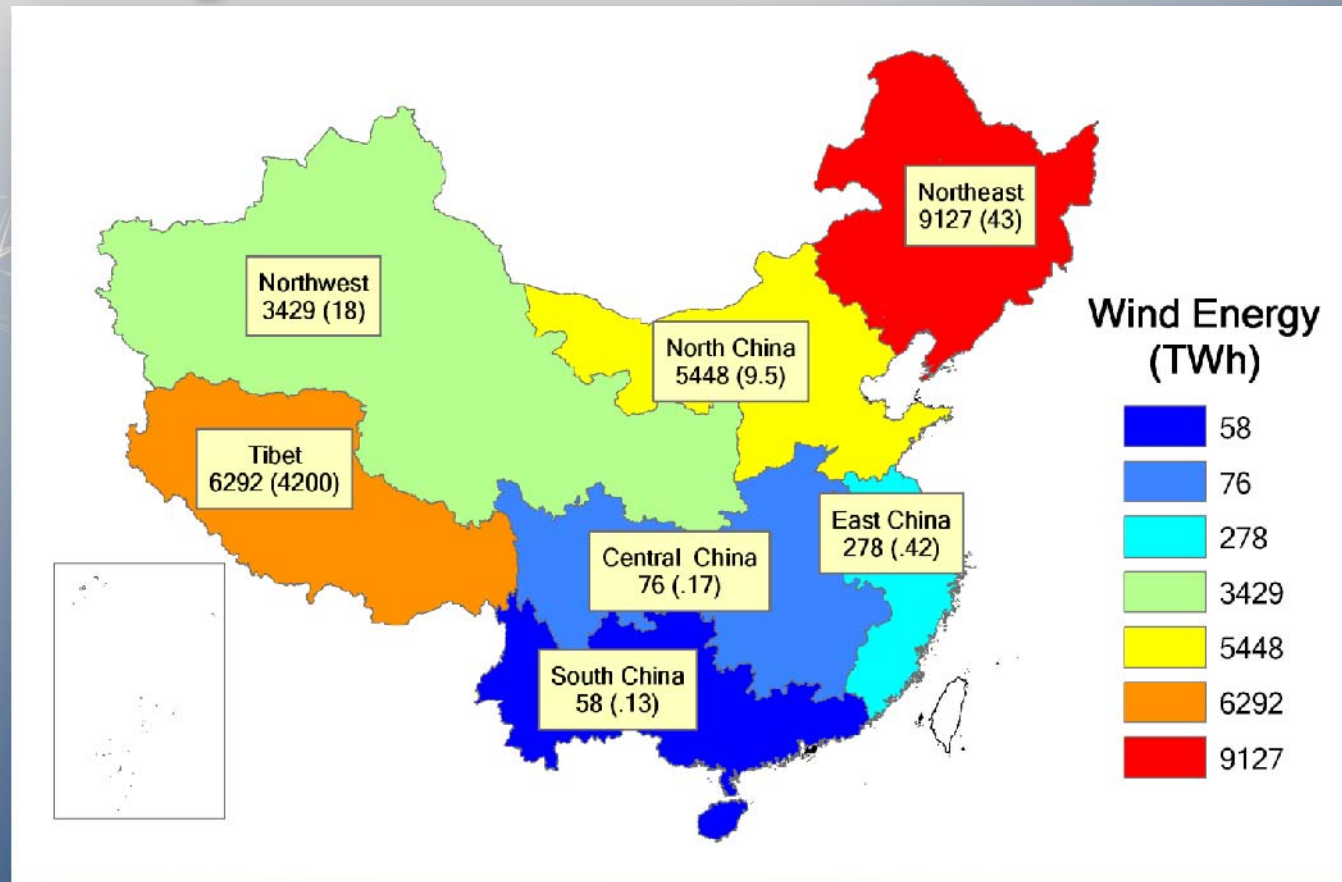
Solar/wind combination to replace the coal electricity in the US



Onshore Wind Power Potential for China (Watts per Unit Land Area)

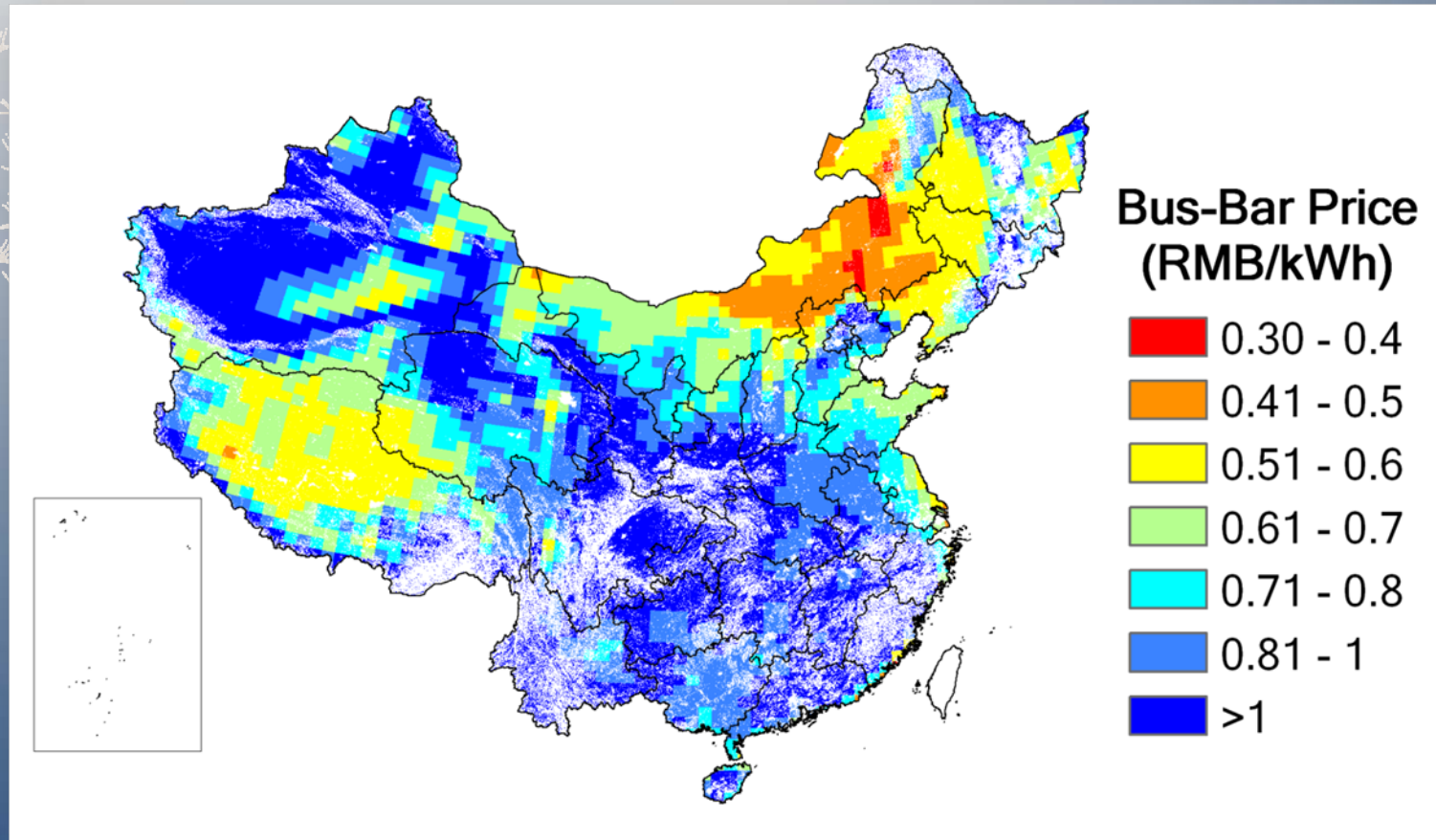


Onshore Wind Energy Potential and its Fraction of the Electricity Generation of Each Regional Grid for China Mainland



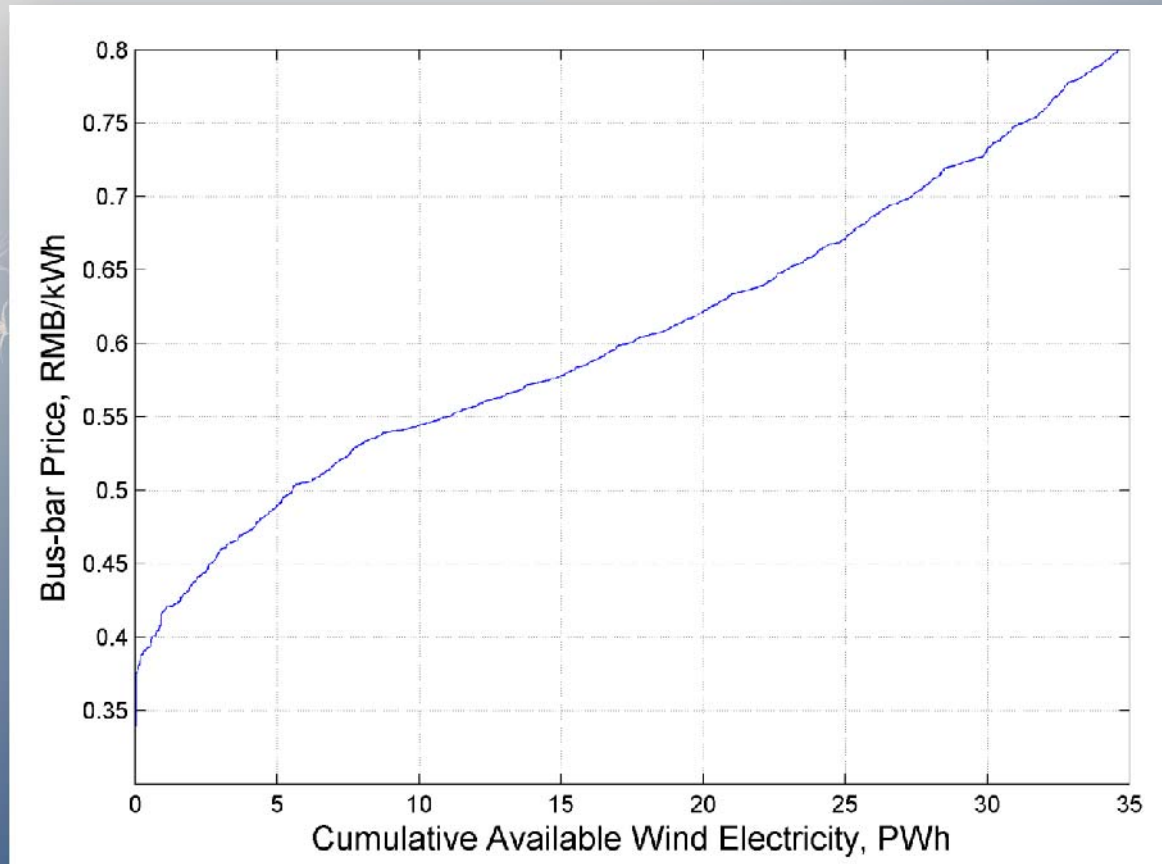
Constraints : Suitable areas only and $CF \geq 20\%$

Bus-Bar Price Estimated of Wind Electricity for China Mainland



1 US dollar \approx 6.8 RMB

Cumulative Available Wind Electricity at Different Bus-bar Price Level for China Mainland



Coal Electricity

- ❑ 1 metric tons of CO₂ will be emitted associated with generation of 1 MWh electricity from coal
- ❑ Bus-bar price of coal electricity will be increased by 0.1 to 0.3 RMB/kWh to capture and sequesterate the emitted carbon (100-300 RMB per metric ton of CO₂)
- ❑ Additional public health cost from burning coal



Thanks!