Modeling the Transition to a Low-Carbon Economy

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A Safe Future for Fossil-Fuel Investments?
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Columbia Law School
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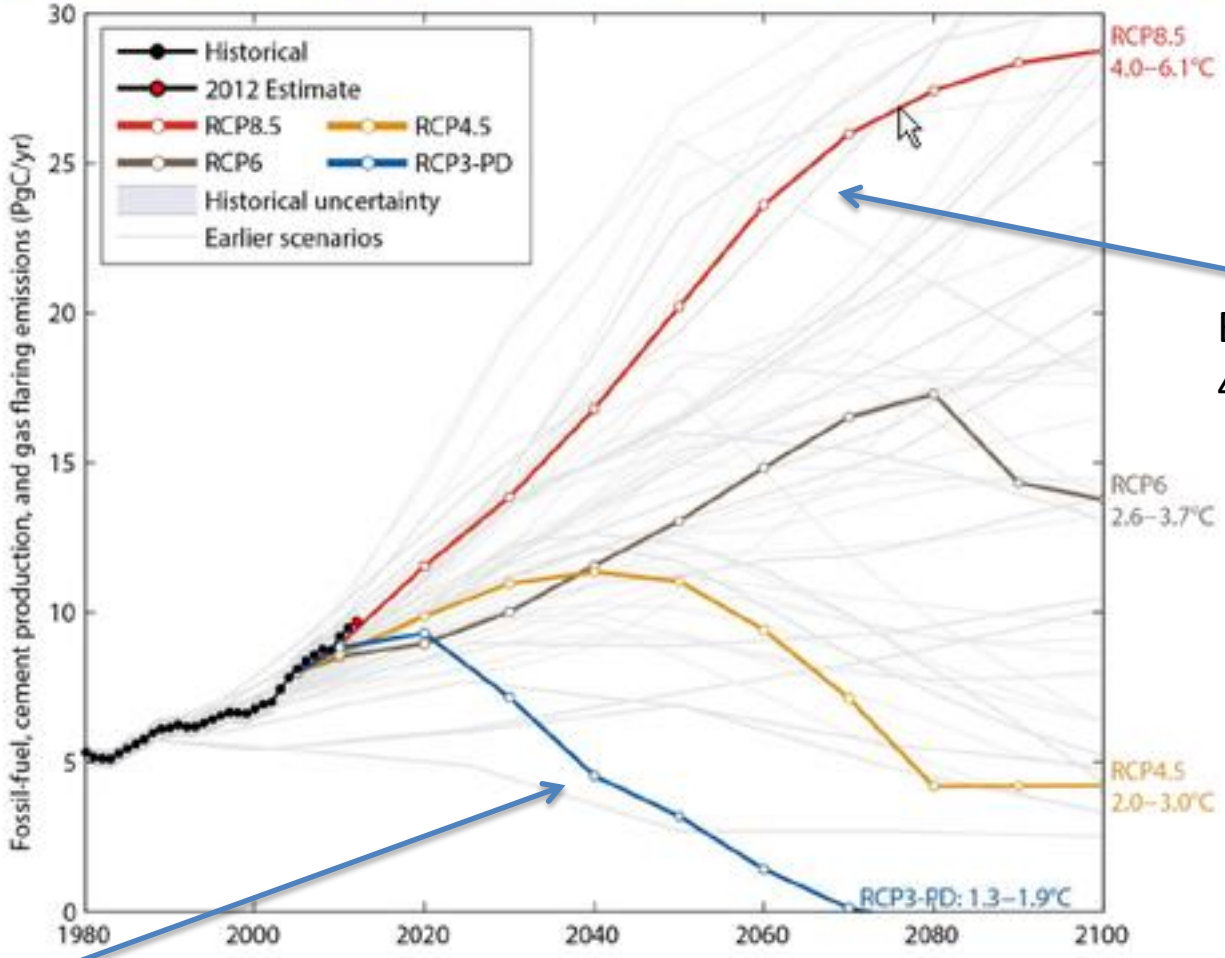
Emissions are heading to a 4.0-6.1°C "likely" increase in temperature
Large and sustained mitigation is required to keep below 2°C



BAU:
4-6 degree C

2-degree C

Linear interpolation is used between individual datapoints

Source: Peters et al. 2012a; Global Carbon Project 2012;

Why 2-Degree C?

Targets	Advocates	Rationale
1-degree C	Hansen	Long-term feedbacks, staying within Holocene
1.5-degree C	AOSIS	Sea level rise
2-degree C	Copenhagen/Cancun	ST Impacts at 2-d C LT Impacts at 2-d C Risks of tipping points
>2-degree C	Numerous	Costs of mitigation

In principle, the world should equate MC of emissions reduction with the MB of emissions reduction (equal to the Social Cost of Carbon)

In practice, we don't know either side of the cost-benefit equation. High uncertainties of long-term costs of abatement and costs of carbon. Also, who's benefit: very strong distributional considerations across class, region, and generations.

CO2-ENERGY EMISSIONS CONSISTENT WITH 2-DEGREE C LIMIT

Emissions	1,000 Billion Tons (Likely 2-degree C)
Current CO2 Emissions Per Year	35 billion tons CO2 (or 10 billion C)
Years remaining at Current Rate	Around 29
Target Emissions 2050	Around 12 billion tons
Target Emissions 2070	Around 0 billion tons
Total CO2 in Proved Coal Reserves	2,126 billion tons
Total CO2 in Proved Oil Reserves	723 billion tons
Total CO2 in Proved Gas Reserves	356 billion tons
Total CO2 in 2-degree C Budget	875 billion tons
Emissions Per Capita 2013 WORLD	4.9 tons per person
Emissions Per Capita 2050 WORLD	1.3 tons per person

MAIN IMPLICATIONS:

Deep Decarbonization Pathways to 2050 (to around 1.3 tons per capita or less, compared with roughly 16 tons pc in the US today)

Net Carbon Storage in Terrestrial Ecosystems (around 350 billion tons CO2, through REDD+ and others)

Halt to Development of Unconventional Oil and Gas and end of coal except with CCS

THE WORLD WILL NEED TO STRAND OIL, GAS, AND COAL RESERVES

Table 1 | Regional distribution of reserves unburnable before 2050 for the 2 °C

	2 °C with CCS					
	Oil		Gas		Coal	
Country or region	Billions of barrels	%	Trillions of cubic metres	%	Gt	%
Africa	23	21%	4.4	33%	28	85%
Canada	39	74%	0.3	24%	5.0	75%
China and India	9	25%	2.9	63%	180	66%
FSU	27	18%	31	50%	203	94%
CSA	58	39%	4.8	53%	8	51%
Europe	5.0	20%	0.6	11%	65	78%
Middle East	263	38%	46	61%	3.4	99%
OECD Pacific	2.1	37%	2.2	56%	83	93%
ODA	2.0	9%	2.2	24%	10	34%
United States of America	2.8	6%	0.3	4%	235	92%
Global	431	33%	95	49%	819	82%

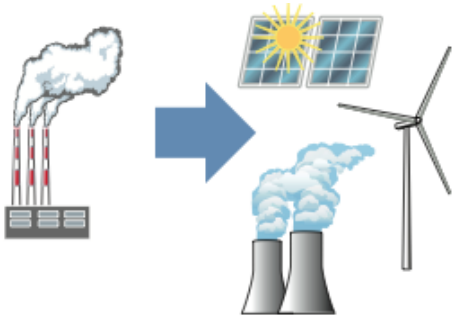
FROM McGLADE AND EKINS, NATURE MAGAZINE, JANUARY 8, 2015

Main Decarbonization Strategies

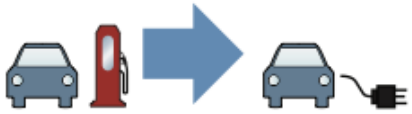
Strategy

Energy Efficiency

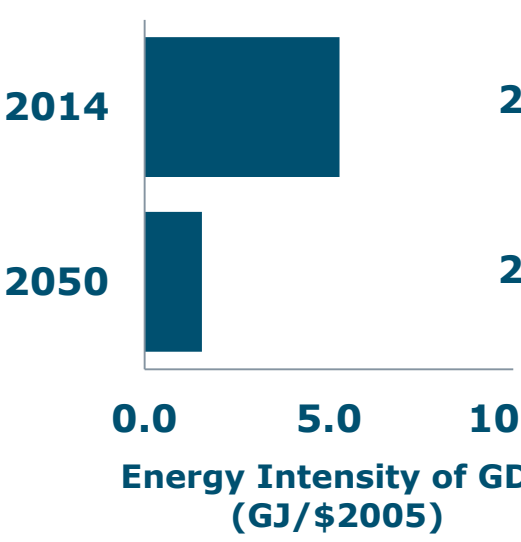
Decarbonization of Electricity

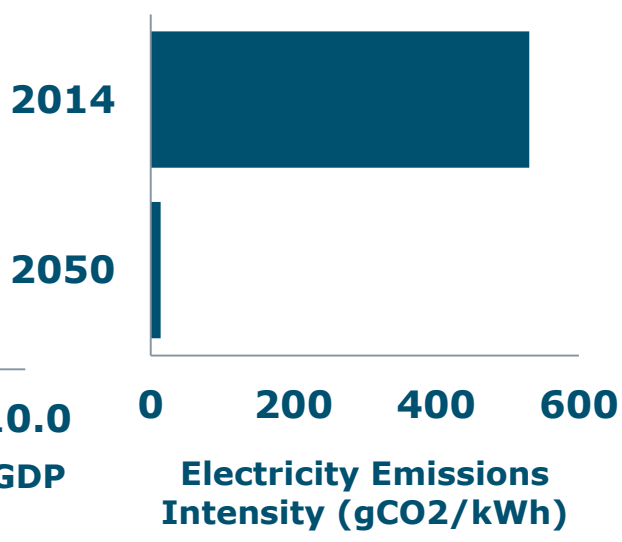


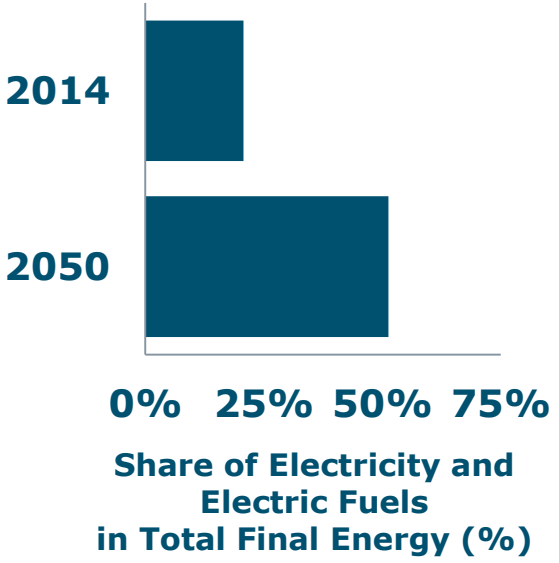
End Use Fuel Switching to Electric Sources



Key Metric of Transformation





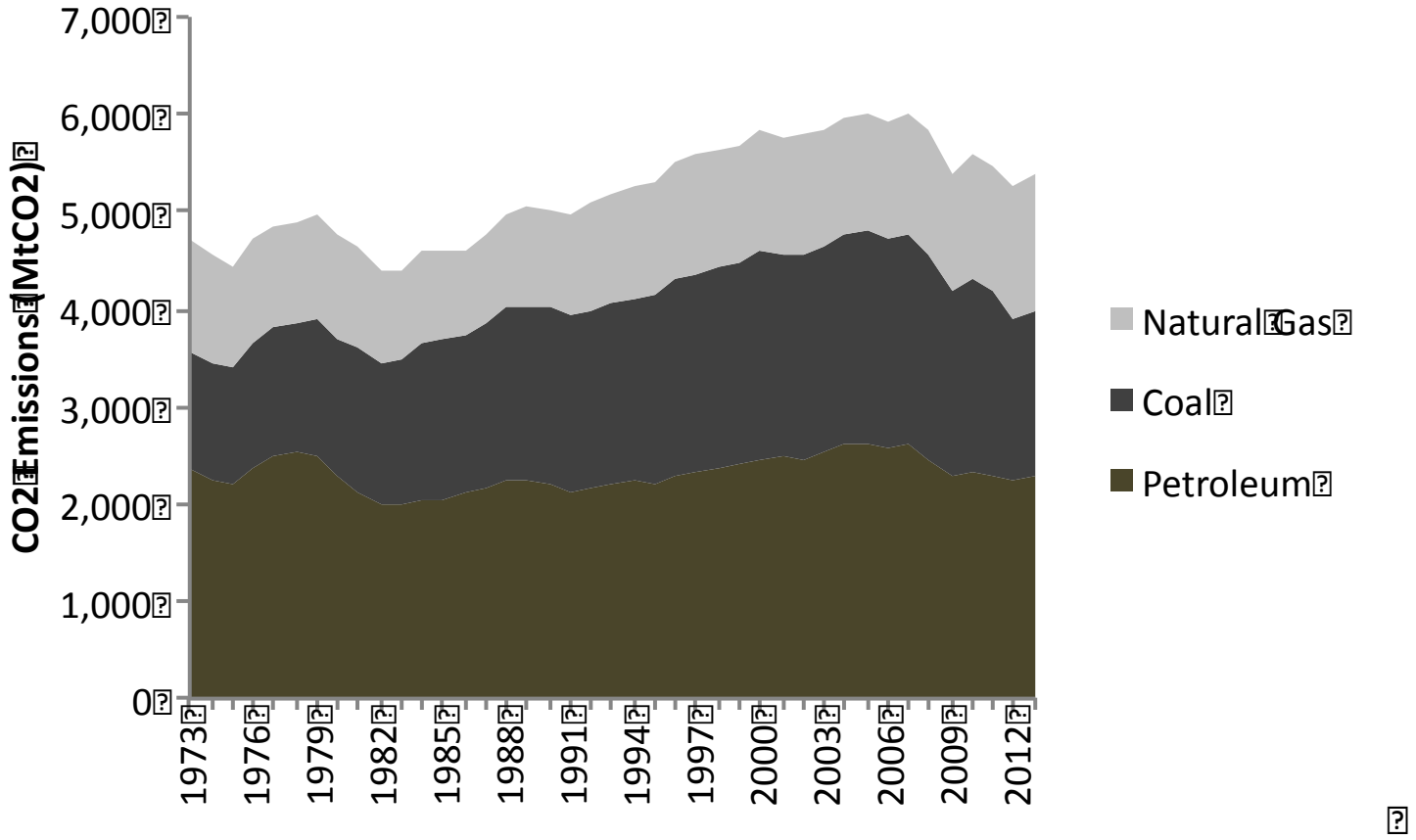


US GHG EMISSIONS, 2012

GHG Source	GHGs	2012 Emissions (TgCO2e)	% Gross 2012 Emissions
Fossil fuel combustion	CO_2	5,065.7	78%
Fossil fuel energy systems	CO_2, CH_4, N_2O	254.9	4%
Agricultural soil management	N_2O	306.6	5%
Enteric fermentation	CH_4	141.0	2%
Substitution of ozone depleting substances	HFC	129.4	2%
Non-energy use of fuels	CO_2	110.6	2%
Landfills	CH_4	102.8	2%
Total above		6,111.0	94%
Total gross emissions	**CO_2, CH_4, N_2O, HFCs, PFCs, SF_6**	**6,501.5**	

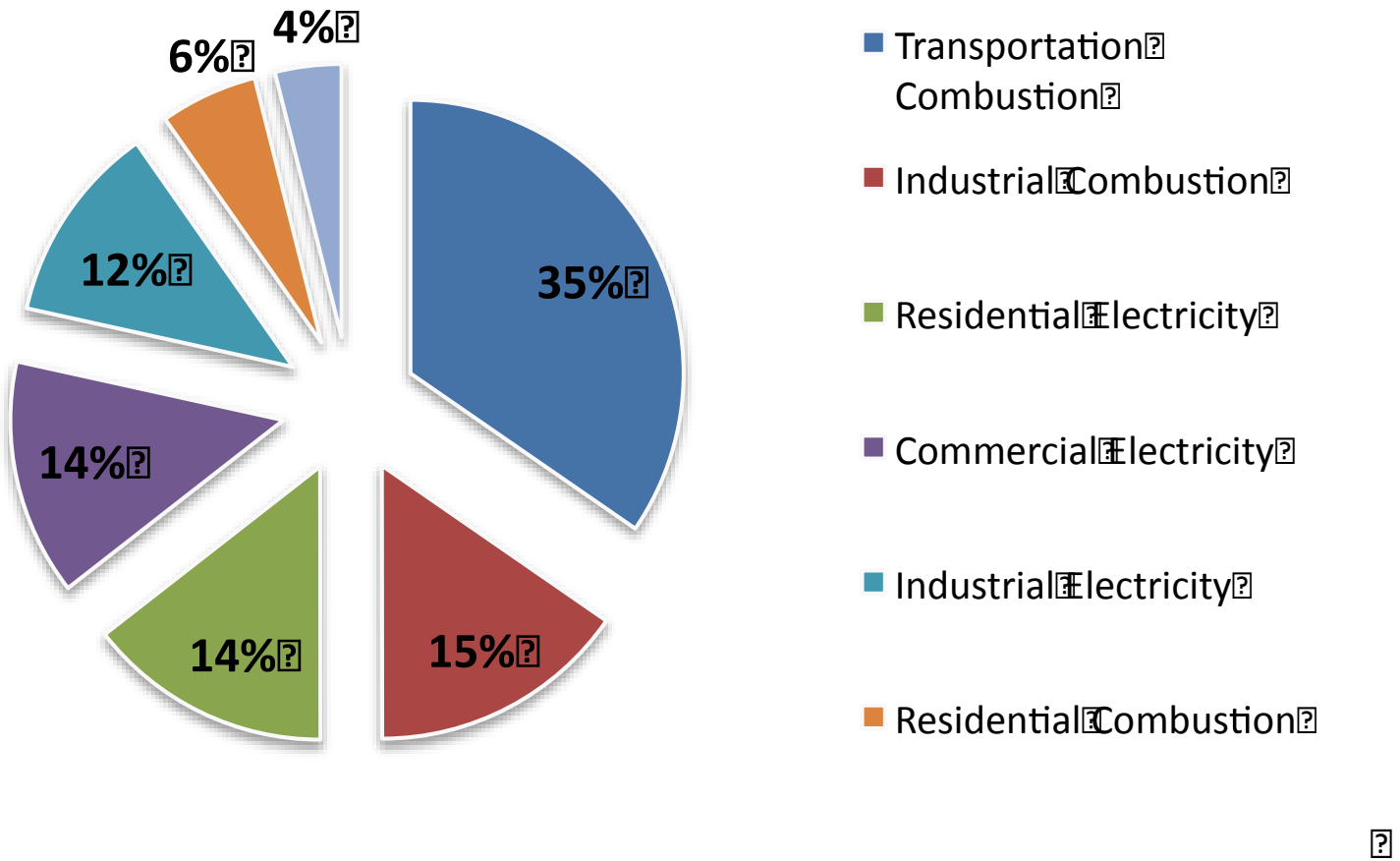
Source: U.S. Environmental Protection Agency (EPA), Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012, February 21, 2014, http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Main-Text.pdf.

Figure 1. U.S. CO_2 Emissions from Fossil Fuel Combustion by Fuel Source, 1973-2013



Source: EIA, March 2014 Monthly Energy Review, March 27, 2014, http://www.eia.gov/.

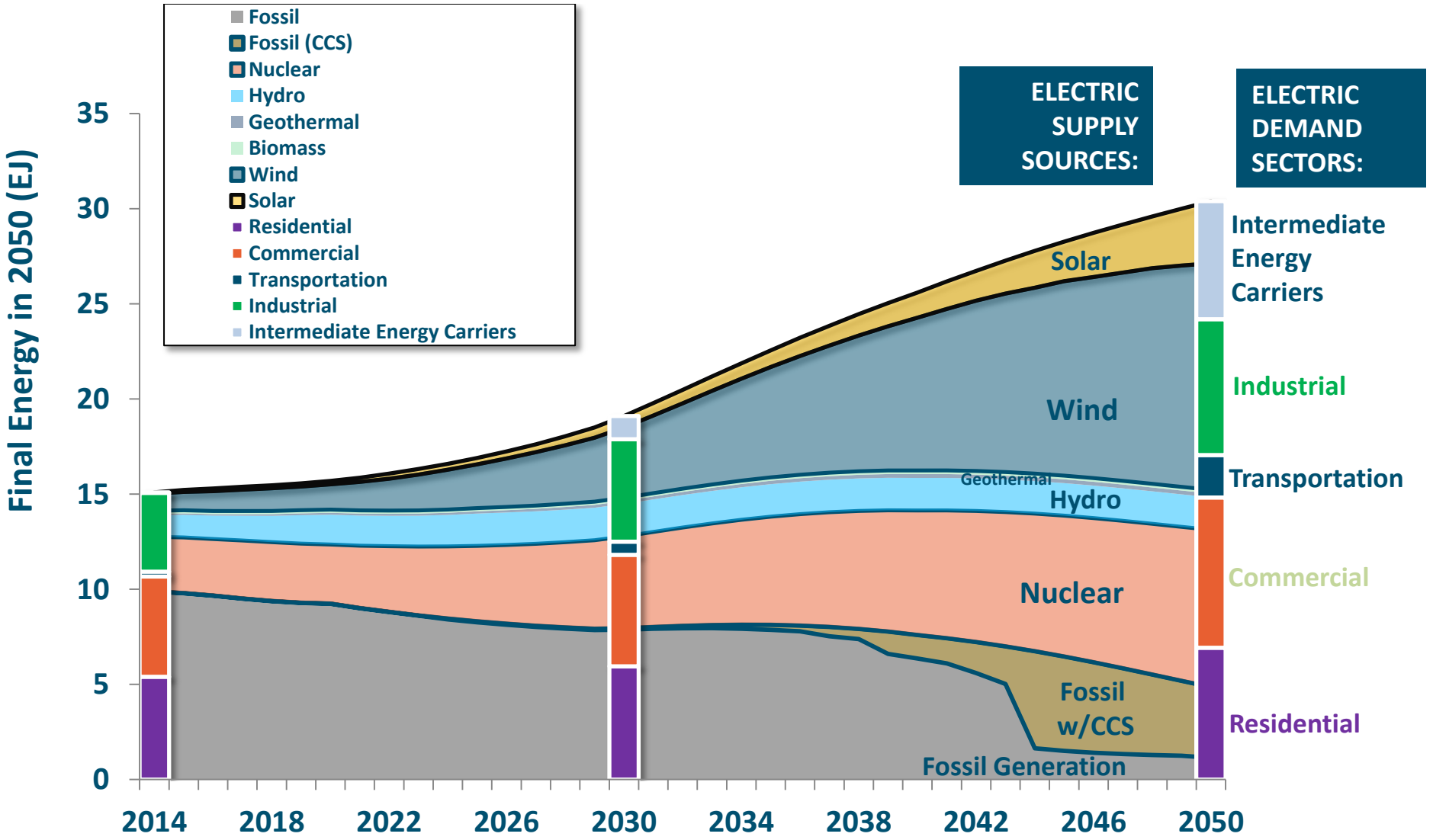
Figure 1. U.S. Direct Fossil Fuel Combustion and Electricity-Induced Fossil Fuel CO_2 Emissions by Major Sector, 2012



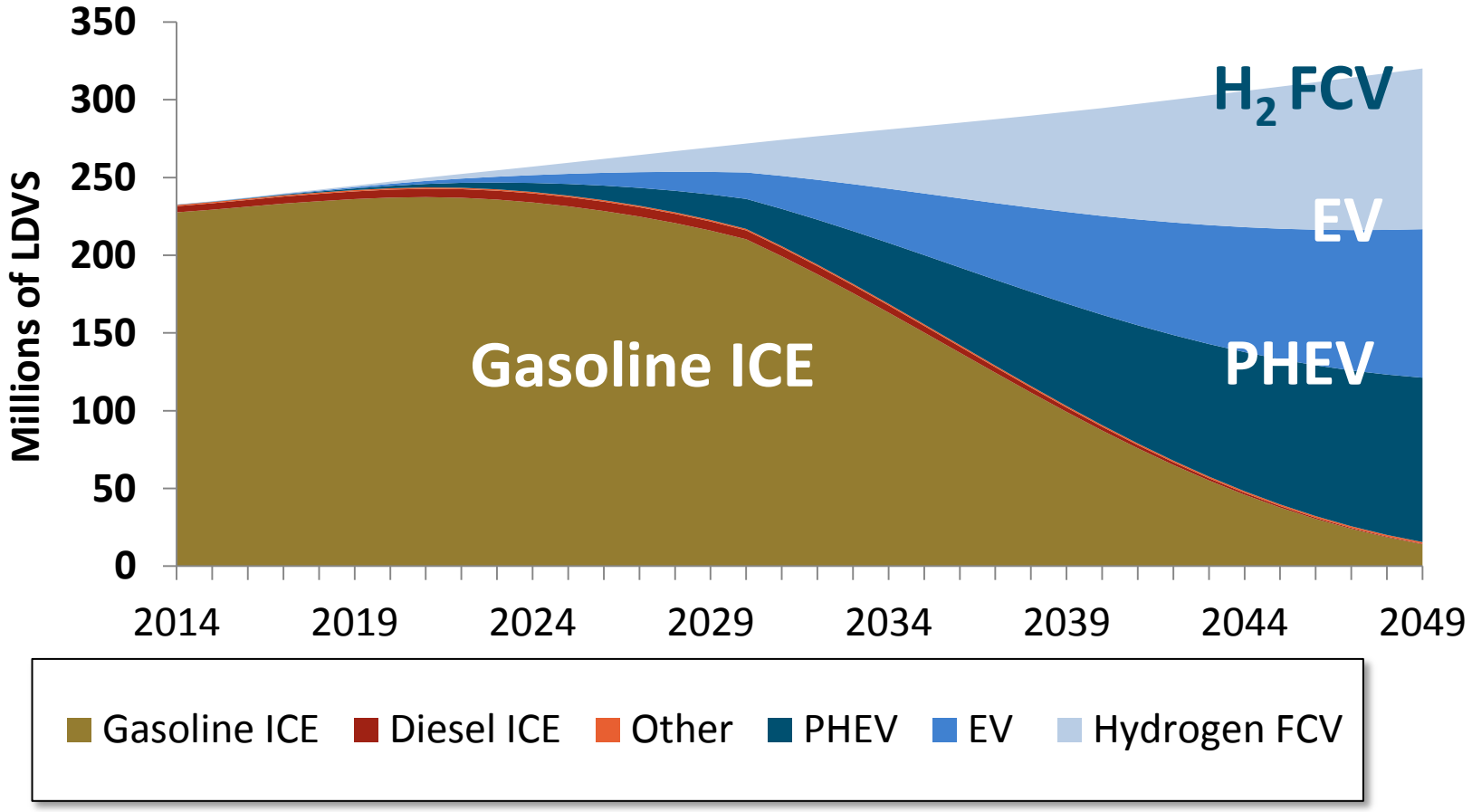
Source: EPA, Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012.

NOTE THAT US IS ALSO A NET IMPORTER OF CO2-INTENSIVE MANUFACTURED GOODS

Electricity Supply: By Fuel Type and Demand Sector



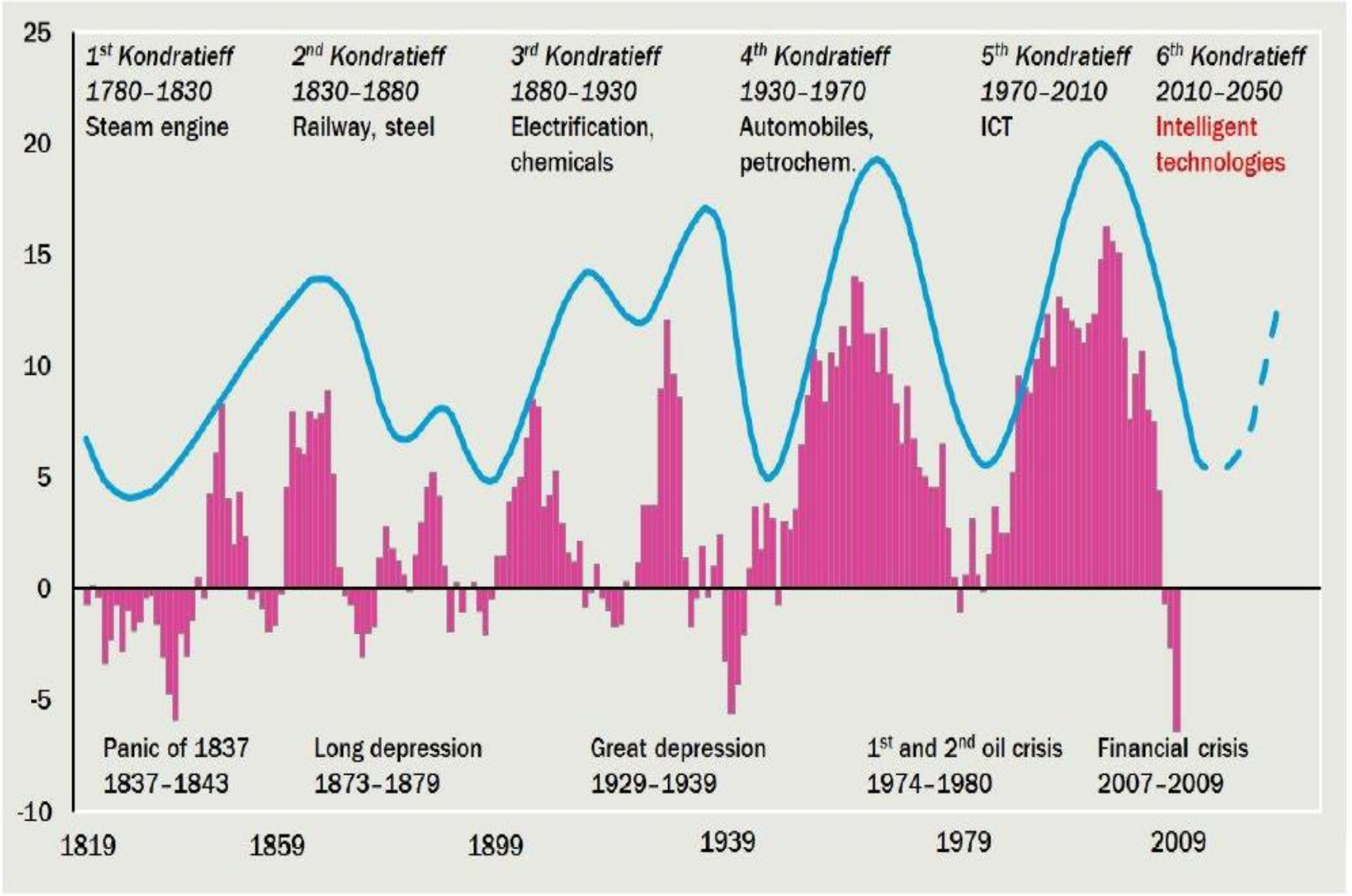
Transportation Sector:
Annual Light-Duty Vehicle Stock



THE NEED FOR NEW LOW-CARBON TECHNOLOGIES

- CARBON CAPTURE AND SEQUESTRATION
- STORAGE OF RENEWABLE ENERGY
- ZERO-EMISSION VEHICLES
- FOURTH-GENERATION NUCLEAR ENERGY
- SMART GRIDS BASED ON HIGH RENEWABLES
- ADVANCED BIOFUELS AND SYNTHETIC FUELS
- ADVANCES IN SOLAR PV

THESE ARE PART OF A BROADER SET OF NEEDED SUSTAINABLE TECHNOLOGIES, INCLUDING SUSTAINBLE AGRICULTURE AND URBAN DESIGN



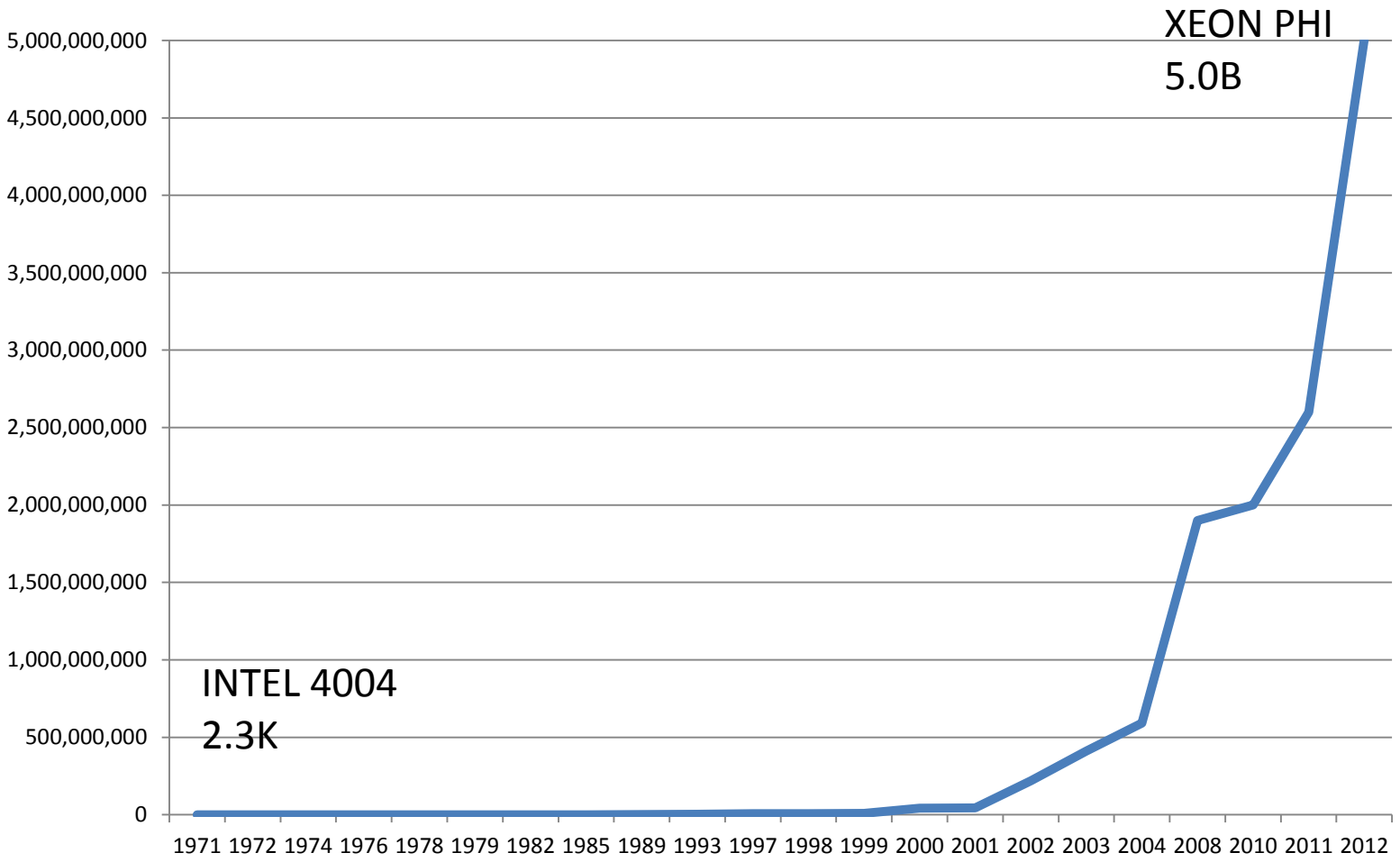
SIXTH WAVE SHOULD BE SUSTAINBLE GROWTH BUILT ON DIGITAL REVOLUTION

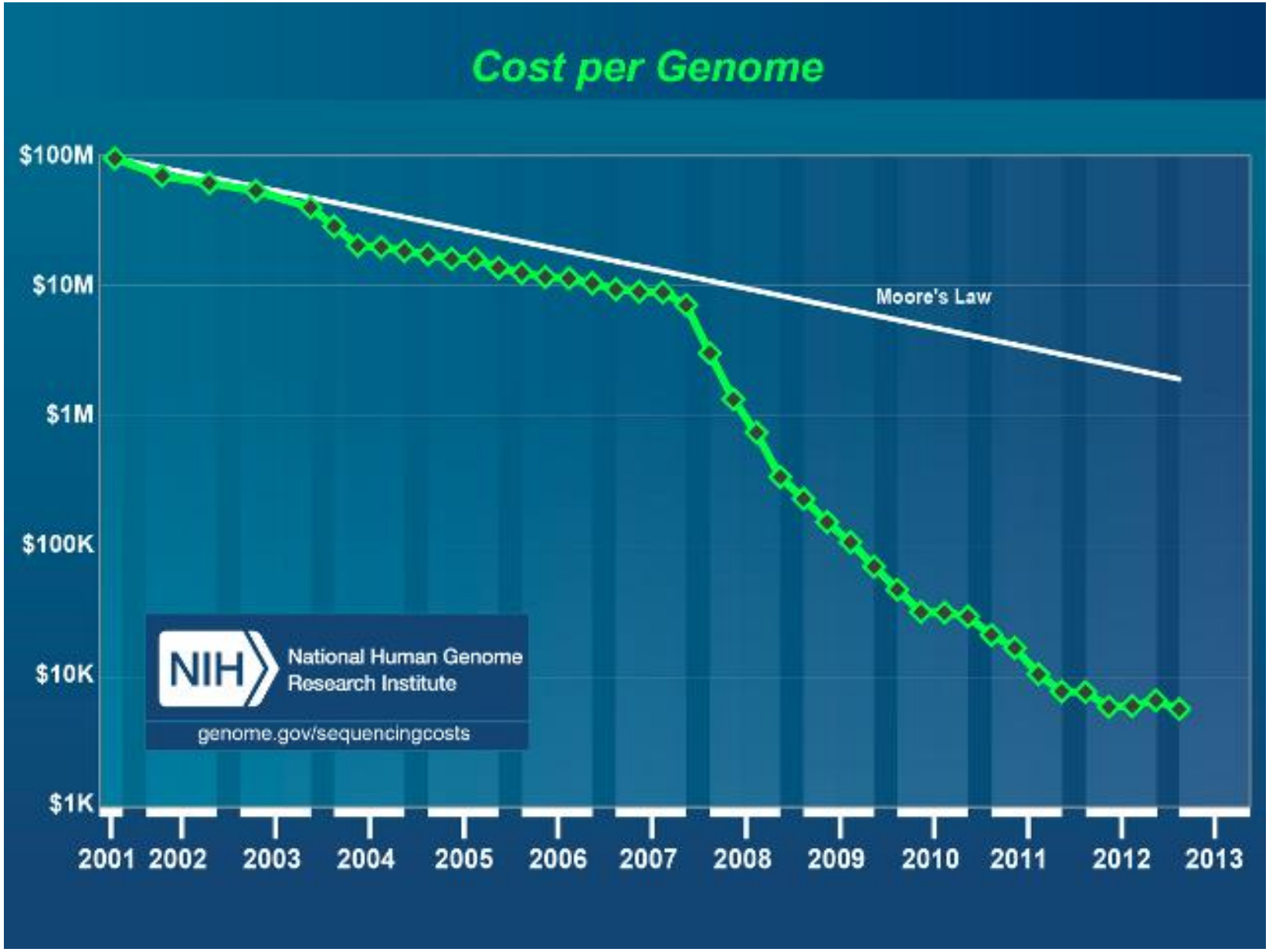
LOW-CARBON ADVANCES CAN BE “DIRECTED” AS WITH OTHER MODERN BREAKTHROUGHS:

RADAR
CRYPTOGRAPHY
MANHATTAN PROJECT
COMPUTING
SEMICONDUCTORS (Intl Tech Roadmap for Semiconductors)
MOON MISSION
INTERNET
HUMAN GENOME PROJECT
PPPS FOR MEDICINES, VACCINES, AND DIAGNOSTICS (GATES)
HIGGS BOSON (CERN)

WHY WE CAN SUCCEED: THE INFORMATION AGE

(TRANSISTOR COUNT ON INTEL MICROPROCESSORS)

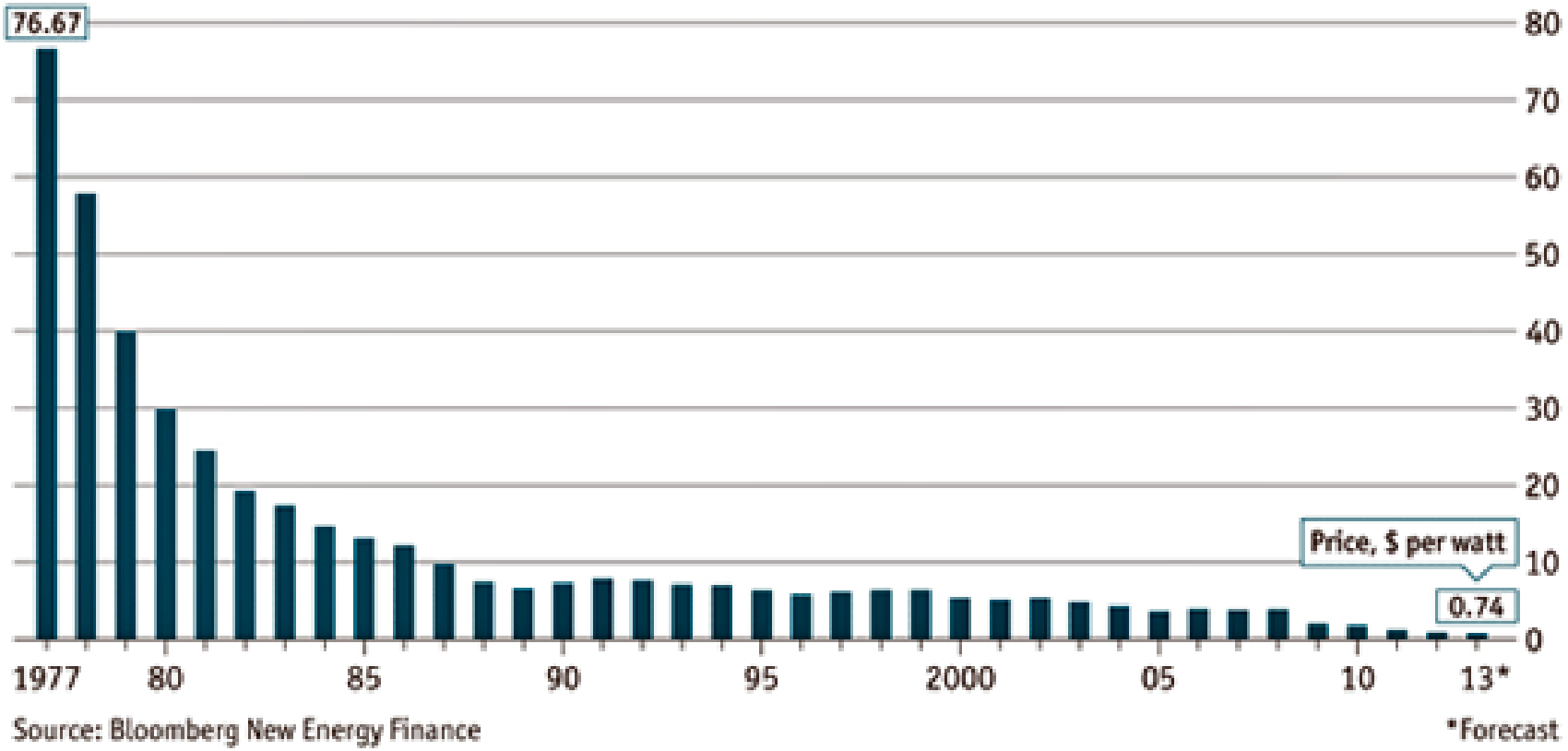




HALVING OF COST ROUGHLY EVERY NINE MONTHS

The Swanson effect

Price of crystalline silicon photovoltaic cells, $ per watt



Source: Bloomberg New Energy Finance

*Forecast

Economist.com/graphicdetail

ISSUES IN THE DESIGN OF TECHNOLOGY PUBLIC-PRIVATE PARTNERSHIPS (PPPs):

TECHNOLOGY ROADMAPPING (TIMELINES AND MILESTONES)
INTELLECTUAL PROPERTY MANAGEMENT
PUBLIC-PRIVATE FINANCING OF RDD&D

PILLARS OF A GLOBAL AGREEMENT AT COP21

AGREEMENT BASED ON 2-DEGREE C UPPER LIMIT (CORE)

GLOBAL CARBON BUDGET FOR 2-D C (ANNEX)

MODEST AND LEGALLY BINDING INDCs TO 2030 (CORE/ANNEX)

BOLD ASPIRATIONAL DDPS TO 2050 BY 2017 (CORE/ANNEX)

PPPS FOR LOW-CARBON TECHNOLOGIES (CORE/ANNEX)

CLIMATE FINANCING (MITIGATION, ADAPTATION, LOSS AND DAMAGE) FOR LOW-INCOME COUNTRIES

THE KEY POLITICAL ECONOMY:

CO2 EMISSIONS, BILLION METRIC TONS, 2012

Country/Group	CO2 Emissions
China	9.9
United States	5.2
European Union	3.7
India	2.0
Russia	1.8
World	34.5
Top 5 % of World	65.5

COAL RESERVES AND PRODUCTION, METRIC TONS, 2012

Country	Reserves (billion)	Consumption (million)
United States	237.2	438
Russia	157.0	94
China	114.5	1,873
Australia	76.4	
India	60.6	298
Japan		124
World	880.9	3,730
Top 5 % of World	73.3%	75.8

PATH TO AN EFFECTIVE AGREEMENT AT COP21:

CHINA AND US CONCUR ON FIVE KEY PILLARS
CHINA, US, AND EU FORM CORE GROUP
CANADA, AUSTRALIA, AND GCC JOIN CORE GROUP
CORE GROUP PLEDGES TECHNOLOGY PACKAGE
PRIVATE SECTOR LEADERS JOIN TECHNOLOGY PLEDGE
C40 CITIES JOIN CORE GROUP
ARCTIC COUNTRIES AGREE ON A MORATORIUM OF ARCTIC EXPLORATION
WORLD AGREES ON DEEP-SEA MORATORIUM
RAINFOREST COUNTRIES PLEDGE END TO DEFORESTATION
FORMULA AGREED FOR FUNDING GREEN CLIMATE FUND

WE CHOOSE TO GO TO THE MOON. WE CHOOSE TO GO TO THE MOON IN THIS DECADE AND DO THE OTHER THINGS, NOT BECAUSE THEY ARE EASY, BUT BECAUSE THEY ARE HARD, BECAUSE THAT GOAL WILL SERVE TO ORGANIZE AND MEASURE THE BEST OF OUR ENERGIES AND SKILLS, BECAUSE THAT CHALLENGE IS ONE THAT WE ARE WILLING TO ACCEPT, ONE WE ARE UNWILLING TO POSTPONE, AND ONE WHICH WE INTEND TO WIN, AND THE OTHERS, TOO.

JFK, RICE UNIVERSITY, SEPTEMBER 1962