Understanding Global Energy

Prof. Mike Mauel

Applied Physics Lunch-Time Seminar

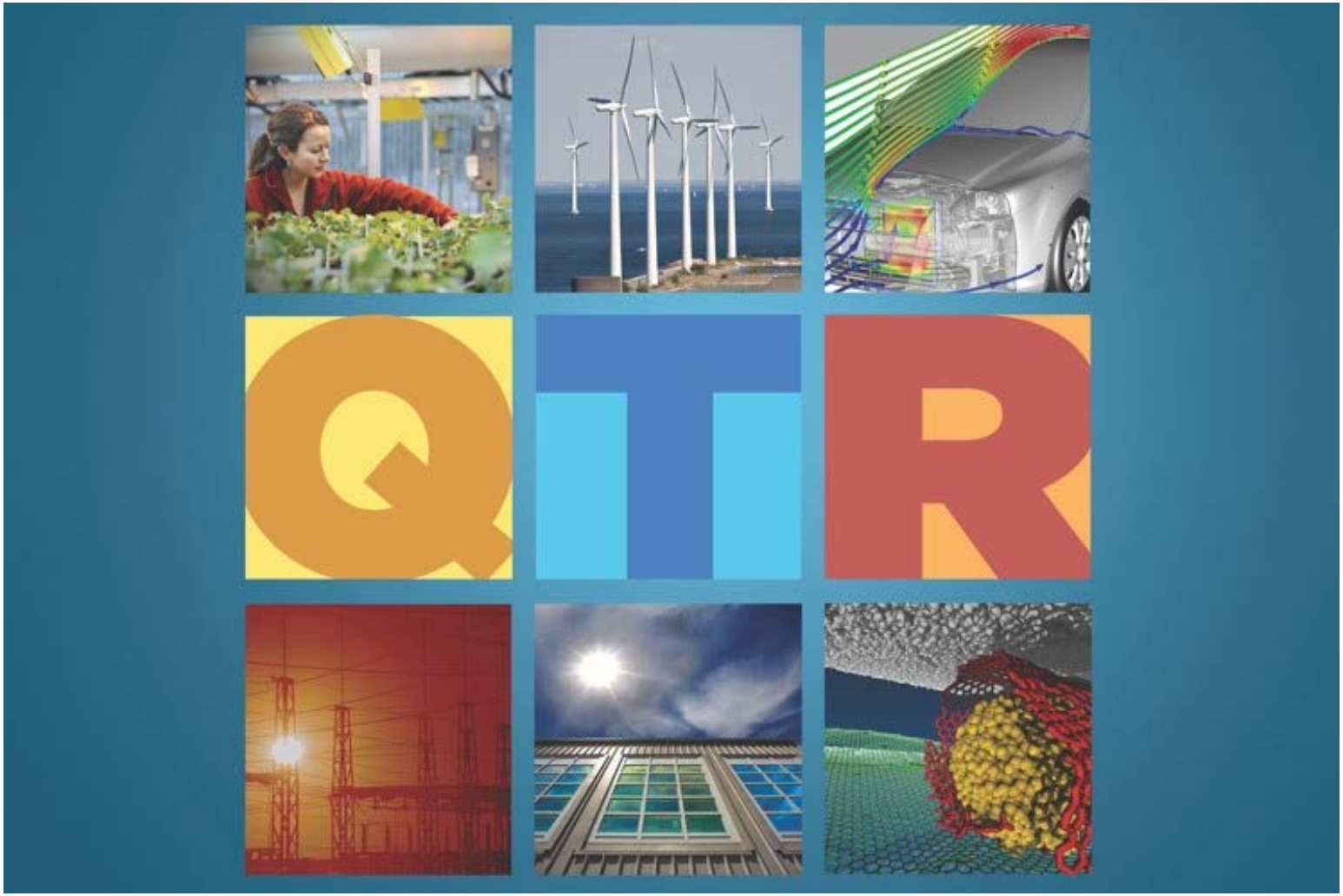
Fall 2015

Current Events (9/23/2015)

- (This week) Columbia hosts 2015 International Conference on Sustainable Development, free for students (http://ic-sd.org)
- (Last week, 9/15) EnterSolar and Bloomberg-L.P., announced the JFK Airport Park roof-top solar PV project. 1.5 MW peak power (about 205 kW-years) as a "remote net metering" project supported by New York state's $1B "Sun Initiative". (http://www.entersolar.com/news/pr/bloomberg-lps-innovative-new-york-city-solar-project-provides-renewable-energy-bridge-from-queens-to-manhattan)
- (Last Thursday) Congressman Chris Gibson (R-NY Poughkeepsie-Cooperstown) and 10 other House Republicans introduce resolution to commit to study and address "causes and effects" of climate change, "including efforts to balance human activities that have been found to have an impact." (https://gibson.house.gov/news/documentsingle.aspx?DocumentID=398414)
- (Tuesday, 9/22) Democratic Senators introduced legislation supporting President Obama's greenhouse gas target: -2%/year through 2025. (http://thehill.com/policy/energy-environment/254505-senate-dems-unveil-energy-policy-vision)
- (9/10) U.S. DOE releases QTR...

DOE Releases QTR (9/10/15)

(Quadrennial Technoligy Review)



http://energy.gov/qtr

http://www.energy.gov/articles/energy-department-releases-second-quadrennial-technology-review

DOE Releases QTR (9/10/15)

(Quadrennial Technology Review)

- QTR: the current status of clean energy technologies and identifies hundreds of clean energy research opportunities that could modernize the power sector
- Secretary Moniz, "The QTR is intended to serve as a blueprint for the Energy Department, its National Laboratories and the public and private sectors as we all work toward additional future technology breakthroughs that can help to mitigate the risks of climate change, modernize our energy infrastructure and enhance our energy security."
- Science Advisor Holdren, "No challenge poses a greater threat to our future than climate change, which is primarily caused by carbon pollution from energy use."

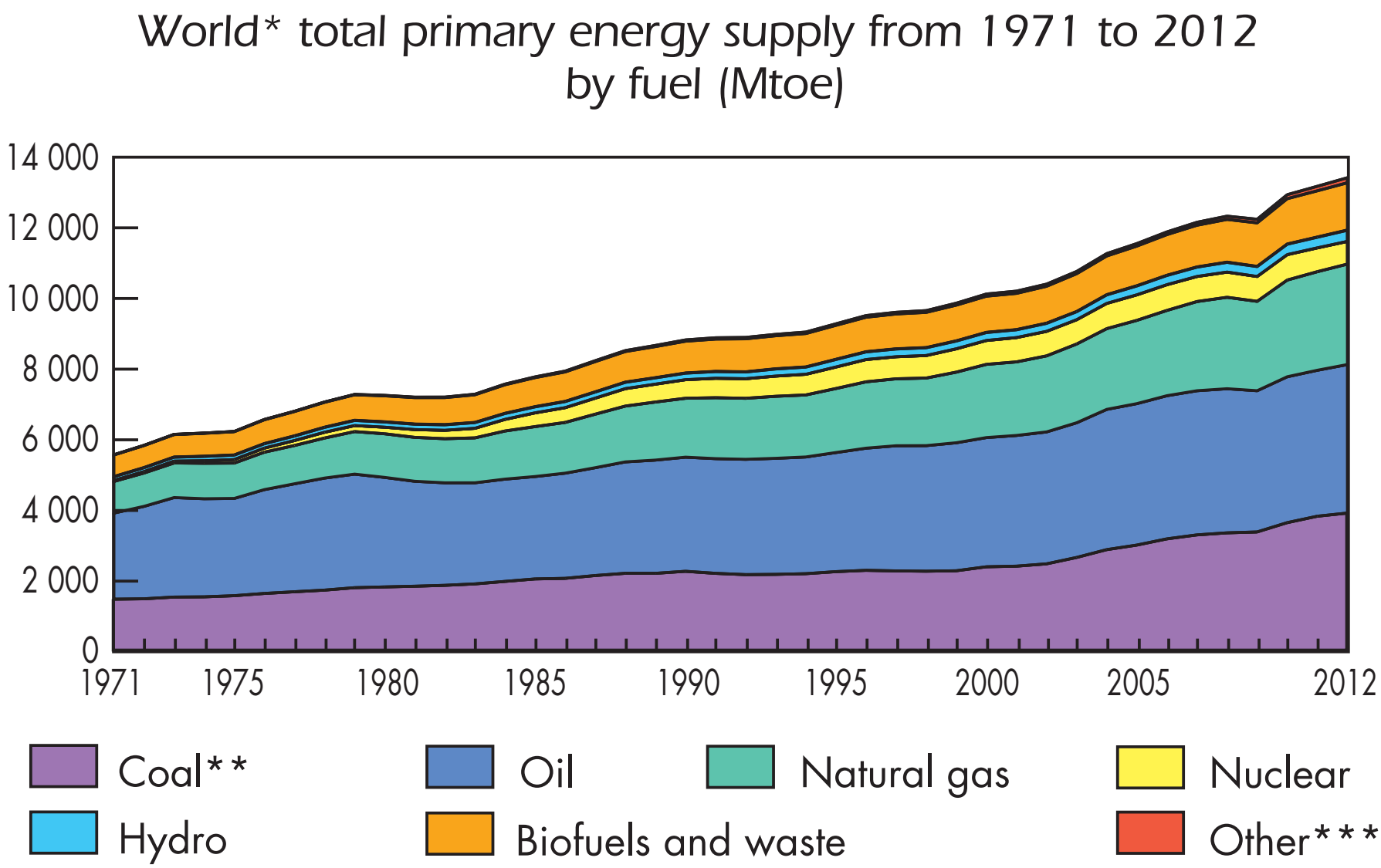
http://energy.gov/qtr

http://www.energy.gov/articles/energy-department-releases-second-quadrennial-technology-review

Energy: Sources

- Richter, Beyond Smoke and Mirrors (2nd Ed).
- U.S. Energy Information Agency (EIA, http://www.eia.gov)
- International Energy Agency (IEA, http://www.iea.org)
- Exxon-Mobil "Outlook for Energy" (http://corporate.exxonmobil.com/en/energy/energy-outlook)
- BP "Energy Outlook" (http://www.bp.com/en/global/corporate/about-bp/energy-economics/energy-outlook.html)

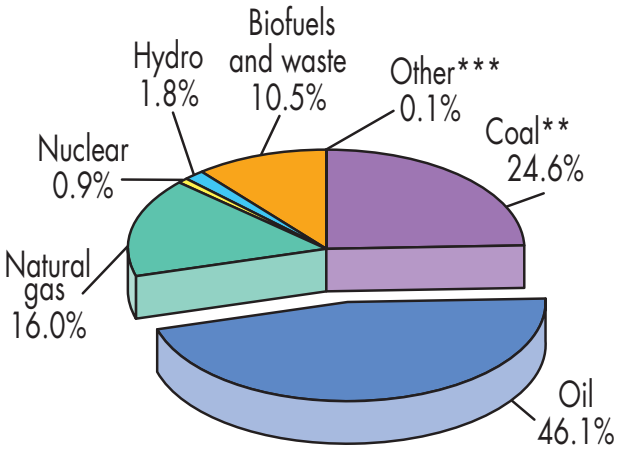
World TEPS



http://www.iea.org/publications/freepublications/publication/keyworld2014.pdf

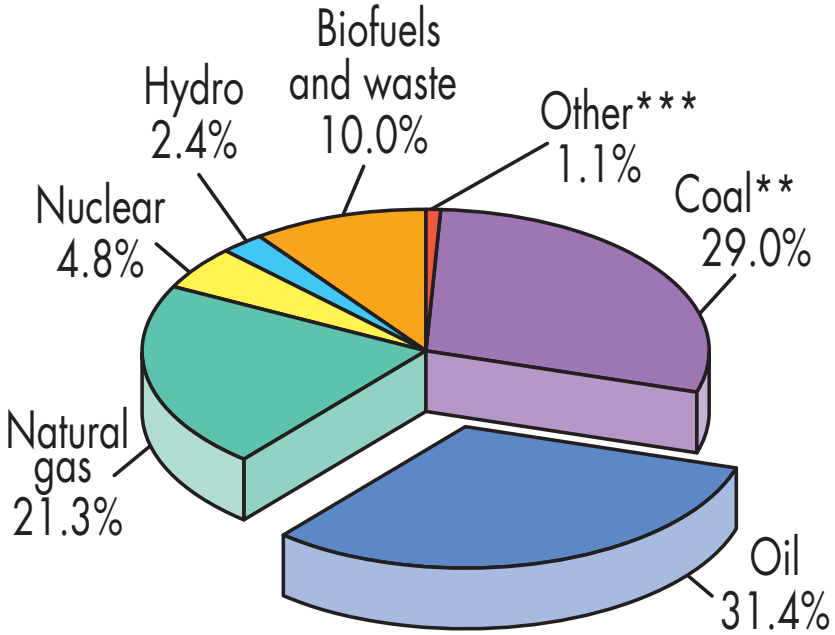
TEPS Fuel Share

1973



6 106 Mtoe

2012



13 371 Mtoe

**World includes international aviation and international marine bunkers.*
***In these graphs, peat and oil shale are aggregated with coal.*
****Includes geothermal, solar, wind, heat, etc.*

ton oil equivalent (toe)

- 41.9 GJ
- 1.3 kW-year
- 10 ton TNT
- 7.4 barrel oil equiv
- 1.43 ton coal equiv
- 3.5 horse-years (12 hr/day)
- 20 man-years (12 hr/day)

13,554 Mtoe (2013)

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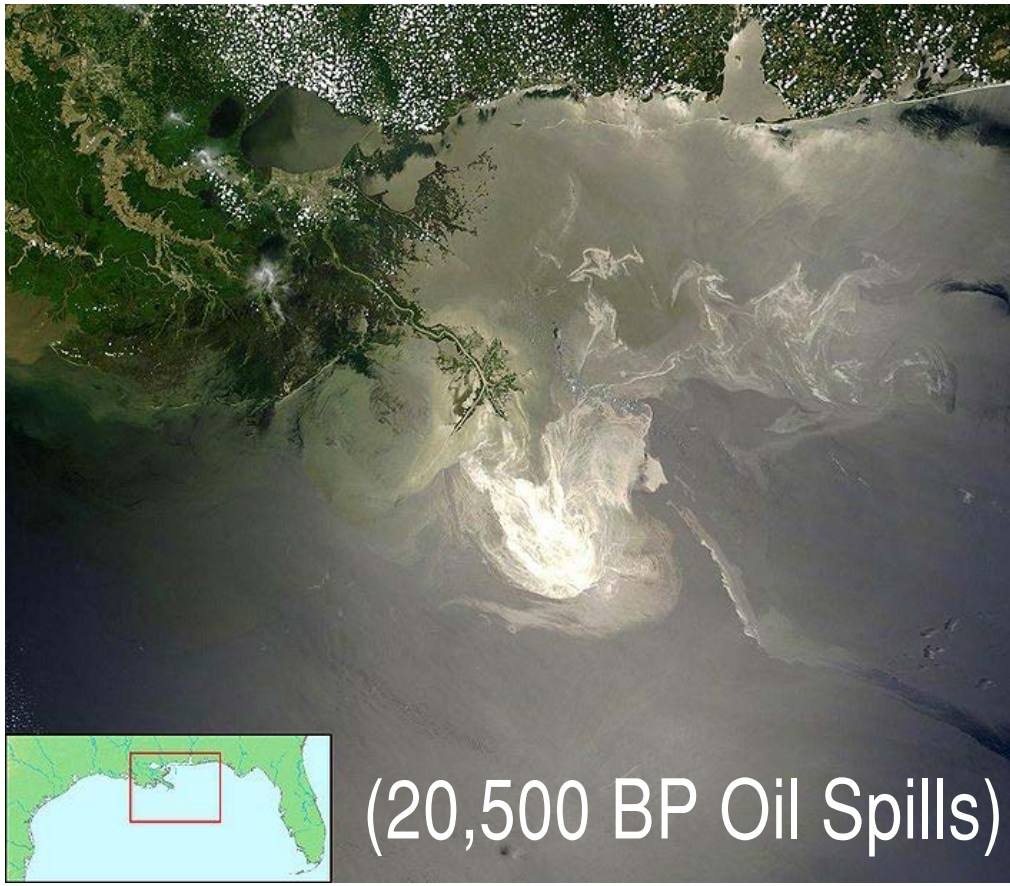

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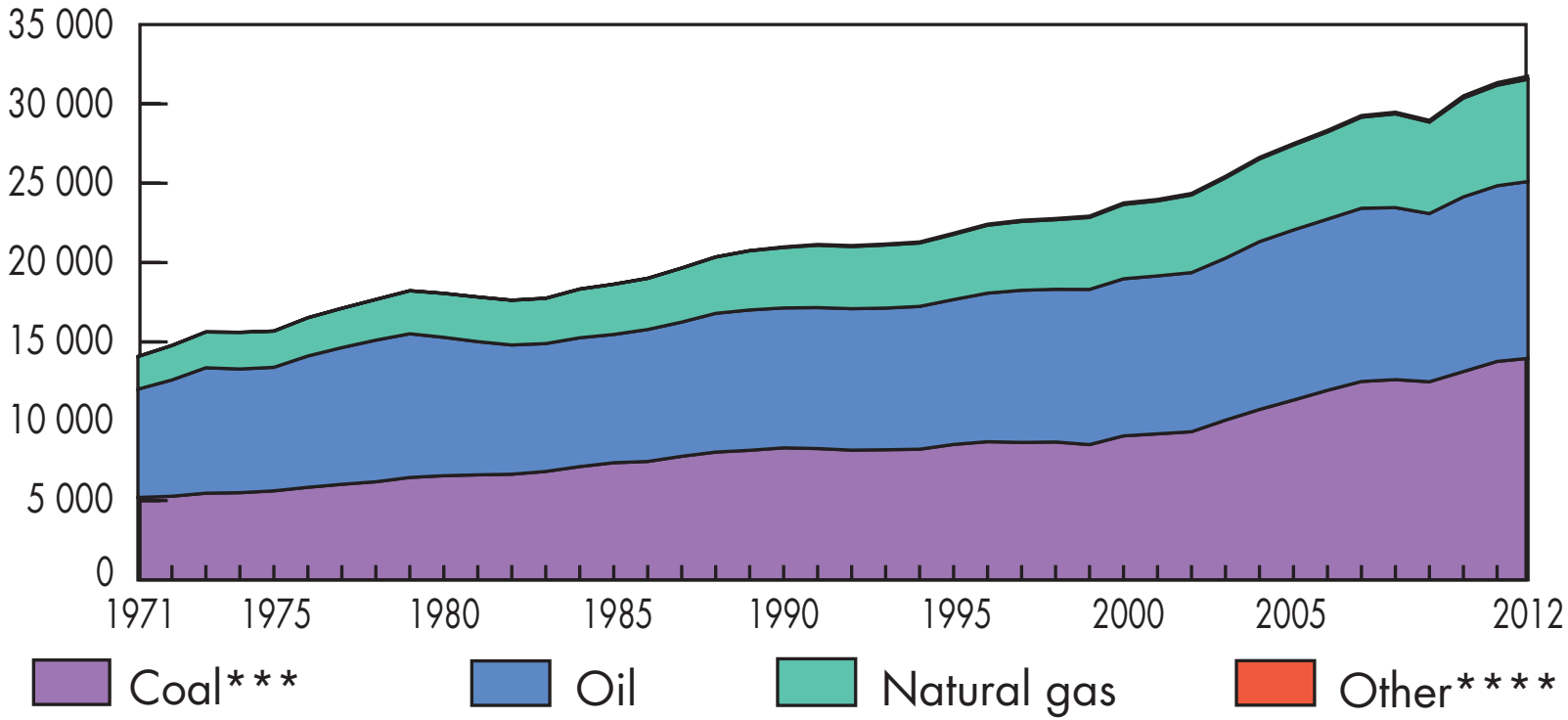
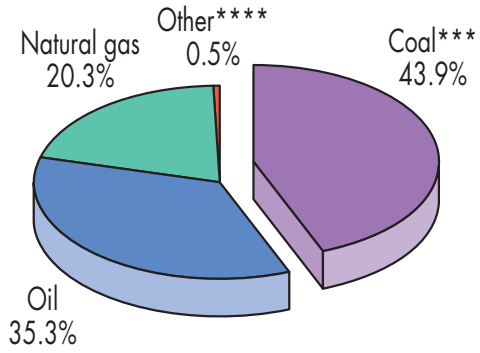
(9,000 Hiroshima “Little Boys”)

CO_2 Emissions

World* CO_2 emissions** from 1971 to 2012 by fuel (Mt of CO_2)

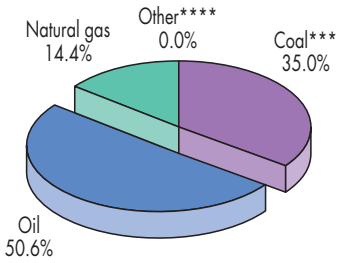


2012



31 734 Mt of CO_2

1973

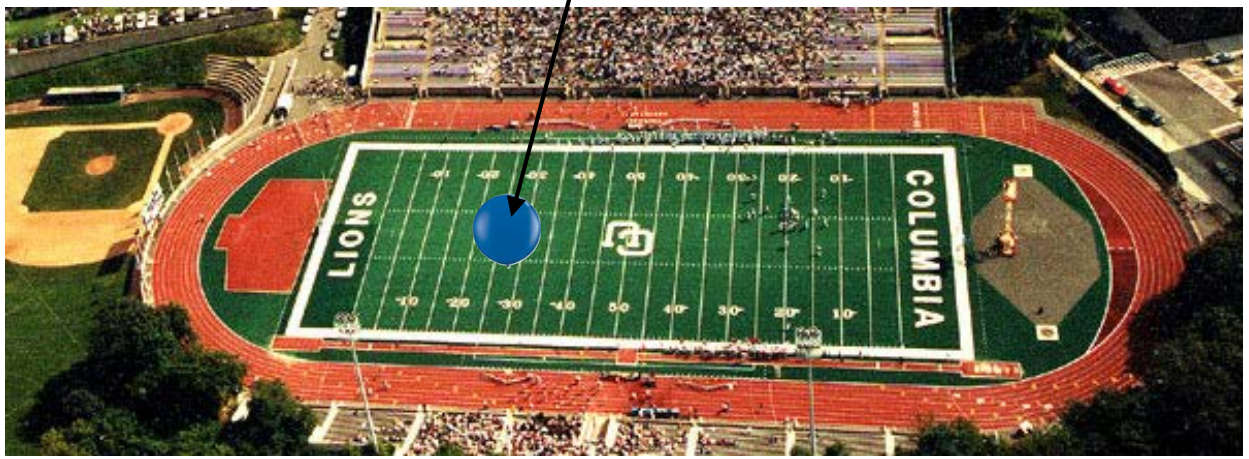


15 633 Mt of CO_2

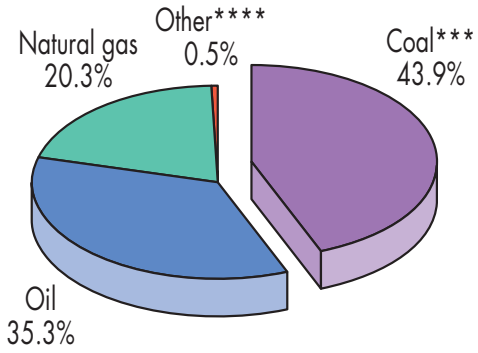
**World includes international aviation and international marine bunkers.*
***Calculated using the IEA's energy balances and the Revised 1996 IPCC Guidelines. CO_2 emissions are from fuel combustion only. ***In these graphs, peat and oil shale are aggregated with coal. ****Includes industrial waste and non-renewable municipal waste.*

CO_2 Emissions

2.4 ton CO_2/toe



2012



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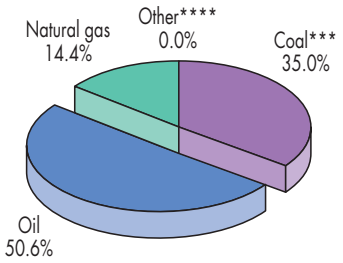

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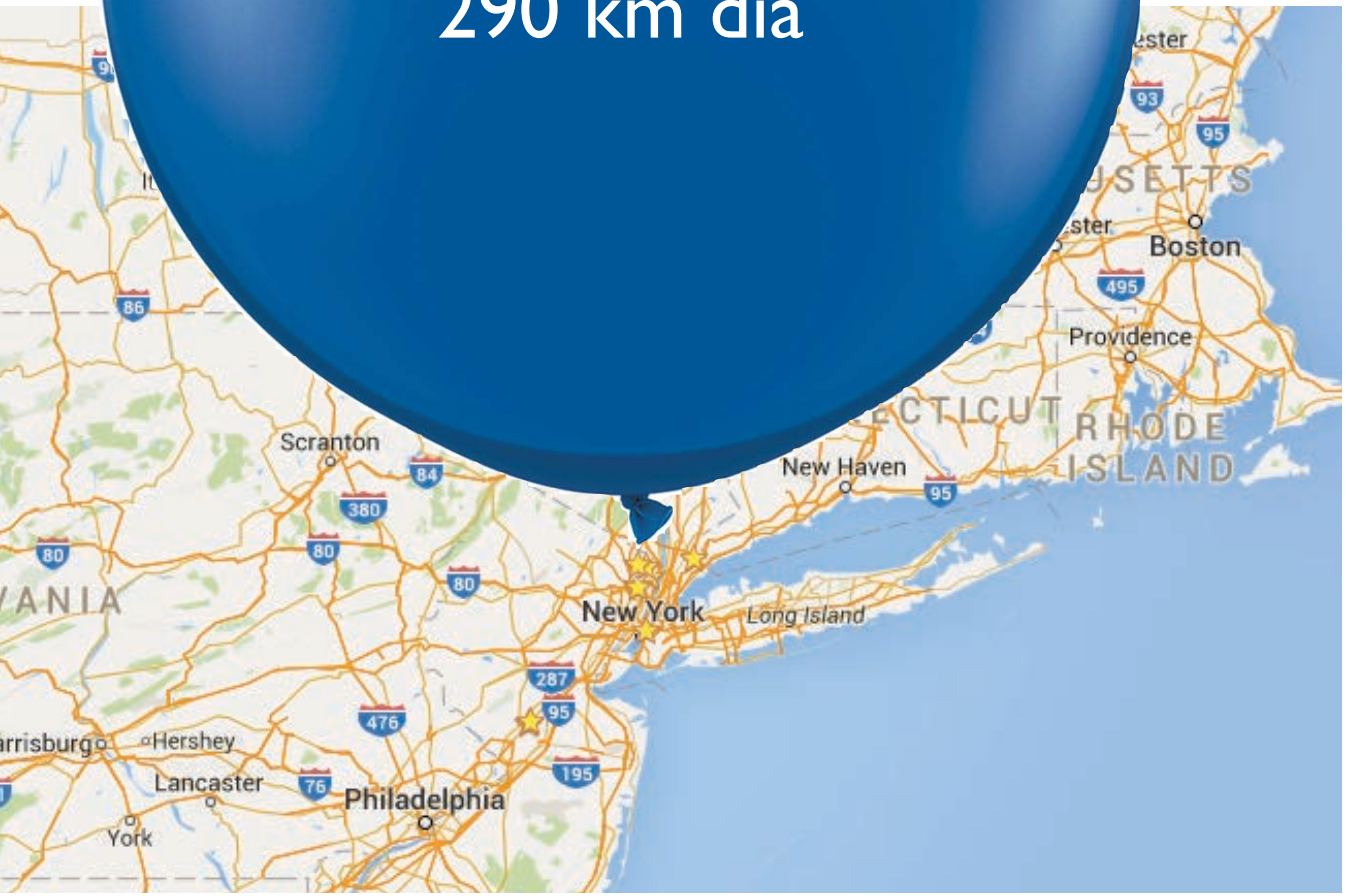
CO_2 Emissions



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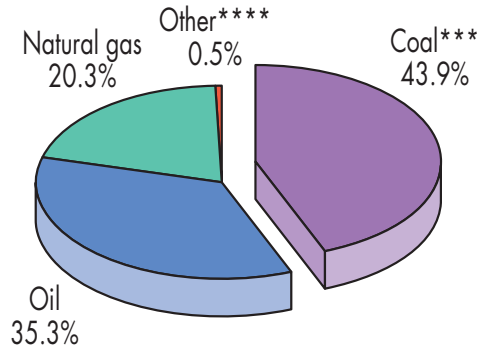

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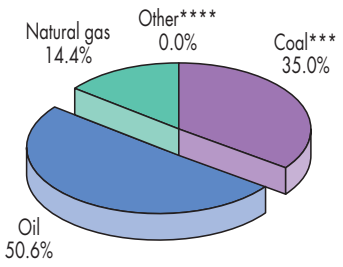


15 633 Mt of CO_2

CO_2 per MJ

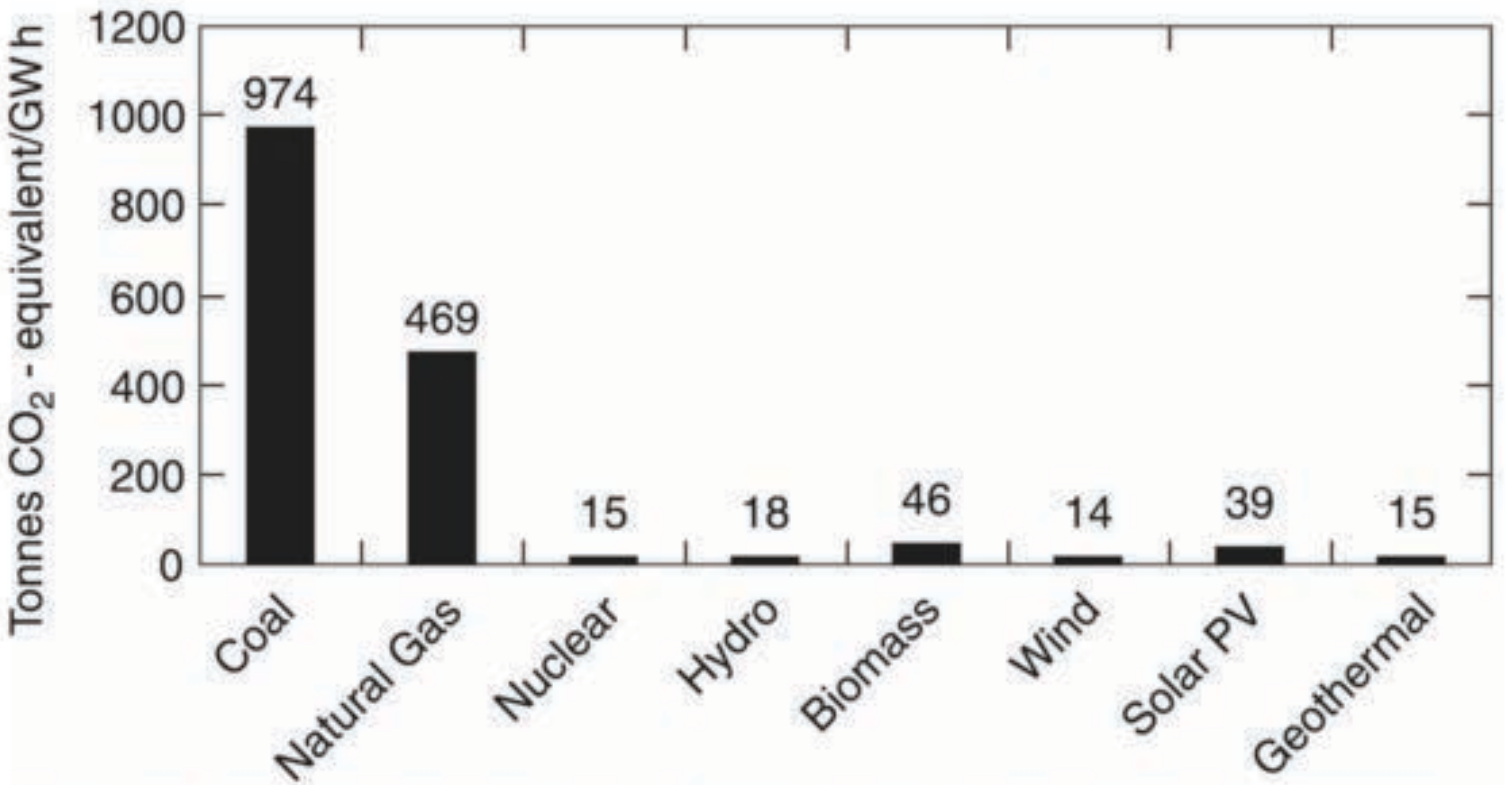


Fig. 10.2 Comparison of life-cycle emissions in metric tonnes of CO_2e per GW-hour for various modes of electricity production. (*Sources of data*: [20, 21, 22])

Energy per Person
(per person)

U.S. = 6.81 toe/person

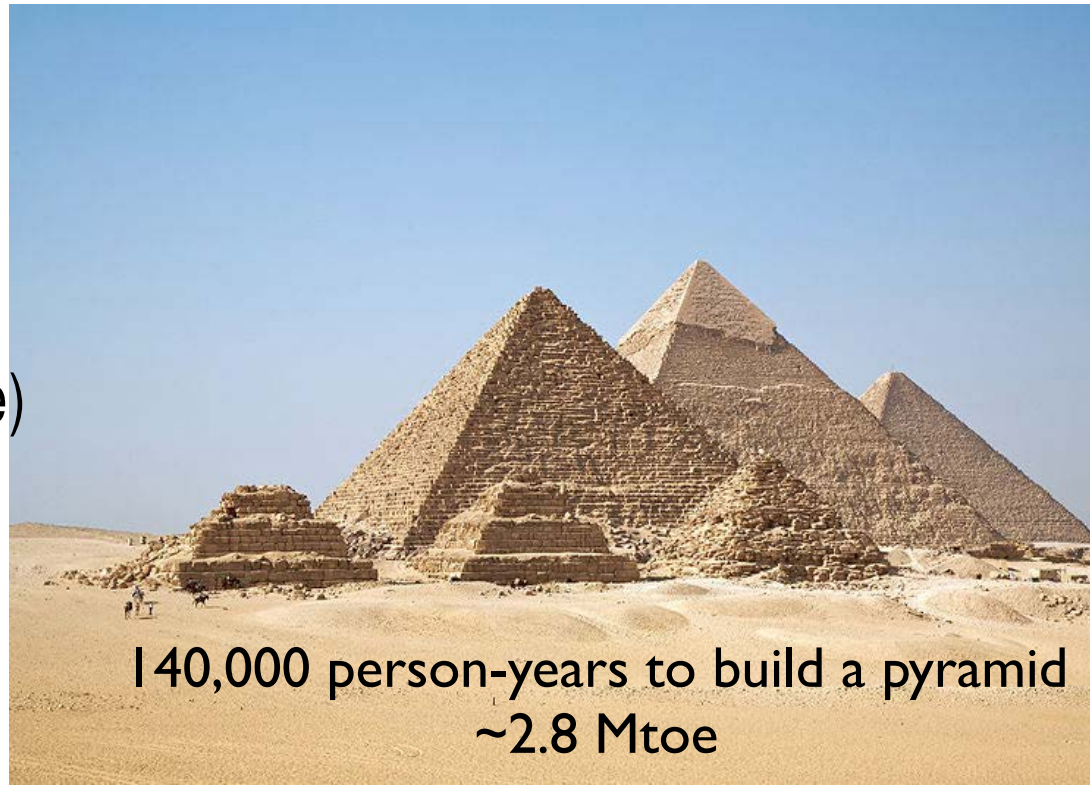
World = 1.90 toe/person

1/2-time Adult = 2.2 GJ/year (0.05 toe)

U.S. = 136 he/person

World = 38 he/person

(he = “human equivalent”)



Economics and Energy

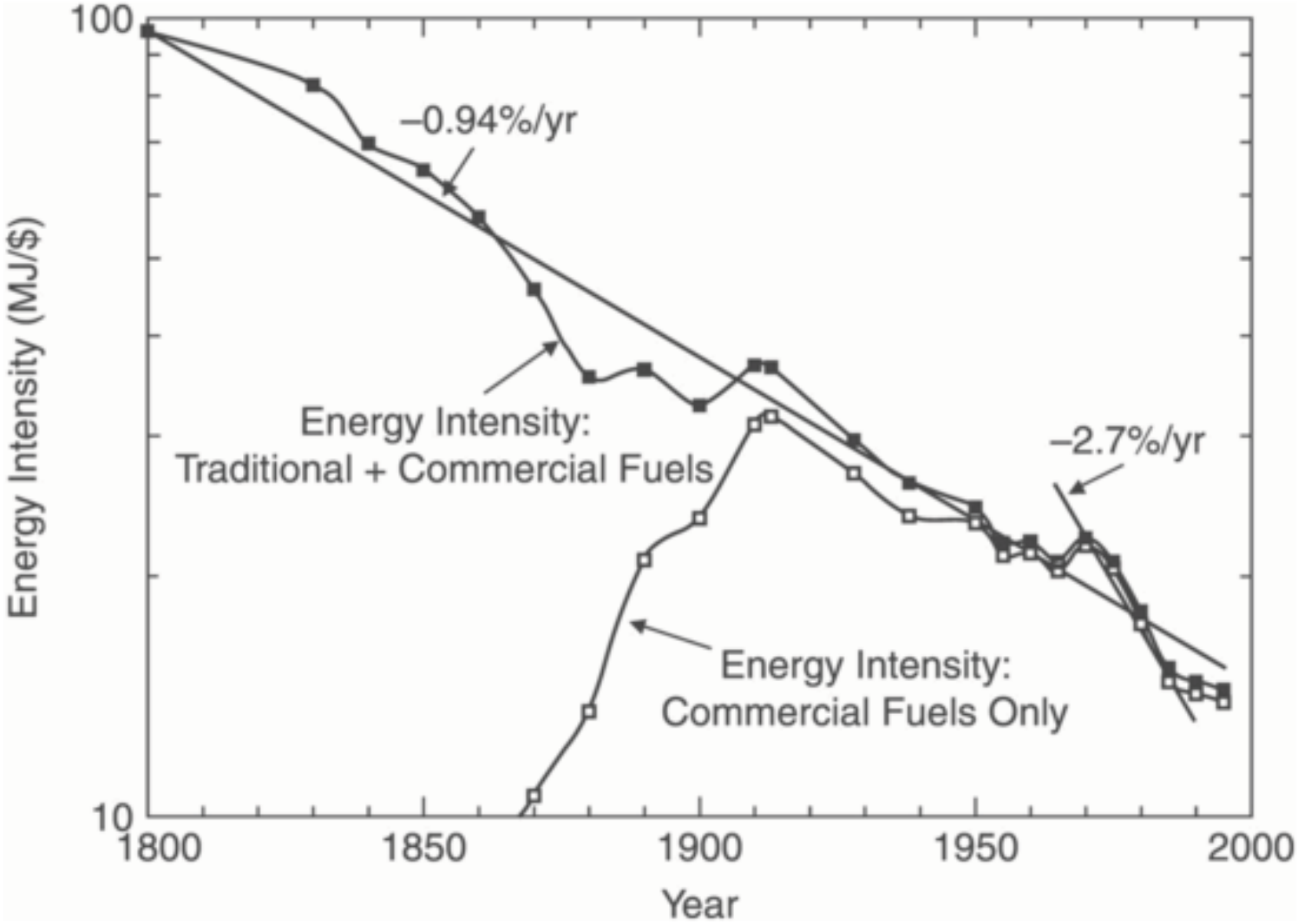
0.24 toe/k$ (world avg energy intensity)
4,000 $/toe (energy economic value)

0.15 toe/k$ (U.S. energy intensity)
6,700 $/toe (energy economic value in U.S.)

This week's price: $44.6/barrel = 330 $/toe
(world "equivalent" ~ $4.4 T$/year)

U.S. Energy Intensity

(showing more effective energy use)



Emission = Population↑ x (GDP/person)↑

x (Energy/GDP)↓

x (Emissions/Energy)↓

Very Large Challenge

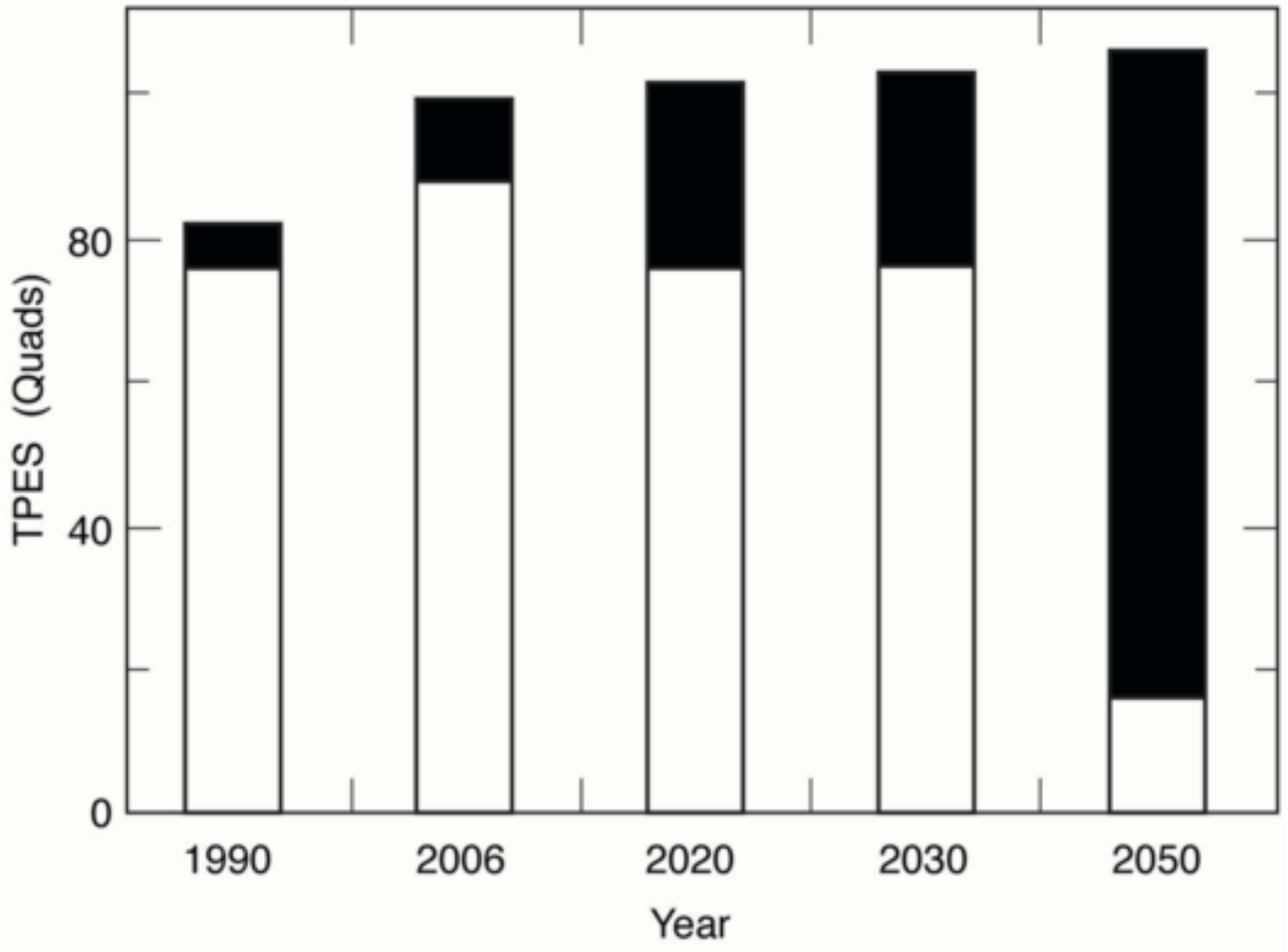


Fig. 15.2 TPES for the US projected to 2050 under the EIA reference case for 2012.

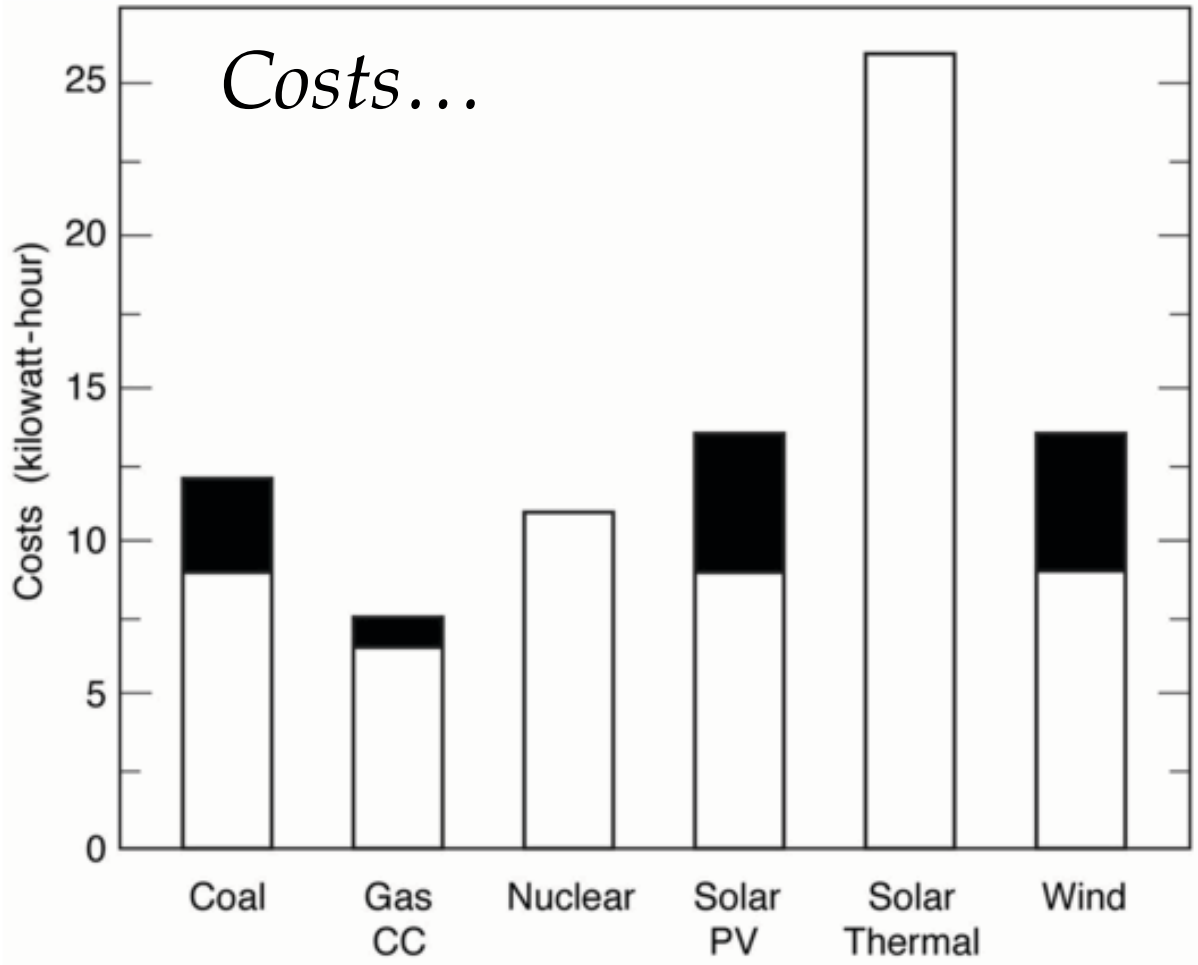


Fig. 15.3 Levelized cost comparison for electric power generation from the EIA Annual Energy Outlook 2013 early release reference case. It includes an emission fee of 3 cents per kilogram of CO_2 which I have explicitly shown for coal and gas; a 50% addition to solar PV to account for the subsidy which is paid by the taxpayers; and a 50% premium on wind from the Royal Academy of Engineering's and Texas Tech University's analyses of the cost of variability.

10-Year Federal R&D $B
(2003-2012)

Fossil	10.1
Renewables	6.6
Nuclear Energy	10.3
Efficiency	6.5

2013 Federal Subsidies $B

Biofuels	2.4
Wind	5.9
Solar	5.3
Nuclear	1.7
Coal & Gas	3.3
Total	29.3

Richter's Winners & Losers

Winners

- **Efficiency** in all sectors (if you don't use it, it doesn't emit)
- **Coal** (with carbon capture and storage and pollution controls)
- **Hydroelectric**
- **Geothermal** (near-surface systems)
- **Nuclear**
- **Natural gas** (as a replacement for coal)
- **Solar heat and hot water**
- **Sugarcane ethanol**
- **Solar photovoltaic** (at present for off-grid applications only or in places with high daytime electricity cost)
- **Wind** (as long as it is not too large a fraction of total electricity)
- **Advanced batteries** (for plug-in hybrid or all-electric vehicles)

Losers

- **Coal** (without carbon capture and storage or without pollution controls)
- **Oil** for transportation (replaced with electric drive)
- **Corn ethanol**
- **Hydrogen** for transportation
- **Ocean systems**

Maybes

- **Enhanced geothermal** (deep mining for heat)
- **Solar thermal electric** (needs cost reduction)
- **Solar photovoltaic** (large subsidies needed, so only for the rich now)
- **Advanced biofuels**
- **New technologies not yet invented** (remember it is hard to predict the future because it hasn't happened yet)

Innovation Teams

Blue	Green	Yellow	Orange	Red
Jonathan Fletcher	**Aton Baleato-Lizancos**	**Sean Ballinger**	**Joshua Cohen**	**Richard Cresswell**
Michael Wang	**Omar Mahmood**	**Seth Olsen**	**Jason Williams**	**Lucas Zeppetello**
Kevin Murphy	Alex Battery	Tyler Cowan	Drew Feldman	Ben Israeli
Edwin Vargas	James Page	Lauren Riddiford	Farrah Simpson	Derek Tropf
	Yumou Wei	Chen Zhang		

Assignment for Next Week

- Circulate your ideas to Team members
- Discuss
- **Everyone**: Prepare at least one one-page summary for an idea that you've shared with your team, explaining...
  - Why you think this is an energy/climate opportunity worthy of further consideration
  - Your reasoning why this is should be considered a "short-term" or a "long-term" effort

Send by email to mauel@columbia.edu
before C.O.B. next Tuesday