Carbon & Energy Markets in the US

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Carbon Markets

US doesn't have carbon markets …

- At least at the Federal level
- BUT it has one regional carbon market – RGGI – for the North East states and
- One proposed carbon market for California and possibly the west coast states
- RGGI is over-supplied and not currently a major force at $5 per ton CO2 – but this could change
- California is currently an unknown with expectations at about $7-10 per ton CO2

But it has implicit carbon markets

- 30 states have RPSs – Renewable Portfolio Standards – requiring that X% of electric power be generated from renewable sources
  - Renewable defined differently in different states, and X varies from state to state
- Generally accompanied by REC markets – Renewable Energy Certificate markets

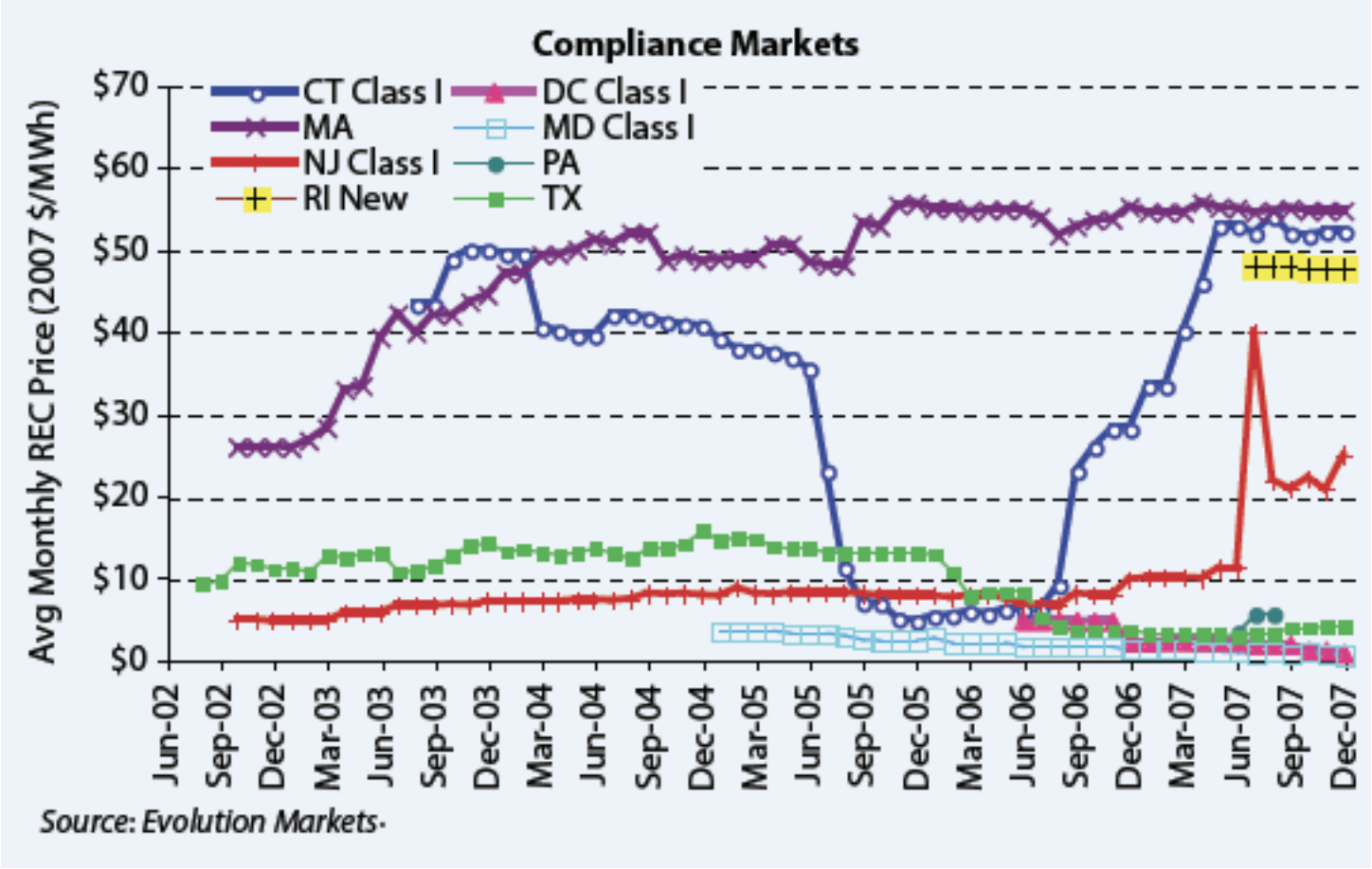
REC markets

- Each MWh of renewable energy generated gives rise to a 1 MWh REC certifying the production of renewable power
- To conform with RPS, utilities have to deliver RECs at year end matching their renewable obligations under the RPS
- RECs are traded and can be sold by renewable producers and are a major source of revenue
- REC markets aren't CO2 markets –they're markets for the absence of CO2 and serve to level the playing field between fossil and non-fossil fuels just as a CO2 market does in the EU

Table 2. Renewable portfolio standards in the 30 States with current mandates

State	Program mandate
AZ	Arizona Corporate Commission Decision No. 69127 requires 15 percent of electricity sales to be renewable by 2025, with interim goals increasing annually. A specific percentage of the target must be from distributed generation. Multiple credits may be provided to solar generation and systems manufactured in-State.
CA	As a follow-up from AB 32 and Executive Order S-21-09, the CARB now administers a new RPS that requires 33-percent renewable generation by 2020.
CO	Enacted in March 2010, House Bill (HB) 1001 strengthens the State's existing RPS program by requiring 20 percent of electricity generated by investor-owned utilities in 2015 to be renewable, increasing to 30 percent by 2020. There is also a distributed generation requirement. In-State generation receives a 25-percent credit premium.
CT	Public Act 07-242 mandates a 27-percent renewable sales requirement by 2020, including a 4-percent requirement for sales from higher efficiency or combined heat and power systems. Of the overall total, 3 percent may be met by waste-to-energy and conventional biomass facilities.
DE	Senate Substitute 1 amended Senate Bill 119 to extend the increasing RPS targets to 2025; 25 percent of generation is now required to come from renewable sources in 2025. There is a separate requirement for solar generation (3.5 percent of the total in 2025) and penalty payments for compliance failure. Offshore wind receives 3.5 times the standard credit amount.
HI	HB 1464 sets the renewable mandate at 40 percent by 2030. All existing renewable facilities are eligible to meet the target, which has two interim milestones.
IL	Public Act 095-0481 created an agency responsible for overseeing the mandate of 25 percent renewable sales by 2025, with escalating annual targets. In addtion, 75 percent of the required sales must be generated from wind and 6 percent from solar. The plan also includes a cap on incremental costs resulting from the penetration of renewable generation. In 2009, the rule was modified to cover sales outside a utility's home territory.
IA	In 1983, an RPS mandating 105 megawatts of renewable energy capacity was adopted.
KS	In 2009, HB 2369 established a requirement that 20 percent of installed capacity must use renewable resources by 2020.
ME	In 2007, Public Law 403 was added to the State's RPS requirements. The law requires a 10-percent increase from the 2006 level of renewable capacity by 2017, and that level must be maintained in subsequent years. The years leading up to 2017 also have new capacity milestones. Generation from eligible community-owned facilities receives a 10-percent credit premium.
MD	In April 2008, HB 375 revised the preceding RPS to include a target of 20 percent renewable generation by 2022, including a 2-percent solar target. HB 375 also raised penalty payments for "Tier 1" compliance shortfalls to 4 cents per kilowatthour. Senate Bill 277, while preserving 2022 target of 2 percent solar, made the interim solar requirements and penalty payments slightly less stringent.
MA	The State RPS has a goal of a 15-percent renewable share of total sales by 2020 and includes necessary payments for compliance shortfalls. Eligible biomass is restricted to low-carbon life cycle emission sources. A Solar Carve-Out Program was also added, which seeks to establish 400 megawatts (DC) of solar generating capacity.
MI	Public Act 295 established an RPS that will require 10 percent renewable generation by 2015. Bonus credits are given to solar energy.

US EIA Annual Energy Outlook 2011


Compliance Markets
Avg Monthly REC Price (2007 $/MWh)
$70
$60
$50
$40
$30
$20
$10
$0
CT Class I
MA
NJ Class I
RI New
DC Class I
MD Class I
PA
TX
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05
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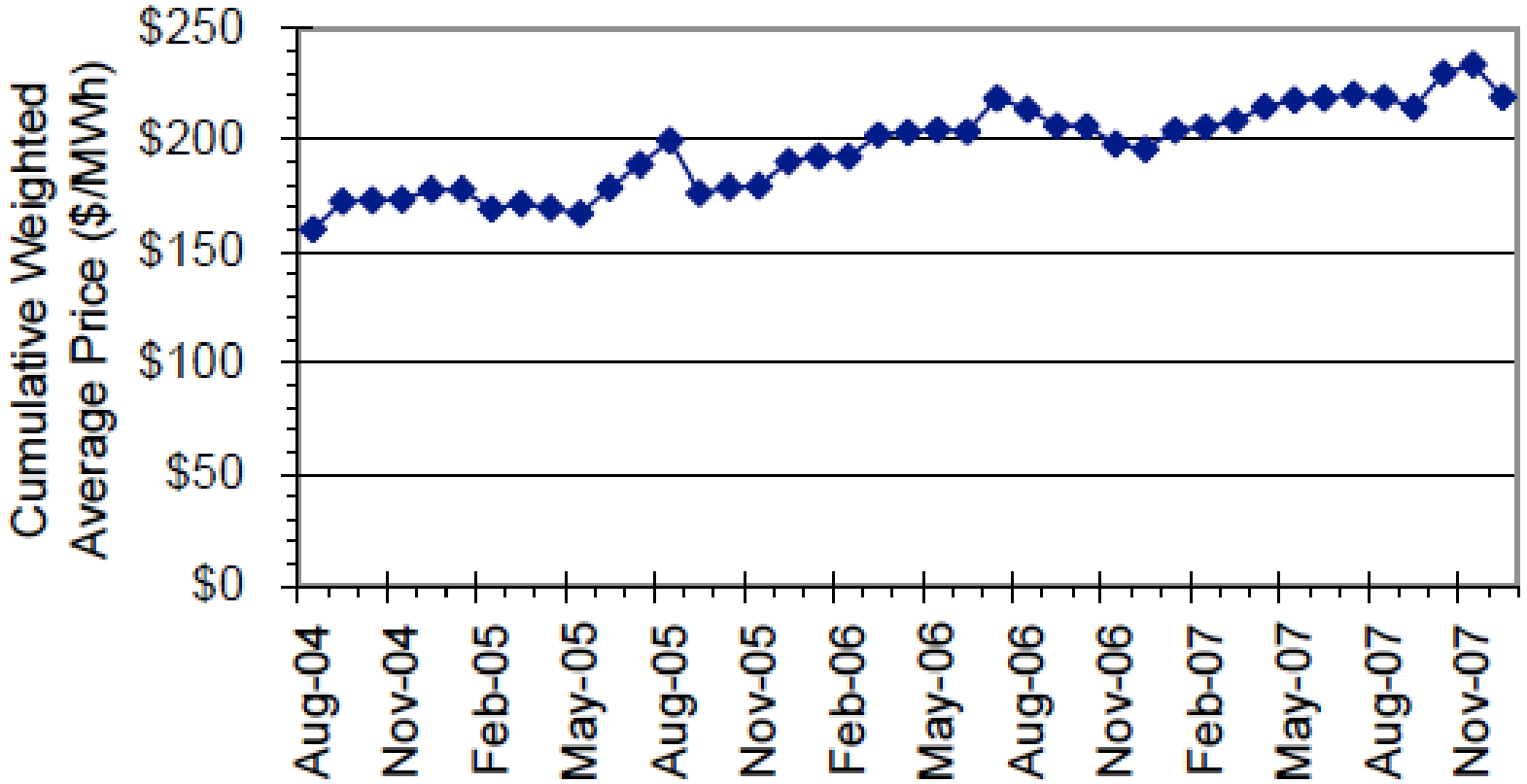
Mar-07
Jun-07
Sep-07
Dec-07
Source: Evolution Markets



Source: NJ Clean Energy 2008

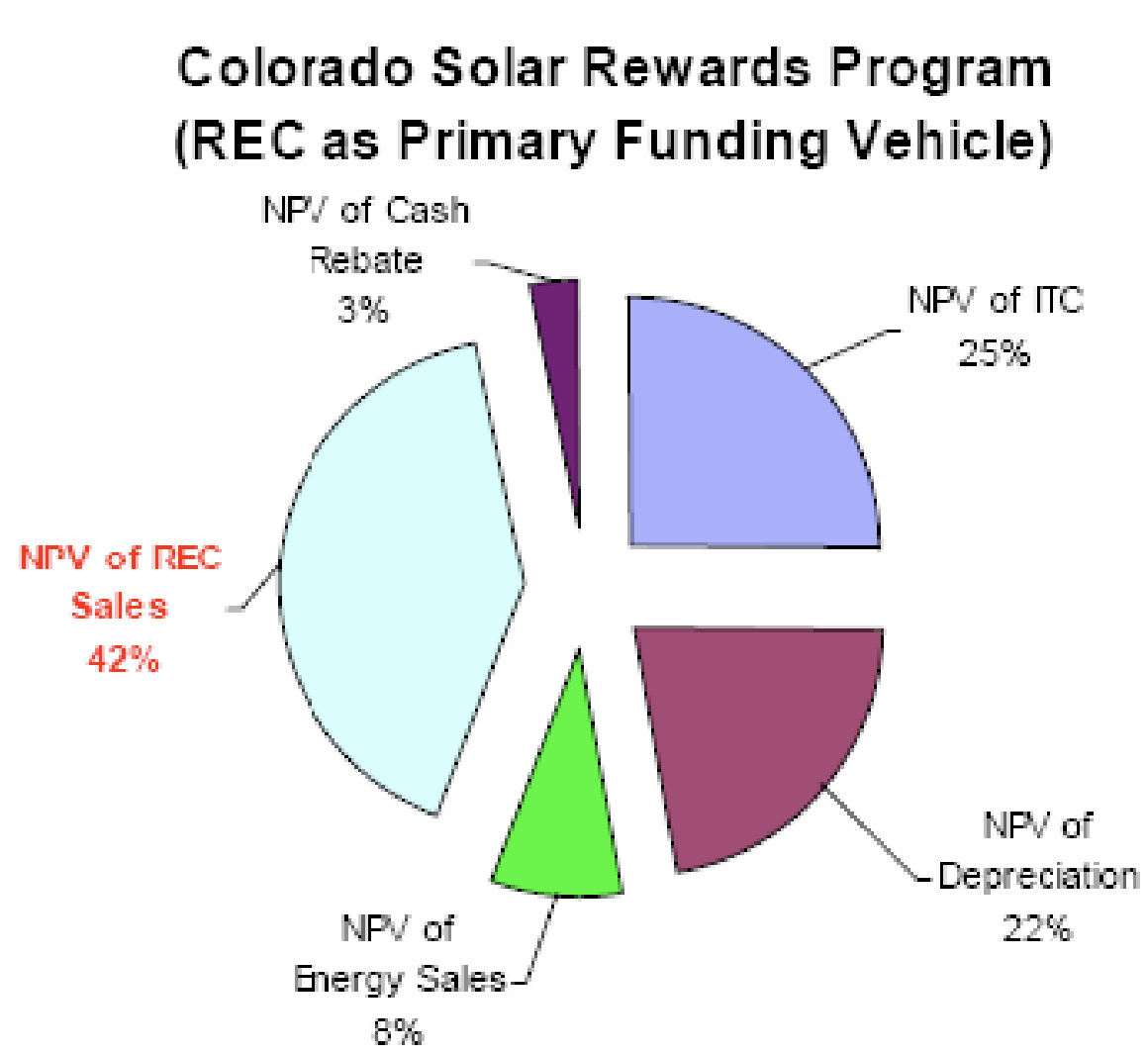
Figure 5. New Jersey Solar REC Prices

Production tax credits

- Available for generation of renewable energy, only to owners. Start-ups tend not to have tax liabilities
- Pattern has been to bring in investors needing tax relief and make them co-owners of facilities
- Drop in incomes of financial institutions means they no longer need tax breaks
- So PTCs have become of limited value
- US Treasury will now give cash grants instead of tax credits

Investment tax credit

- Renewable Energy Investment can generate federal tax credit or a cash grant
- Eligibility is same as PTC

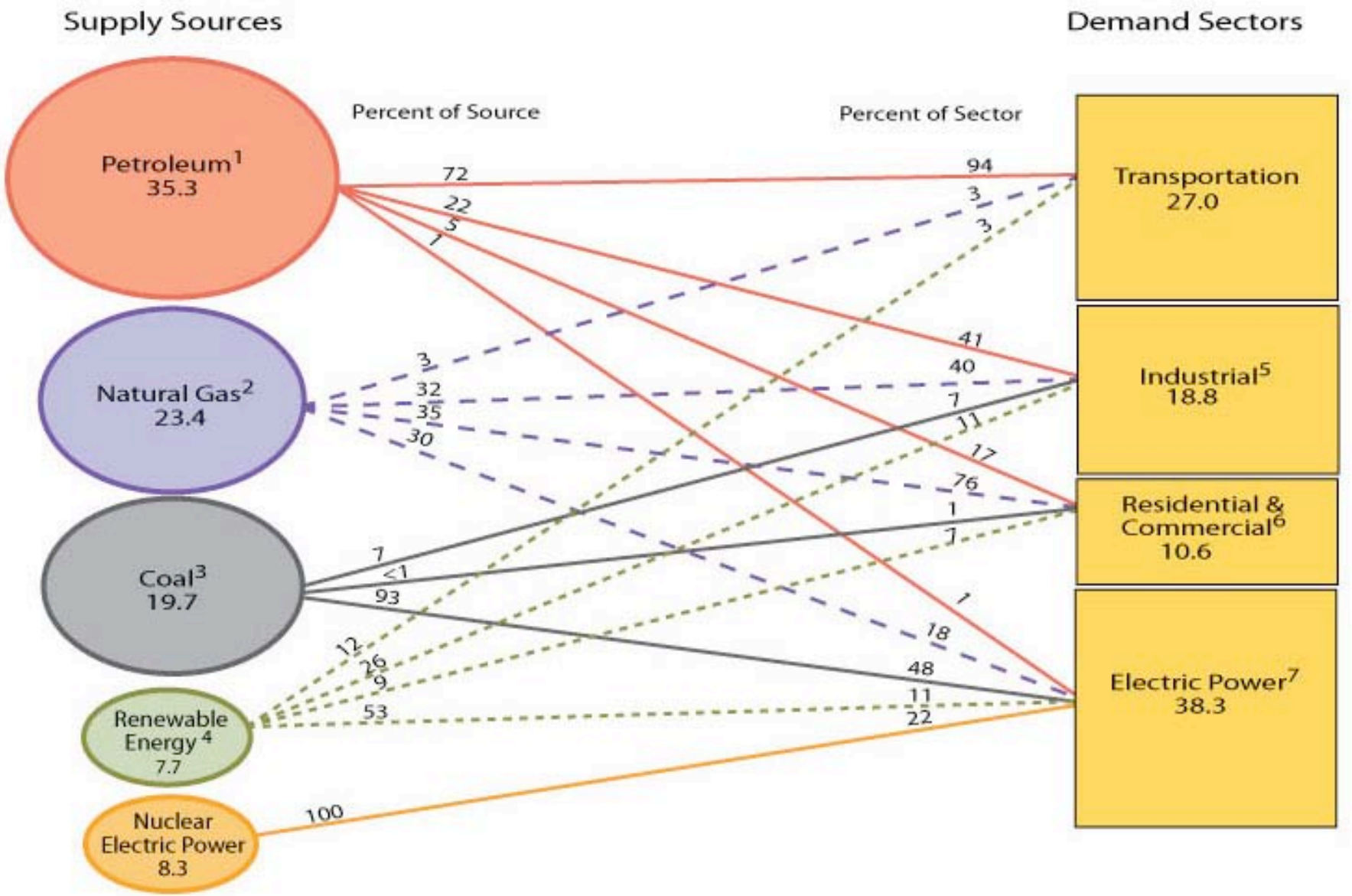


Source: 3 Phases 2007

Figure 6. Colorado Solar Rewards Program

Fossil Fuels

Coal Gas Oil in the US

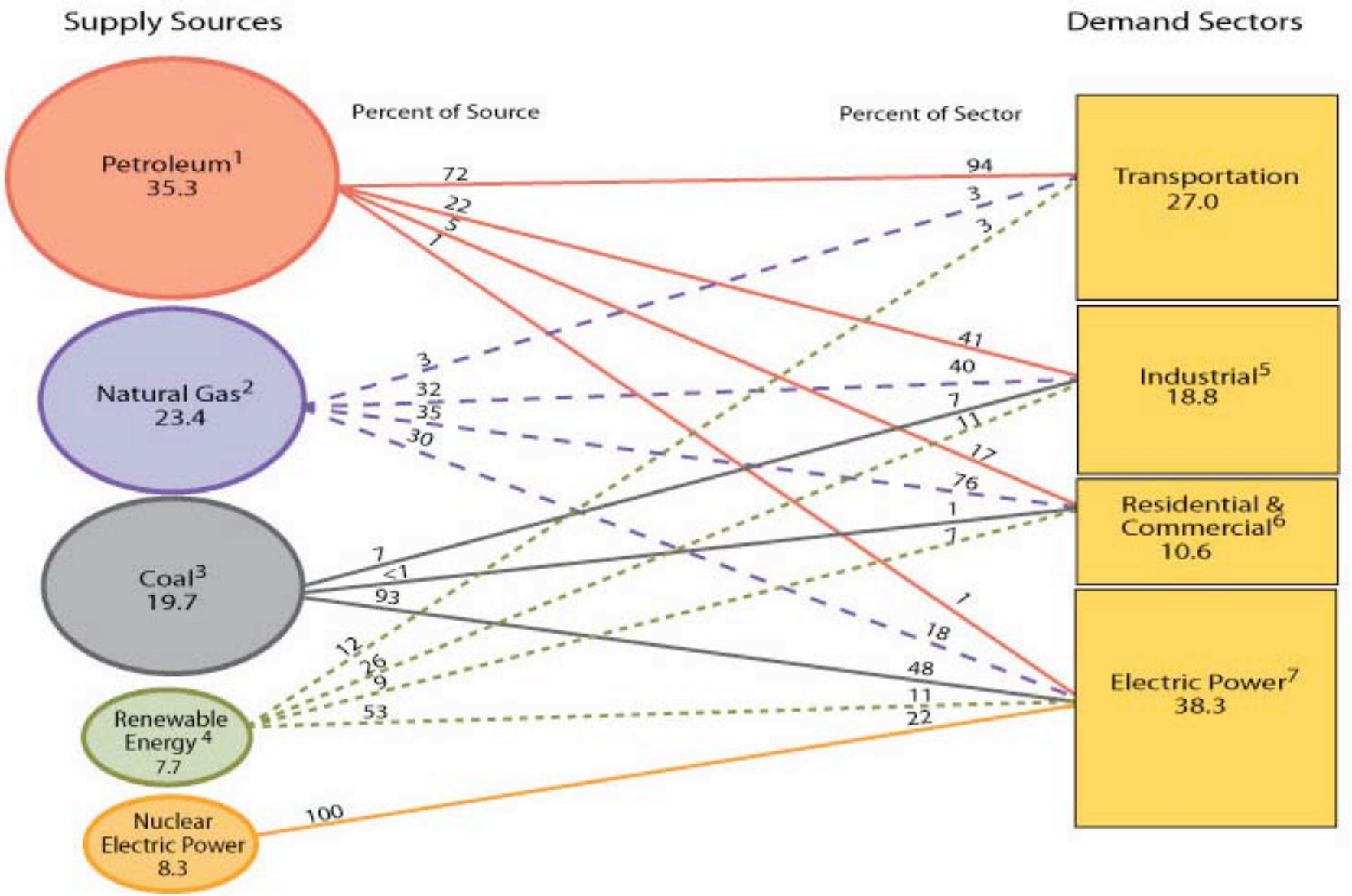


US EIA Annual Review 2010. Supplies in quadrillion BTUs.

Coal in the US

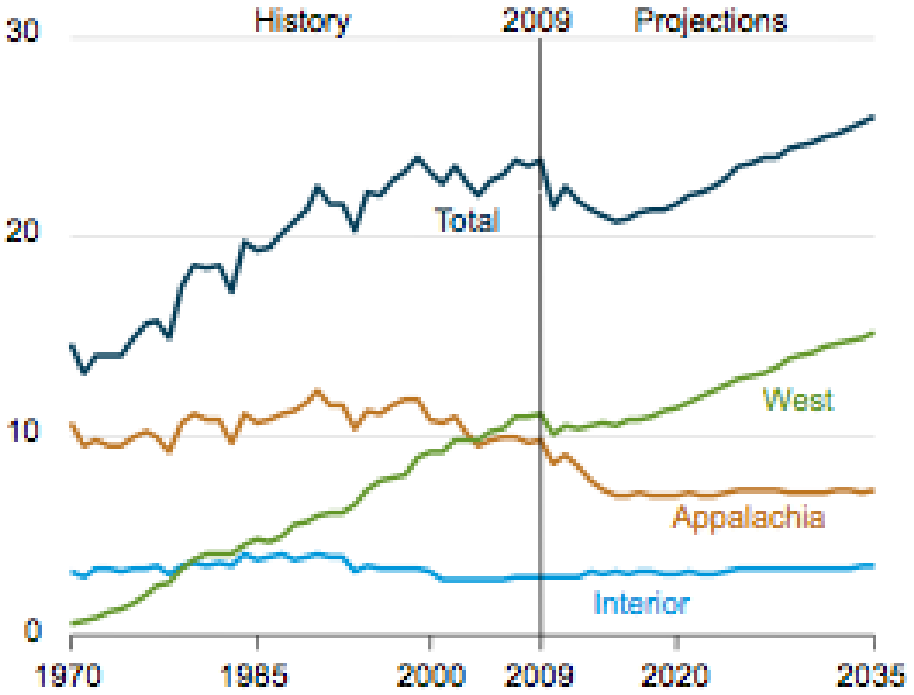
Coal

- Coal is the most widespread fuel in electricity generation
  - Over 40% of world's installed base of electricity generating capacity is coal-fired
  - Main source of industrial energy for about 200 years
- Until recently it was also the least expensive
  - Today wind and gas are competitive or perhaps less costly
  - Coal produces a lot of CO2 and is sensitive to a price on carbon



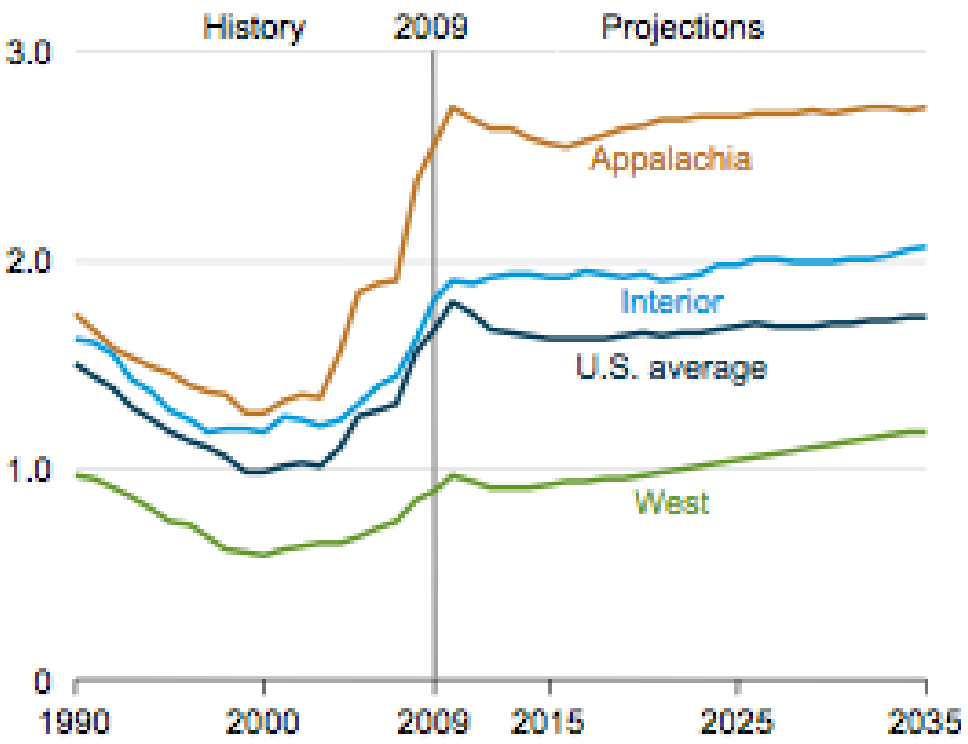
US EIA Annual Review 2010. Supplies in quadrillion BTUs.

Figure 101. Coal production by region, 1970-2035 (quadrillion Btu)



US coal production from US EIA AEO 2011. Risen since 1970 as oil prices have increased. Now almost no power stations burn oil.

Figure 103. Average annual minemouth coal prices by region, 1990-2035 (2009 dollars per million Btu)



US coal prices "minemouth" i.e. before transportation, which can add 10% or more. EIA AEO 2011. Natural gas is >$4 per mm BTU.
Coal is cheaper than gas but coal burning power stations are more expensive

Country	Proven reserves MT	% world total
US	237,295	22.6%
Russia	157,010	14.4%
China	114,500	12.6%
Australia	76,500	8.9%
India	60,600	7.0%
Germany	40,699	4.7%

World coal reserves millions of tons

Country	Annual prod'n MT	% of total	Years of prod'n
China	3240	48.3%	35
US	984.6	14.8%	241
Australia	423	6.3%	180
Russia	316.9	4.7%	495

Coal production and years left at current rates of production

Coal technology

- Most power stations crush coal and burn the powder – pulverized coal.
- Pulverized coal has a thermal efficiency of 35-45%
- Can also gasify coal using IGCC technology – Integrated Gasification Combined Cycle
  - Turn coal into natural gas then burn in combined cycle power plant – much cleaner than conventional power stations.
  - Only 2 IGCC power plants in the US. Capital costs higher.

Environmental Impact

- Burning coal produces
  - Carbon dioxide CO2 the main greenhouse gas. Roughly half world's CO2 comes from coal
  - Particulates, fine particles that enter the lungs and cause respiratory illness
  - SO2, precursor of acid rain
  - NOx, the oxides of nitrogen (all fossil fuels produce these by oxidizing the nitrogen in the atmosphere)

Environmental Impact

- In addition coal mining is dangerous and leads to accidents – over 5,000 deaths annually worldwide
- 29 in US in 2009
- Mountain top removal

West Virginia

Air pollution headlines

- **Air Pollution Blamed for 3% of Deaths in the United States**
- … Switzerland, France, and Austria). The findings of this study stunned participants at the recent World Congress on Lung Diseases in Florence, Italy, where it was revealed that PM10s in the 3 countries concerned were responsible for 40,000 deaths a year.
- Medscape.com

Air pollution deaths China

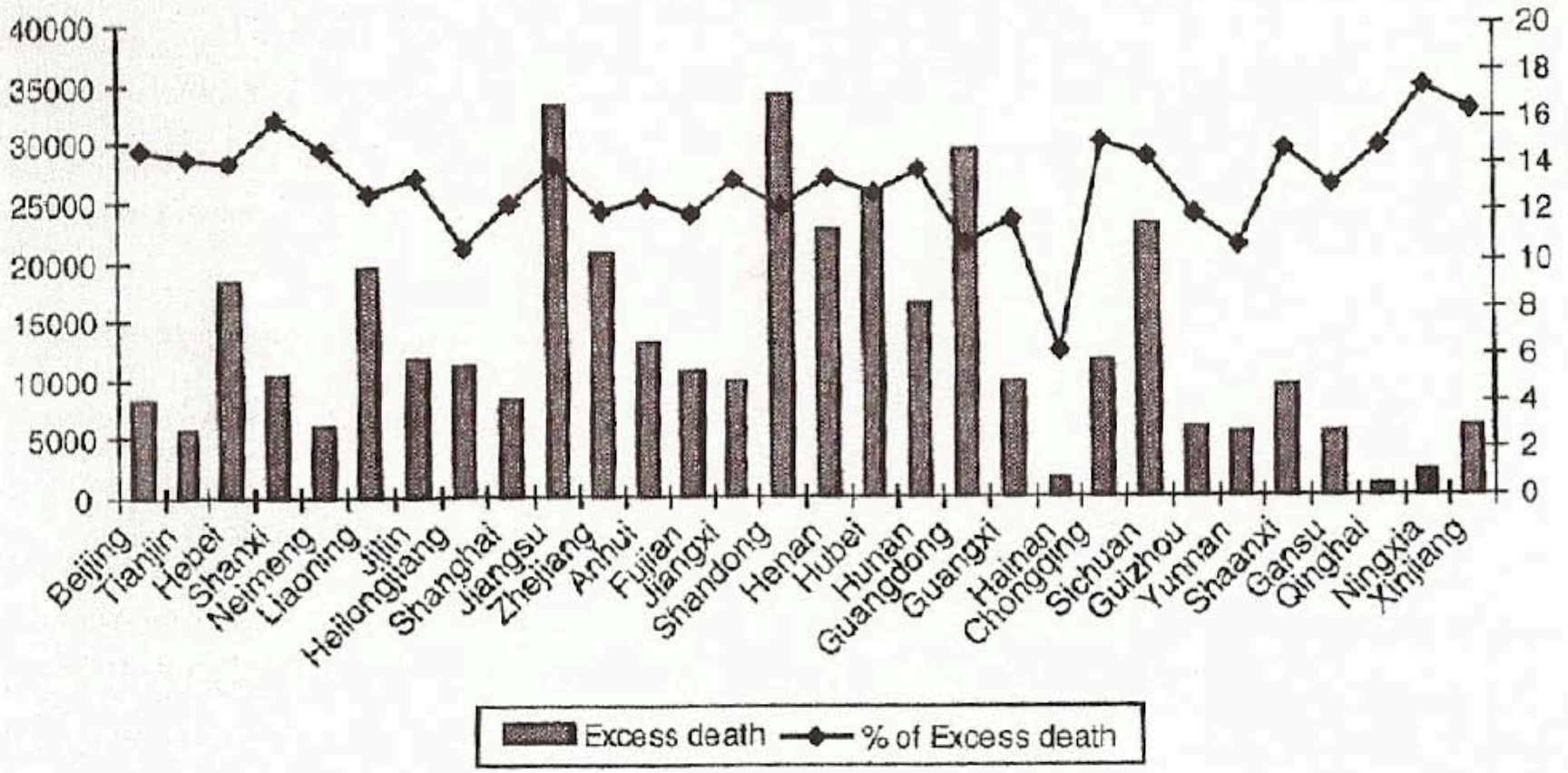


Figure 1.4 Excess deaths attributed to ambient air pollution, by province

External costs of coal

- Provides 40% of world's electric power and >50% of its GHGs
- External costs in US of about $350 billion annually
  - Mining accidents
  - Pollution impacts on health – 20-50,000 deaths annually in US from particulate pollution
- Charging for these would send cost of power from coal from 7 cents/kWh to 25 cents
- Would radically change inter-fuel competition

Carbon capture and storage

- Critical to future of coal
- Currently no commercial-scale implementations though some being built now
- Capturing CO2 probably easy
- Storing for 1000 yrs more difficult
- Some efficiency loss in power generation
- Probably expensive – some controversy about possible cost, so far no hard data

CCS involves 3 stages

1. Capture CO2
2. Transport CO2 to storage location
3. Store CO2

Summary: Economics of Coal

- Low cost energy source – about 6-7cents kWh LCOE
- Capital costs $2000 kW for pulverized coal but much more for IGCC plants
- But its environmental costs are high – this makes it vulnerable to environmental policies
- Capturing CO2 or paying for CO2 could add 2-4 cents to a kWh, taking this above wind, gas and even solar

Natural Gas in the US

Gas ----

- Abundant in the US
- Cheap: LCOE of about 5-6.5 cents kWh, capital costs low, $500-1000 per kW
- Environmentally benign – some controversy about how much
- No world market – regional markets are North America, Russia/Europe, SE Asia
  - Gas is costly to transport – requires pipelines or LNG facilities

Gas fired power stations

- Can be either conventional gas turbines – low capital costs, lots of waste heat
  - Generally used for "peaking" plants
  - These plants can be started and stopped quickly
  - Lost of spare capacity in peaking or load-following plants
- Or CCGT plants, more expensive and more efficient
- Too expensive to use for peaking – capital costs such that need to use them all the time

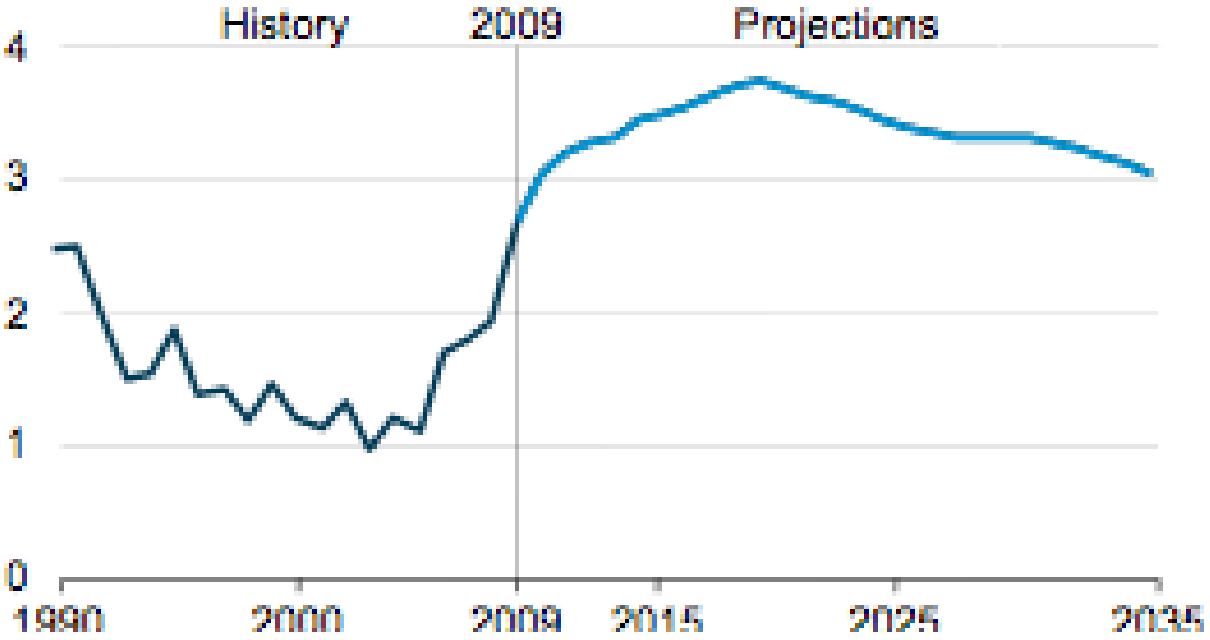
	LNG	Natural gas				Crude oil
	Japan cif	European Union cif †	UK (Heren NBP Index)*	US Henry Hub †	Canada (Alberta) ‡	OECD countries cif
1984	5.10	4.00	-	-	-	5.00
1985	5.23	4.25	-	-	-	4.75
1986	4.10	3.93	-	-	-	2.57
1987	3.35	2.55	-	-	-	3.09
1988	3.34	2.22	-	-	-	2.56
1989	3.28	2.00	-	1.70	-	3.01
1990	3.64	2.78	-	1.64	1.05	3.82
1991	3.99	3.19	-	1.49	0.89	3.33
1992	3.62	2.69	-	1.77	0.98	3.19
1993	3.52	2.50	-	2.12	1.69	2.82
1994	3.18	2.35	-	1.92	1.45	2.70
1995	3.46	2.39	-	1.69	0.89	2.96
1996	3.66	2.46	1.87	2.76	1.12	3.54
1997	3.91	2.64	1.96	2.53	1.36	3.29
1998	3.05	2.32	1.86	2.08	1.42	2.16
1999	3.14	1.88	1.58	2.27	2.00	2.98
2000	4.72	2.89	2.71	4.23	3.75	4.83
2001	4.64	3.66	3.17	4.07	3.61	4.08
2002	4.27	3.23	2.37	3.33	2.57	4.17
2003	4.77	4.06	3.33	5.63	4.83	4.89
2004	5.18	4.32	4.46	5.85	5.03	6.27
2005	6.05	5.88	7.38	8.79	7.25	8.74
2006	7.14	7.85	7.87	6.76	5.83	10.66
2007	7.73	8.03	6.01	6.95	6.17	11.95
2008	12.55	11.56	10.79	8.85	7.99	16.76
2009	9.06	8.52	4.85	3.89	3.38	10.41
2010	10.91	8.01	6.56	4.39	3.69	13.47

* Source: 1984-1990 German Federal Statistical Office 1991-2010 German Federal Office of Economics and Export Control (BAFA).
† Source: Heren Energy Ltd.
‡ Source: Energy Intelligence Group, *Natural Gas Week*.
Note: Btu = British thermal units; cif = cost+insurance+freight (average prices).

Gas markets

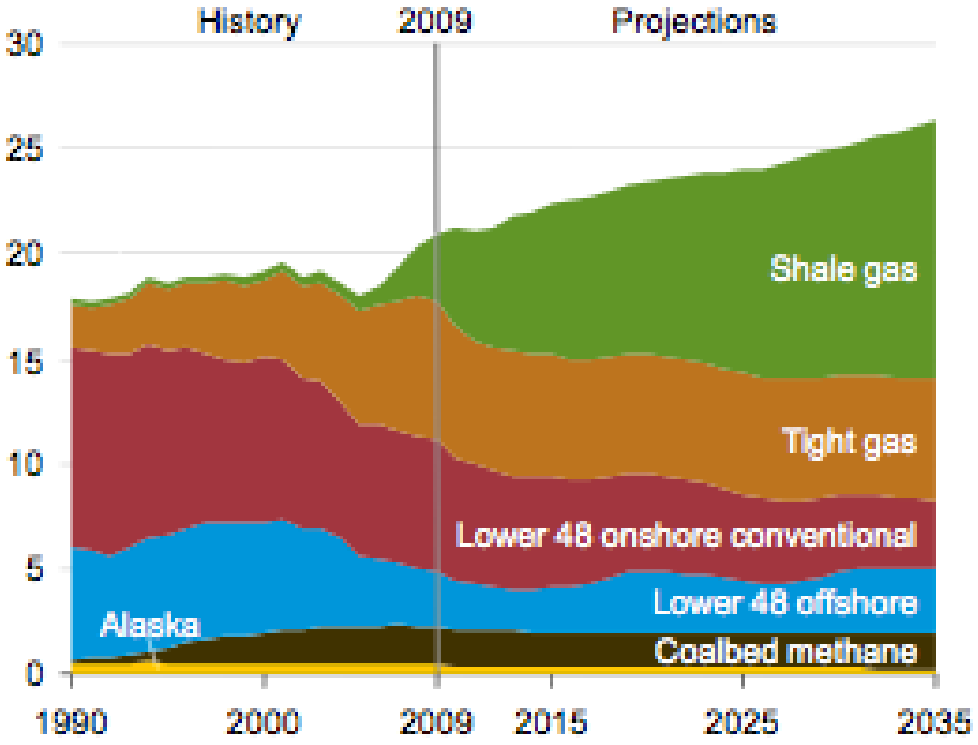
- Gas is expensive to transport – need either
  - Pipelines or
  - LNG plants, LNG carriers, and LNG terminals – trains and terminals cost several billion $ each
  - LNG carriers have to be refrigerated
  - NIMBY opposition to LNG terminals
- Some prospects for US gas exports
- No world market – separate European, Asian and North American markets

Figure 87. Ratio of low-sulfur light crude oil price to Henry Hub natural gas price on an energy equivalent basis, 1990-2035



US EIA AEO 2011. Drop in gas prices has made gas very attractive relative to oil.

Figure 2. U.S. natural gas production, 1990-2035
(trillion cubic feet per year)



U.S. Energy Information Administration

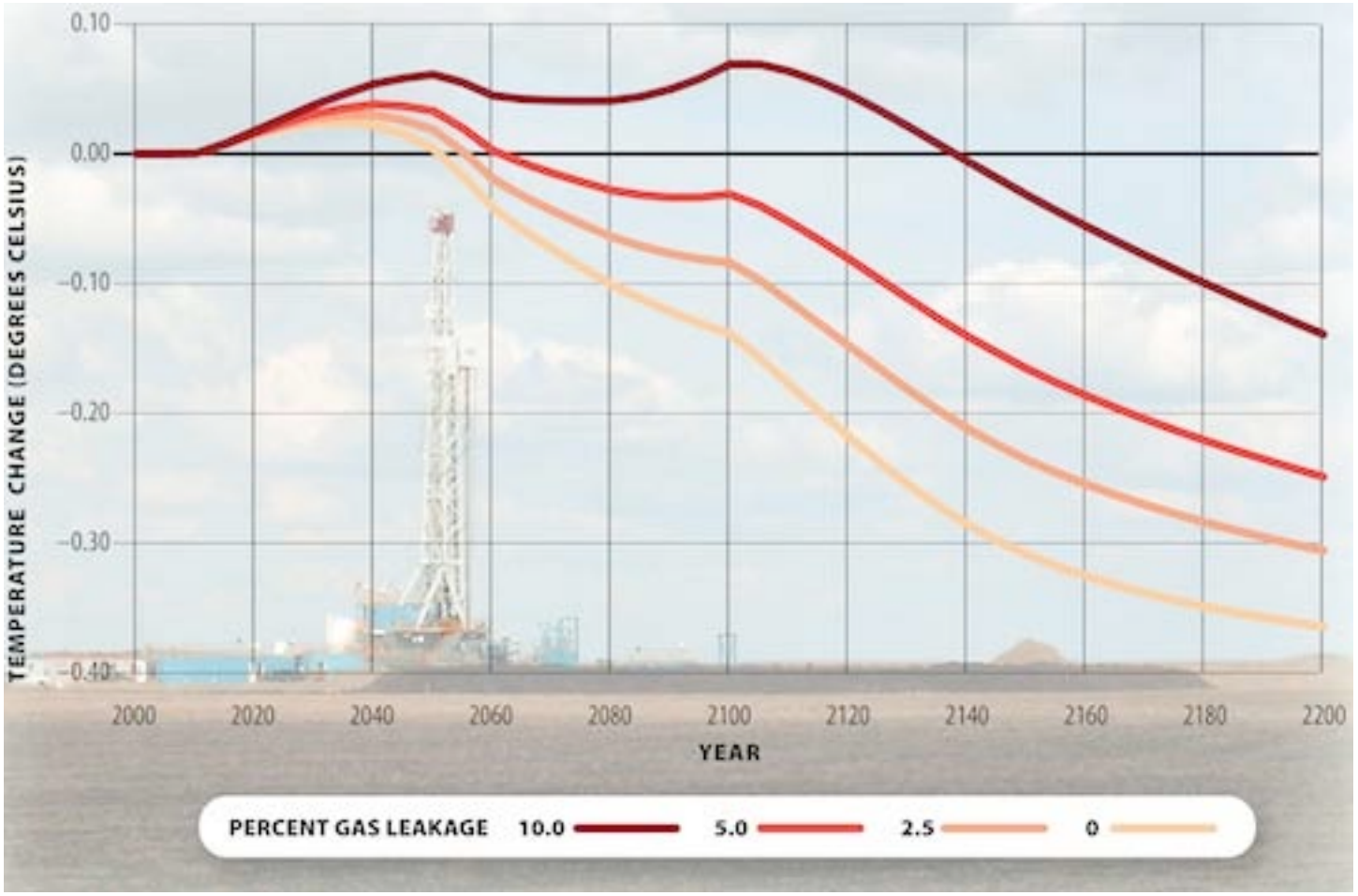
Gas reserves

- EIA estimates proven reserves of 283.9 tcf, annual production is 22 tcf
  - Shale gas is 60 tcf
- Industry estimates are 1451-2000 tcf. This includes probable reserves as well as proven
- MIT report uses 650 tcf, with 400 tcf at < $4 MMBTU
- Worldwide about 150 years reserves at current consumption
- 70% of world reserves in Qatar, Russia and Iran

Recent developments ..

- "The carbon footprint for shale gas is greater than that for conventional gas or oil on any time horizon, particularly so over 20 years.
- Compared to coal, the footprint for shale gas is at least 20% greater and perhaps more than twice as great on the 20 year horizon and comparable when compared over 100 years."
- Howarth et al, Climatic Change, Methane and the greenhouse gas footprint of natural gas from shale formations

UCAR study of gas vs coal



UCAR study of gas vs coal

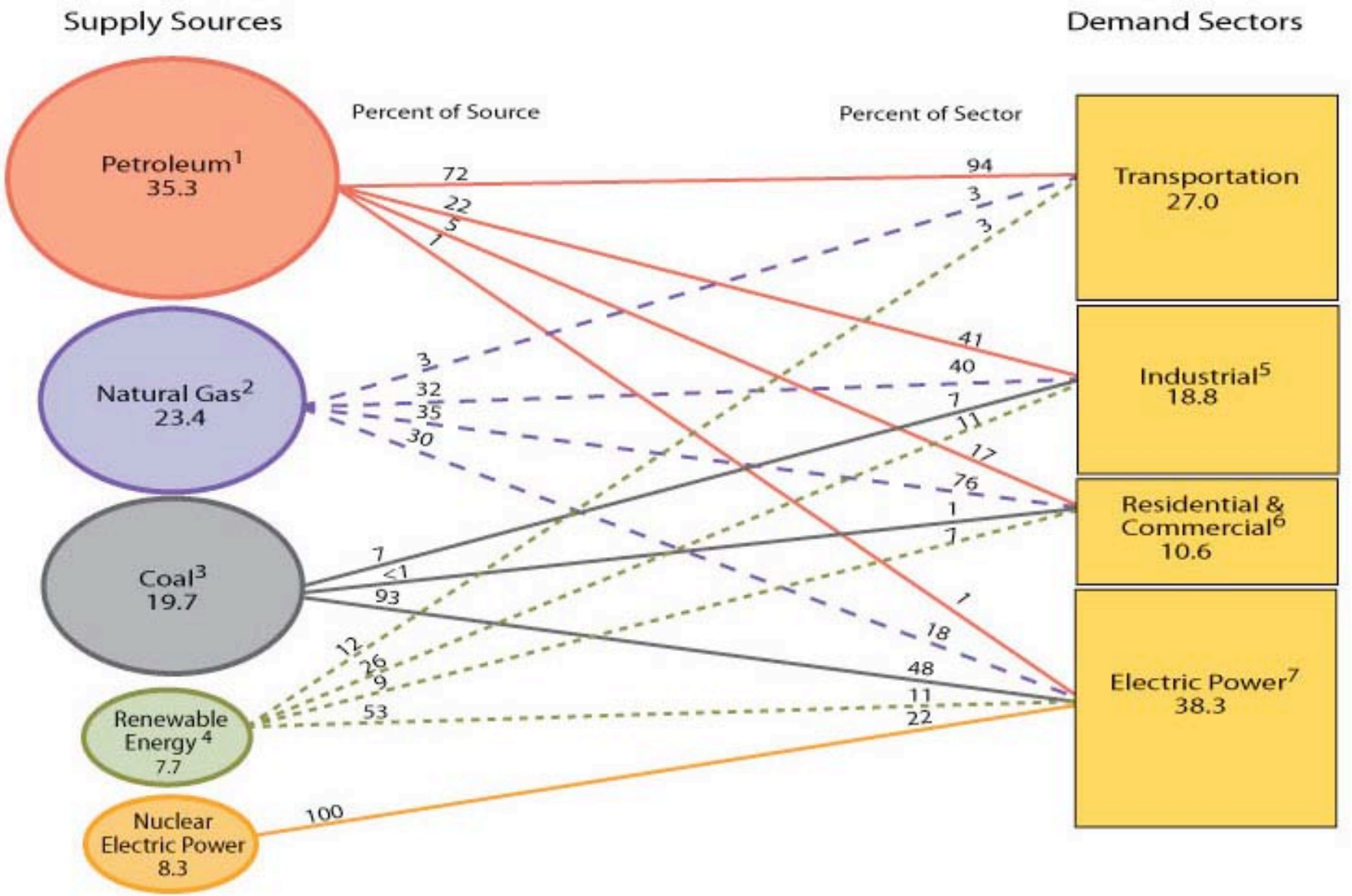
- Gas emits less GHGs than coal per unit heat – good – BUT
- Coal generates particles and aerosols that block the sun and cool the planet, offsetting some of the impacts of GHGs
- Claim is that net of these cooling effects of coal gas is only a very marginal improvement

Where does this leave us?

- Natural gas is still
  - Cheap and
  - Abundant
  - Flexible – plants can start and stop in minutes, making them a good backup for wind/solar
  - Still cleaner than coal – recall deaths from coal pollution
- The issue is – what is its impact on the climate? And on groundwater?
- We are not yet sure. Most recent estimate is that gas's GHG impact is about 50-60% that of coal, so it is relatively clean and can contribute to climate change mitigation

Oil in the US

The transport fuel



US EIA Annual Review 2010. Supplies in quadrillion BTUs.

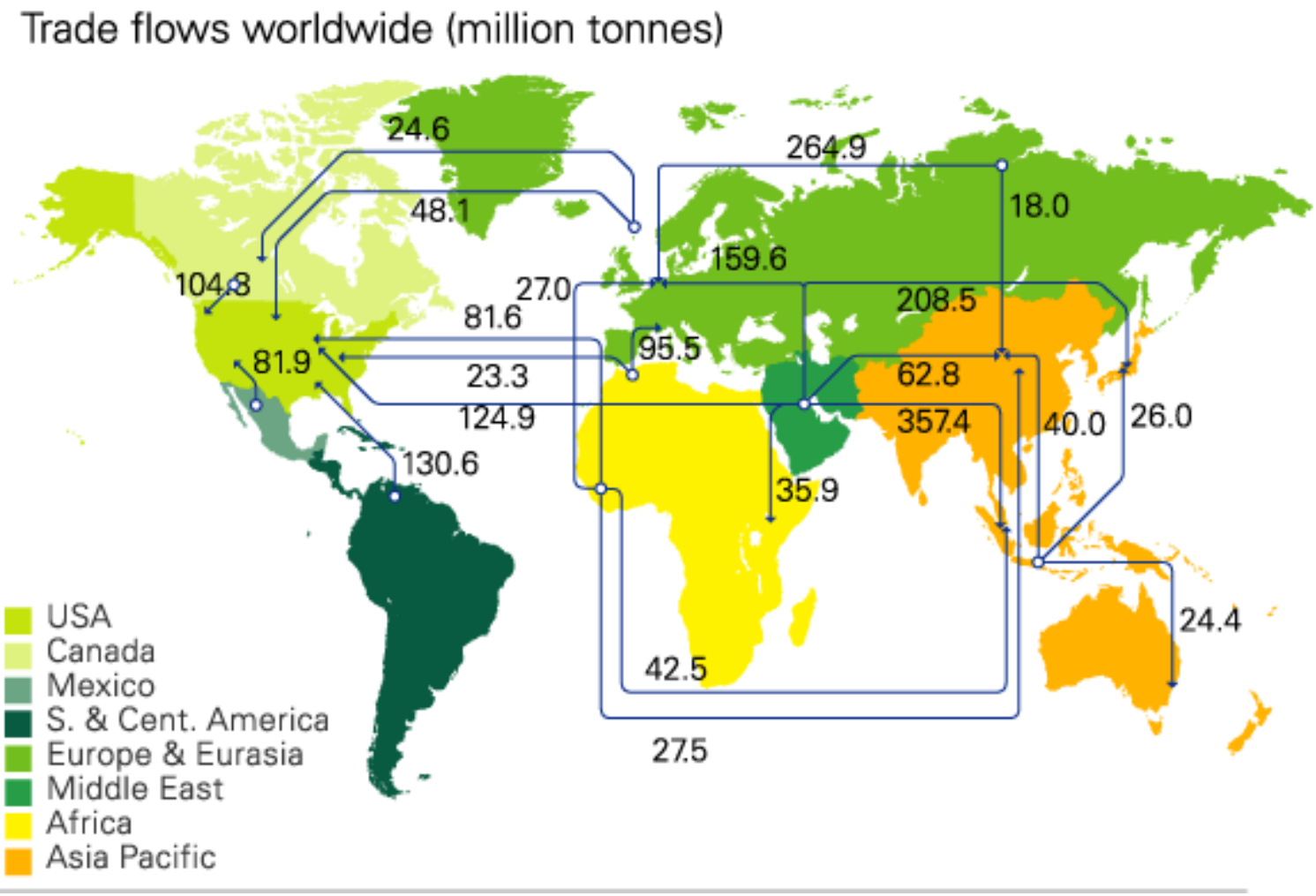
Oil facts

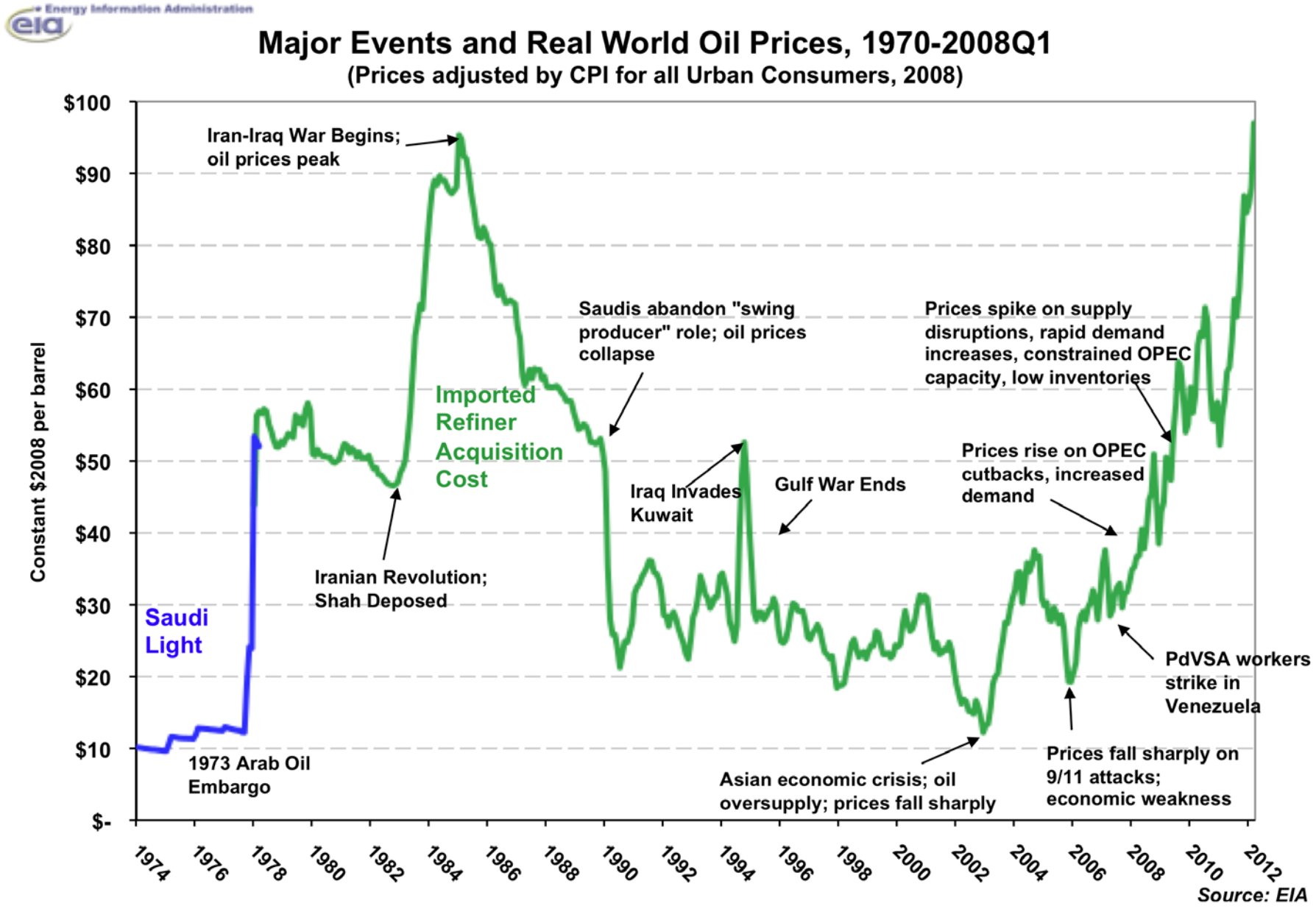
- World-wide consumption about 84 million barrels per day (mbd)
  - Equivalent to 32 billion barrels annually
- U.S. consumption 20 mbd
- Saudi production 7-10 mbd
- Russian production 7-8 mbd
- US production 7+ mbd
  - No other country > 5 mbd

	Producing Nation	2006	2007	2008	2009	Present Share
1	Saudi Arabia (OPEC)	10,665	10,234	10,782	9,760	11.8%
2	Russia	9,677	9,876	9,789	9,934	12.0%
3	United States	8,331	8,481	8,514	9,141	11.1%
4	Iran (OPEC)	4,148	4,043	4,174	4,177	5.1%
5	China	3,846	3,901	3,973	3,996	4.8%
6	Canada	3,288	3,358	3,350	3,294	4.0%
7	Mexico	3,707	3,501	3,185	3,001	3.6%
8	UAE (OPEC)	2,945	2,948	3,046	2,795	3.4%
9	Kuwait (OPEC)	2,675	2,613	2,742	2,496	3.0%
10	Venezuela (OPEC)	2,803	2,667	2,643	2,471	3.0%
11	Norway	2,786	2,565	2,466	2,350	2.8%
12	Brazil	2,166	2,279	2,401	2,577	3.1%
13	Iraq (OPEC)	2,008	2,094	2,385	2,400	2.9%
14	Algeria (OPEC)	2,122	2,173	2,179	2,126	2.6%

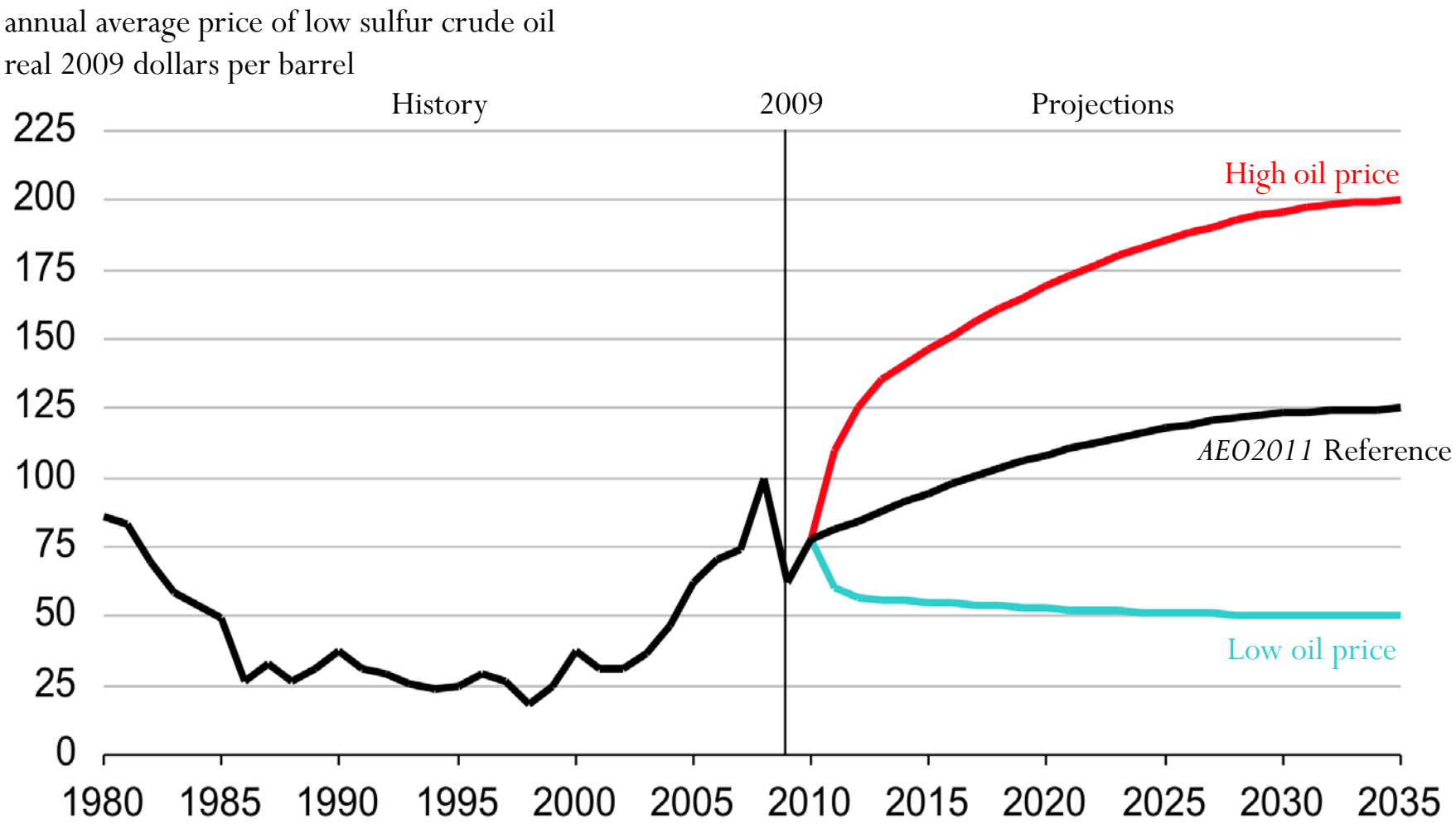
Source US EIA

Major oil trade movements



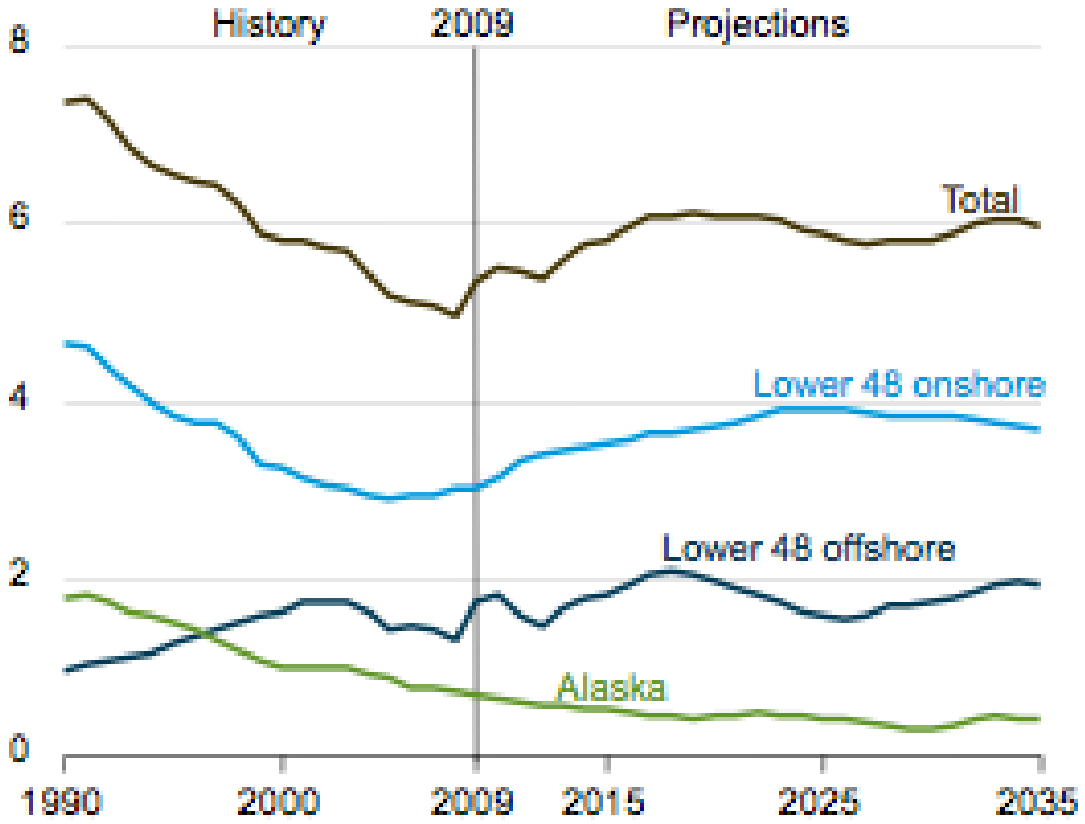

Energy Information Administration
eia
Major Events and Real World Oil Prices, 1970-2008Q1
(Prices adjusted by CPI for all Urban Consumers, 2008)
Constant $2008 per barrel
$100
$90
$80
$70
$60
$50
$40
$30
$20
$10
$-
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Iran-Iraq War Begins; oil prices peak
Saudis abandon "swing producer" role; oil prices collapse
Prices spike on supply disruptions, rapid demand increases, constrained OPEC capacity, low inventories
Imported Refiner Acquisition Cost
Iraq Invades Kuwait
Gulf War Ends
Prices rise on OPEC cutbacks, increased demand
Saudi Light
Iranian Revolution; Shah Deposed
PdVSA workers strike in Venezuela
1973 Arab Oil Embargo
Asian economic crisis; oil oversupply; prices fall sharply
Prices fall sharply on 9/11 attacks; economic weakness
Source: EIA

Oil prices in the Reference case rise steadily



Source: EIA, *Annual Energy Outlook 2011*

Figure 95. Domestic crude oil production by source, 1990-2035 (million barrels per day)



US EIA AEO 2011 Domestic US crude oil production

Competition for Oil

- Coal and natural gas can both be converted to oil at about $40-60 per barrel
- There are huge reserves of coal
- Oil can be derived from tar sands – as in Athabasca, Canada – at a cost of about $60-90 per barrel
- Tar sands are vast – Canada has more oil than Saudi Arabia in its tar sands but production capacity is limited

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Competition for Oil

- All of these can replace conventional oil on a large scale at a cost of around $90
- But they require initial investments of $ billions.
- These investments will only be made if investors expect prices to remain above $60, ideally above $90.

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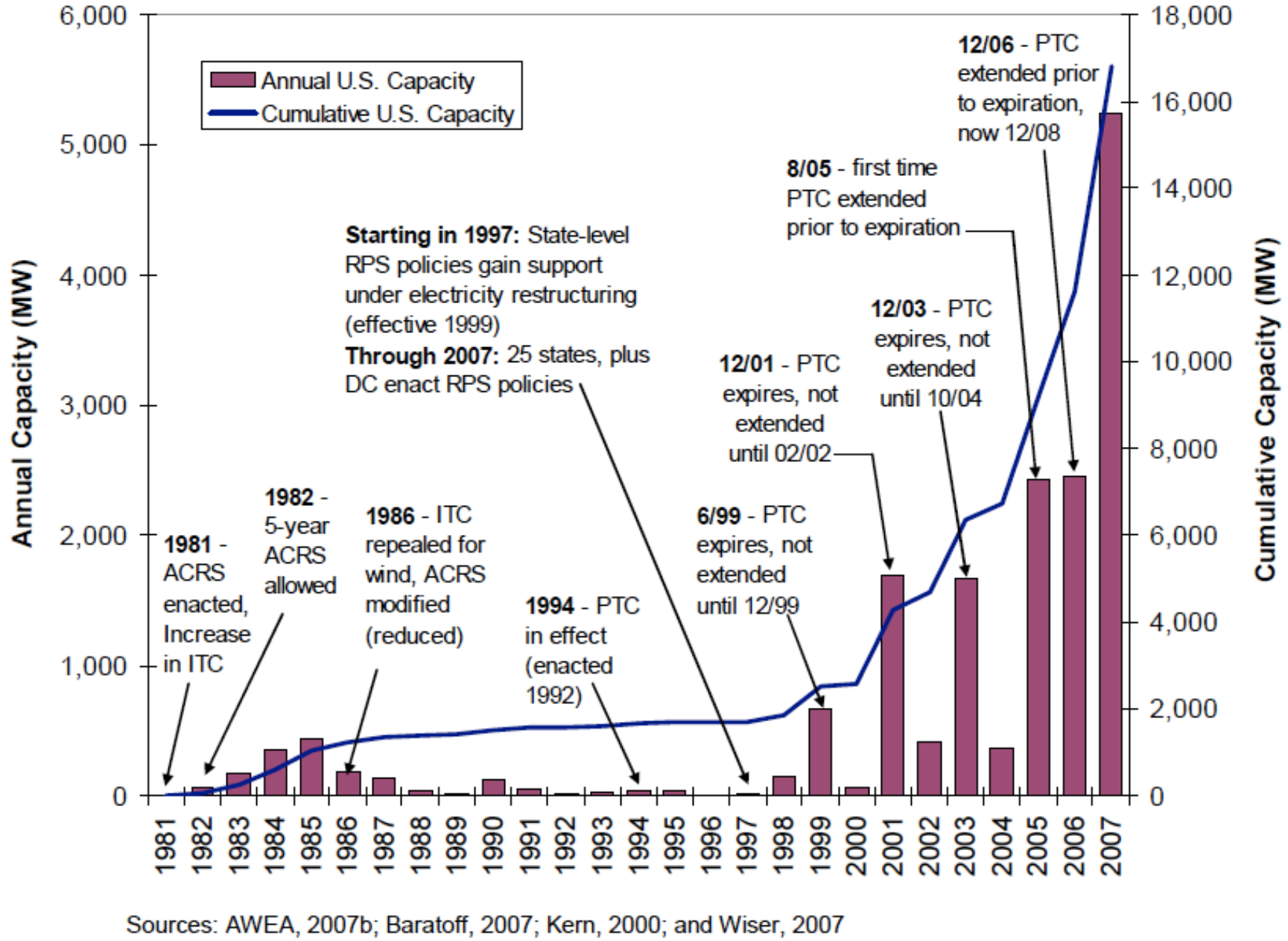
Mining tar sands

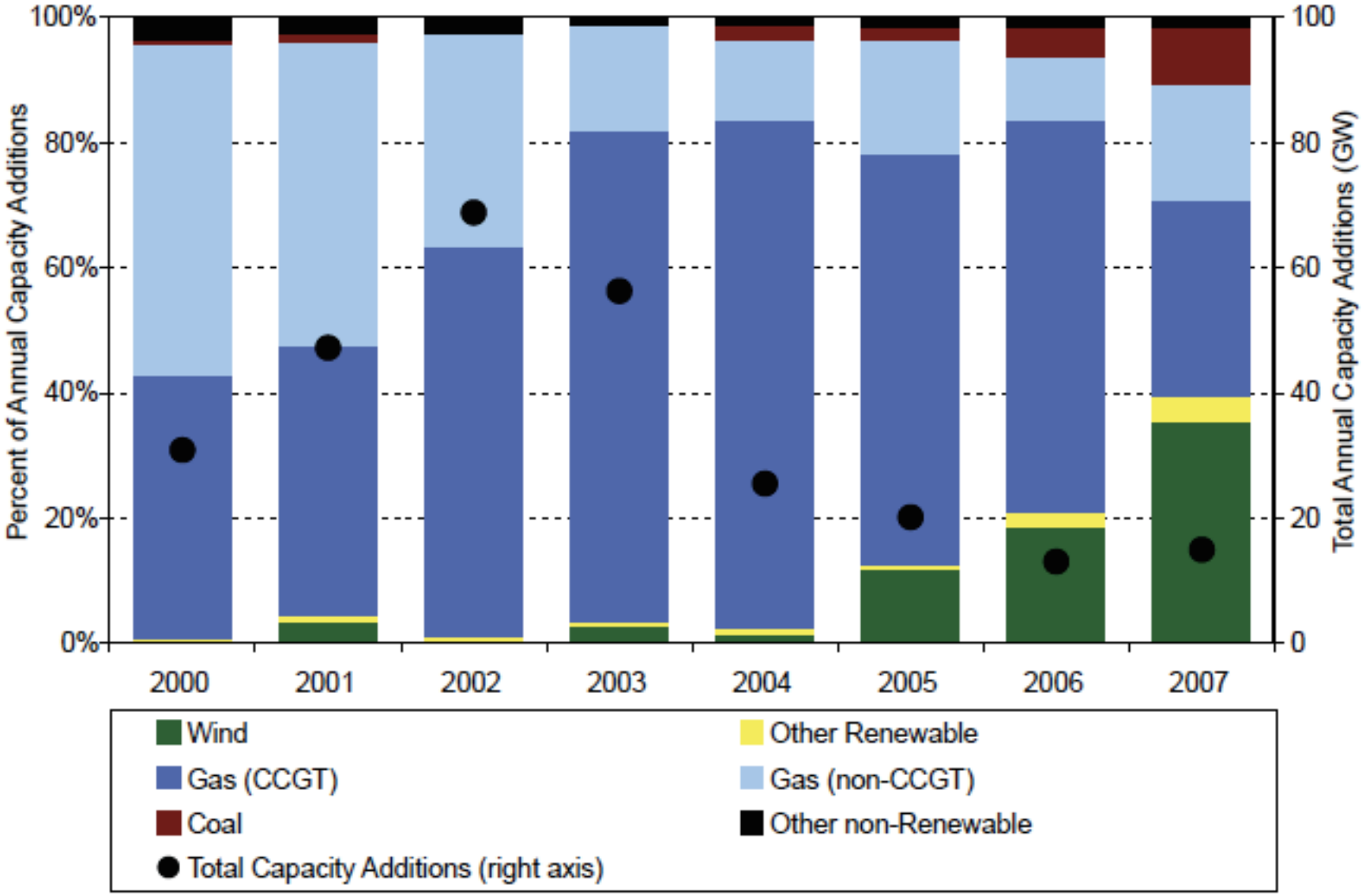
Renewables -

Wind and Solar in the US



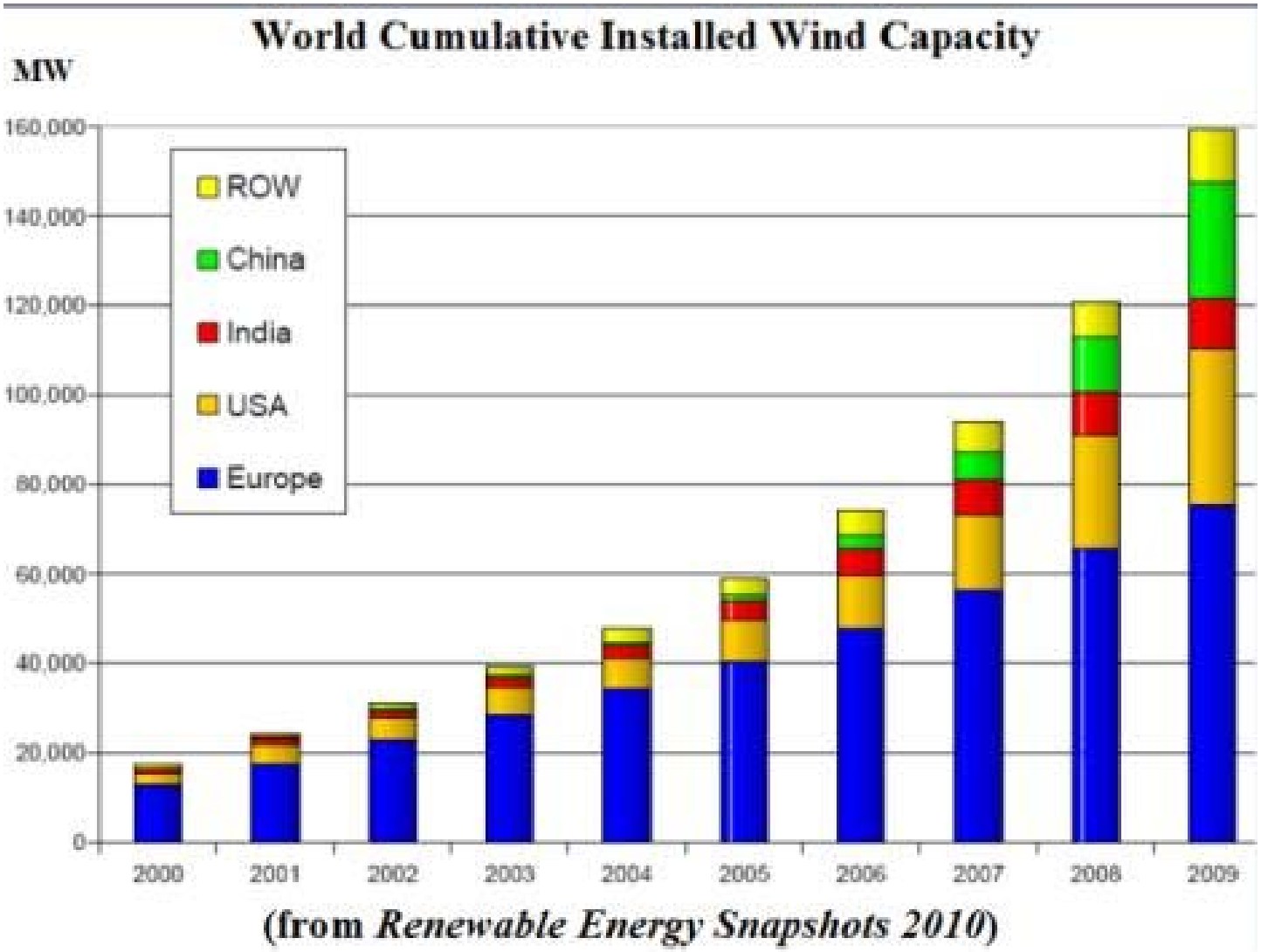
Sources: AWEA, 2007b; Baratoff, 2007; Kern, 2000; and Wiser, 2007

Figure 1. U.S. Wind Power Capacity Additions, 1981-2007



Source: EIA, Ventyx, AWEA, IREC, Berkeley Lab.

Figure 2. Relative Contribution of Generation Types to Annual Capacity Additions



(from *Renewable Energy Snapshots 2010*)

Economics of Wind

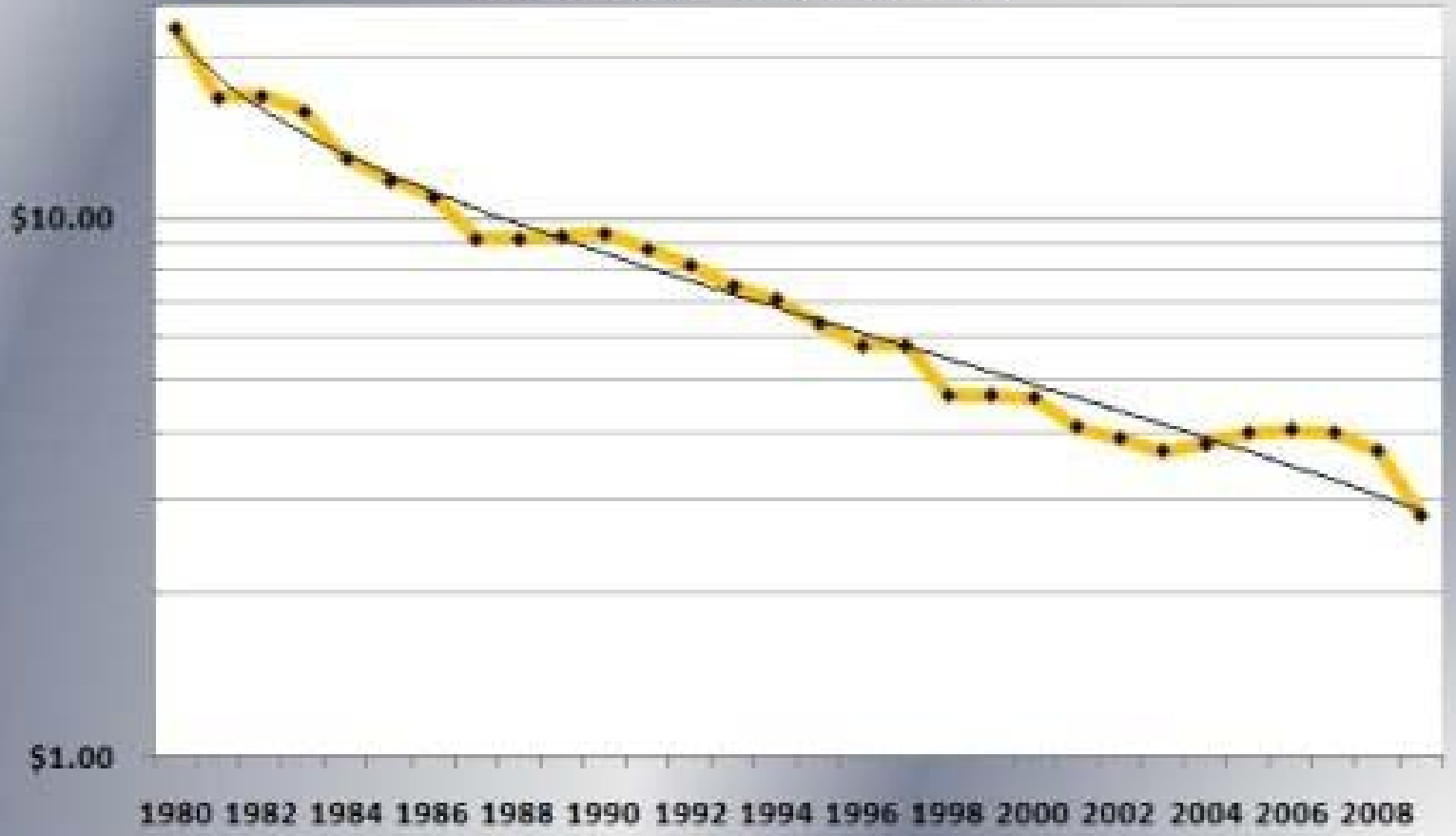
- LCOE about 5-6 cents kWh for onshore wind
- With RECS, ITC and PTC can be profitable as low as 3 cents kWh
- Wind and Gas are now power sources of choice

Solar Power

PV and Solar Thermal in the US

Plummeting Cost of Solar PV

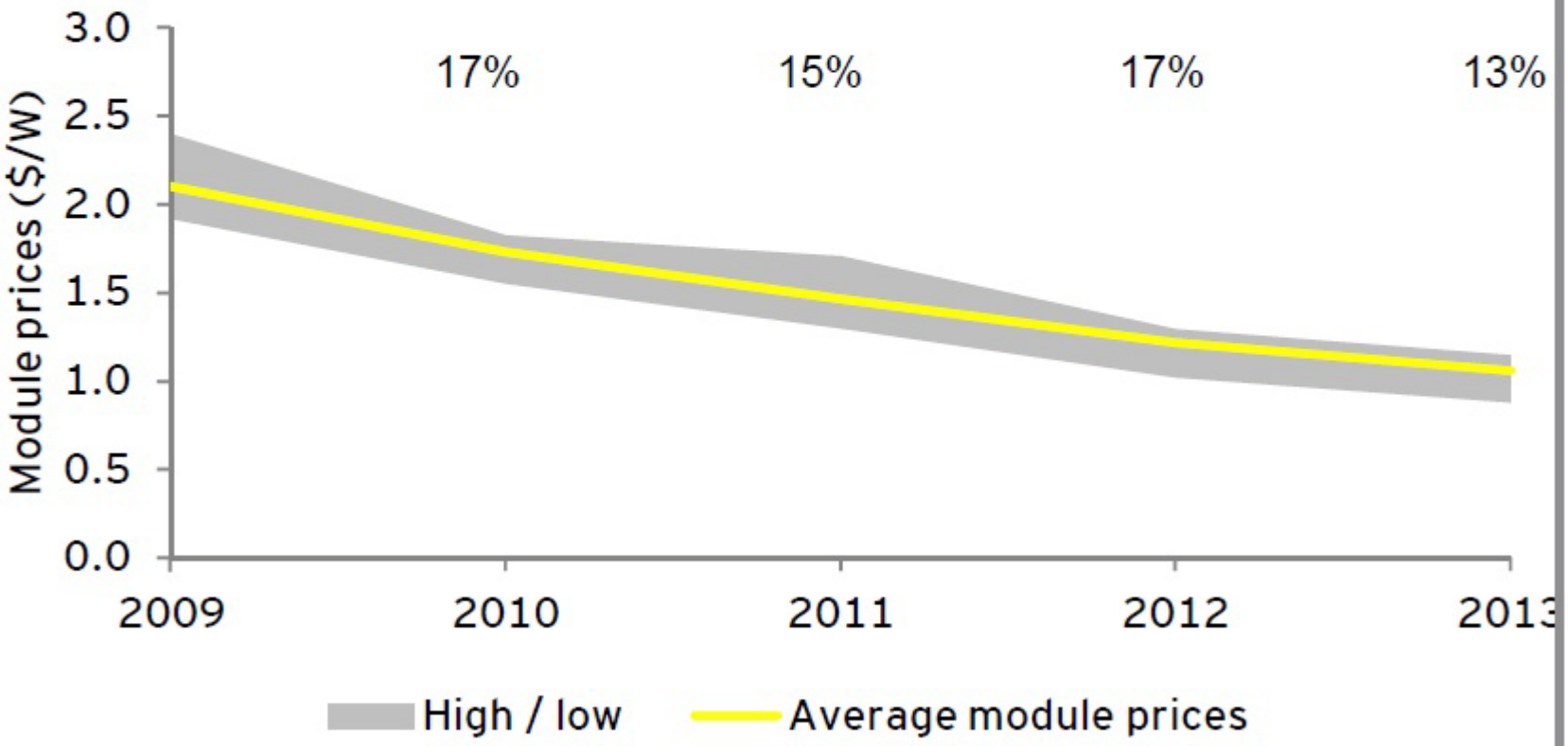
(Cost Per Watt in 2009 Dollars)



Source Data: DOE NREL Solar Technologies Market Report, Jan 2010

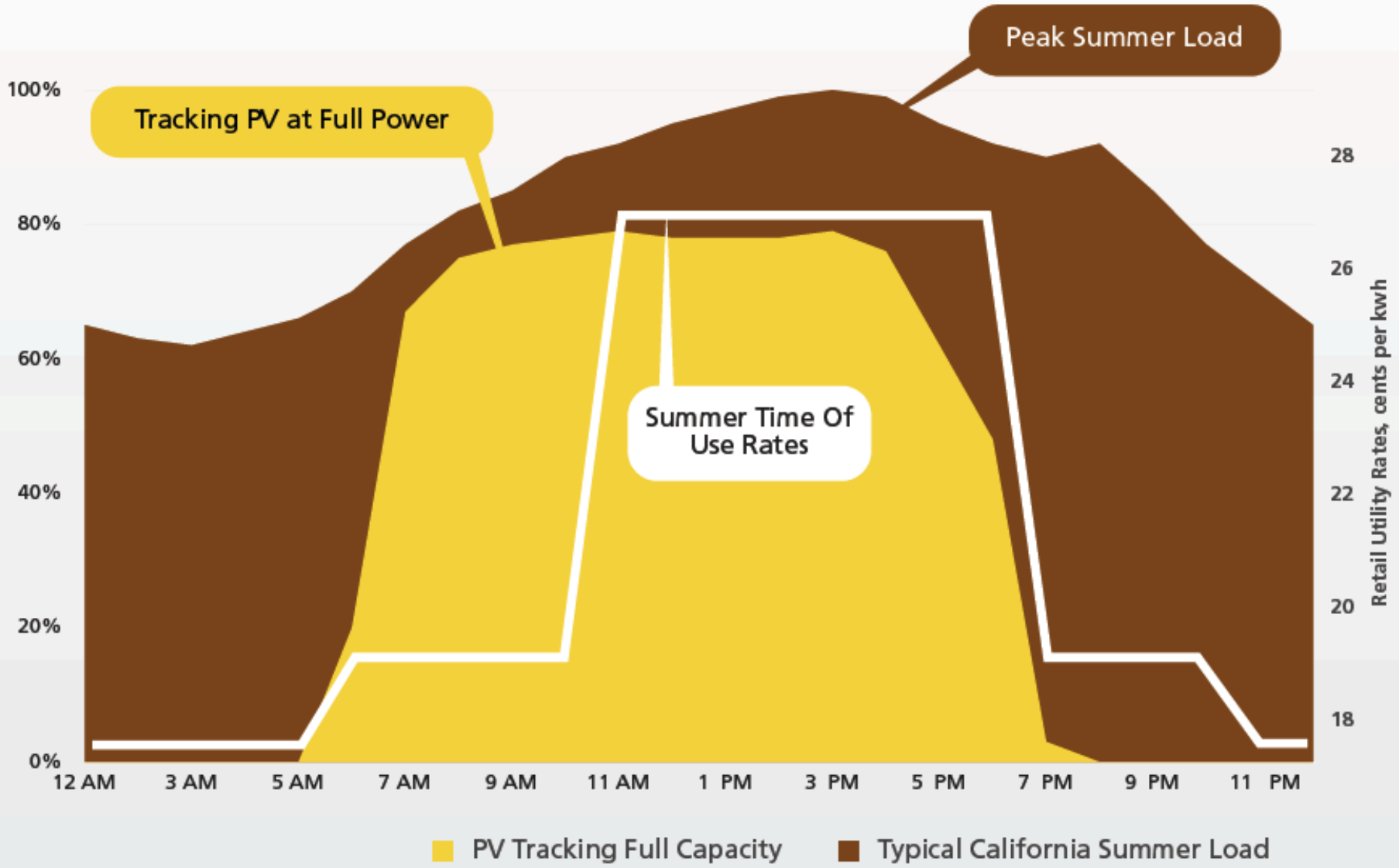
Module price evolution

- Analysis of broker reports shows range of expectations of module average selling price (ASP) to 2013.
- Average year on year percentage reductions are also shown.
- We note that modules are priced in US dollars and we have not included the impact of future foreign exchange movements in our analysis.



Source: HSBC, Numora, Morgan Stanley, Rolf, JP Morgan, EY analysis

Solar Meets Critical Peak Power Demand



Sources: For summer peak load shape – California Independent System Operator (CAL-ISO); For time of use rates – Pacific Gas and Electric Company (PG&E); For PV Tracking Output – Solaria Corporation

Solar Economics

- At current module prices PV has an LCOE of about 8-9 cents kWh, above gas and wind, above coal unless it has to pay for CO2
- But this is below retail power prices and off-grid solar is growing fast via agents such as SunEdison and Soltage
- Solar Thermal is about 12 cents kWh, but can be base load with storage

Economics Summary

Coal Gas Oil Wind Solar Geothermal Nuclear

Costs of Power Generation

- Coal
- Gas
- Oil
- Wind
- Solar
- Geothermal
- Nuclear

- 6 cent – before CO2
- 5-6 cents – before CO2
- Not competitive
- < 6 cents
- > 8 cents
- 3-6 cents and baseload
- High – investors reluctant, cost of capital and capital costs high