Beyond Paris: The Electricity Industry and the Accelerated Momentum of Climate Policy

IEA ELECTRICITY SECURITY ADVISORY PANEL PLENARY

Melanie Kenderdine, U.S. Department of Energy

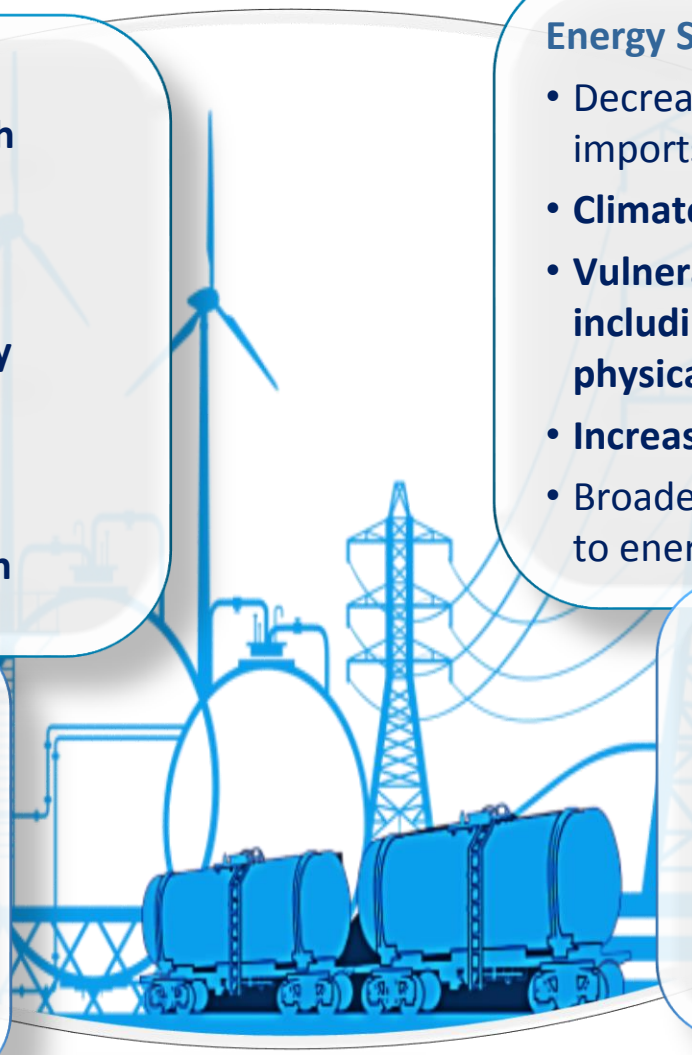
Paris, France

June 23, 2016

Discussion

- US Trends
- Quadrennial Energy Review
- A Few Global Data Points
- Climate Change, Paris and Innovation
- Examples: Global Innovation Needs
- Analyzing the Emissions Reduction Value of Innovation

Changing Energy Landscape in the United States



Supply/Demand

- **Natural gas production growth**
- **Oil production growth**
- **Intermittent renewables cost reductions**
- **Distributed generation/energy resources**
- **Increased efficiency**
- **Low electric load growth**
- **Natural gas generation growth**

Energy Security

- Decreased N. American energy imports
- **Climate change impacts**
- **Vulnerabilities more evident, including aging infrastructures, physical and cyber threats**
- **Increased interdependencies**
- Broader more collective approach to energy security

Policy Developments

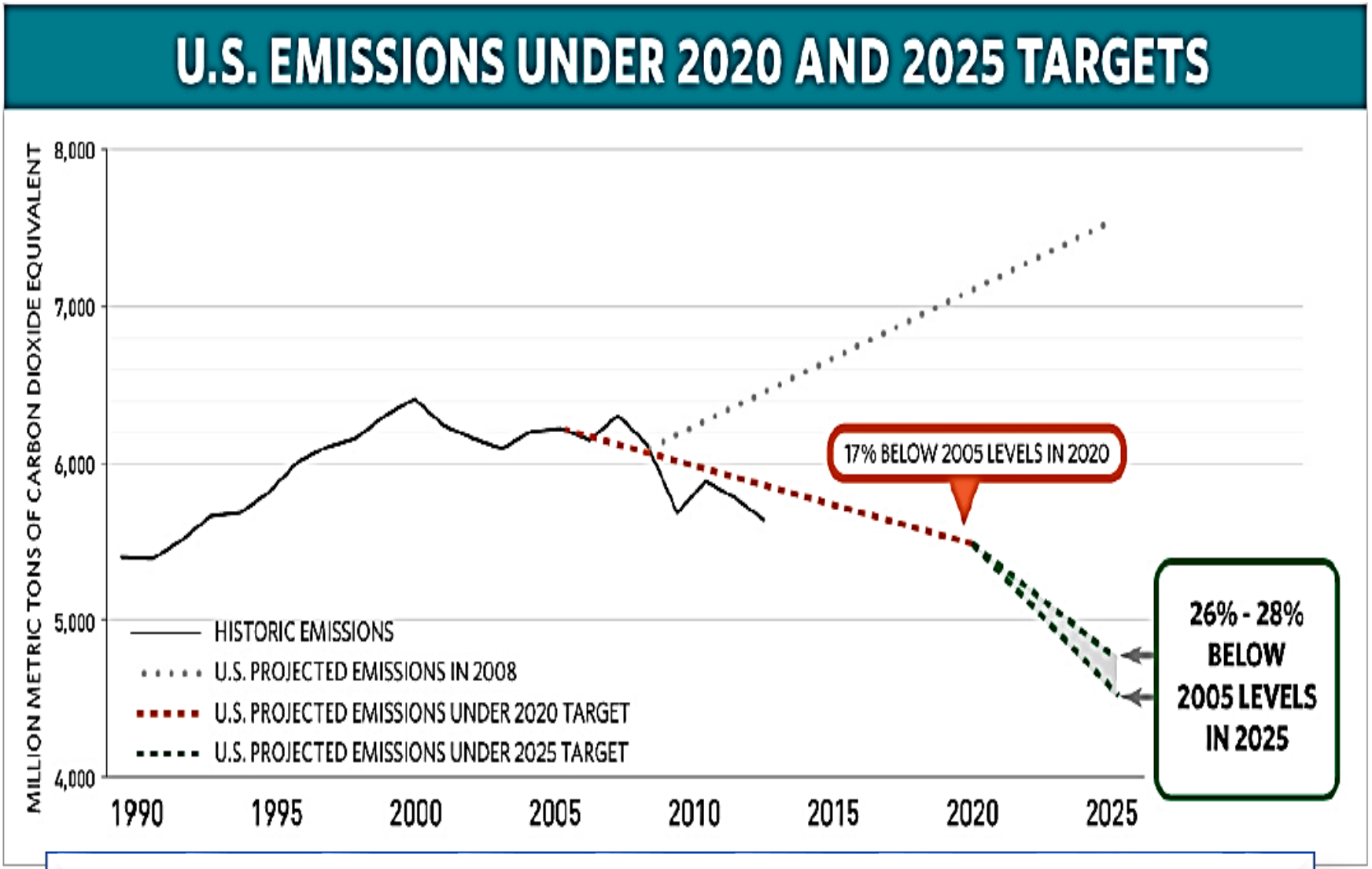
- CAFÉ
- **Clean Air Act -111 (d), other**
- Clean Water Act/other
- Oil and gas exports
- **RPS (state)**
- **Extension PTC/ITC**
- SPR modernization

Technology Advances

- **Solar (central and rooftop)**
- **Wind**
- **Demand-side technologies**
- **CCS**
- **Hydraulic fracturing**
- **Storage**

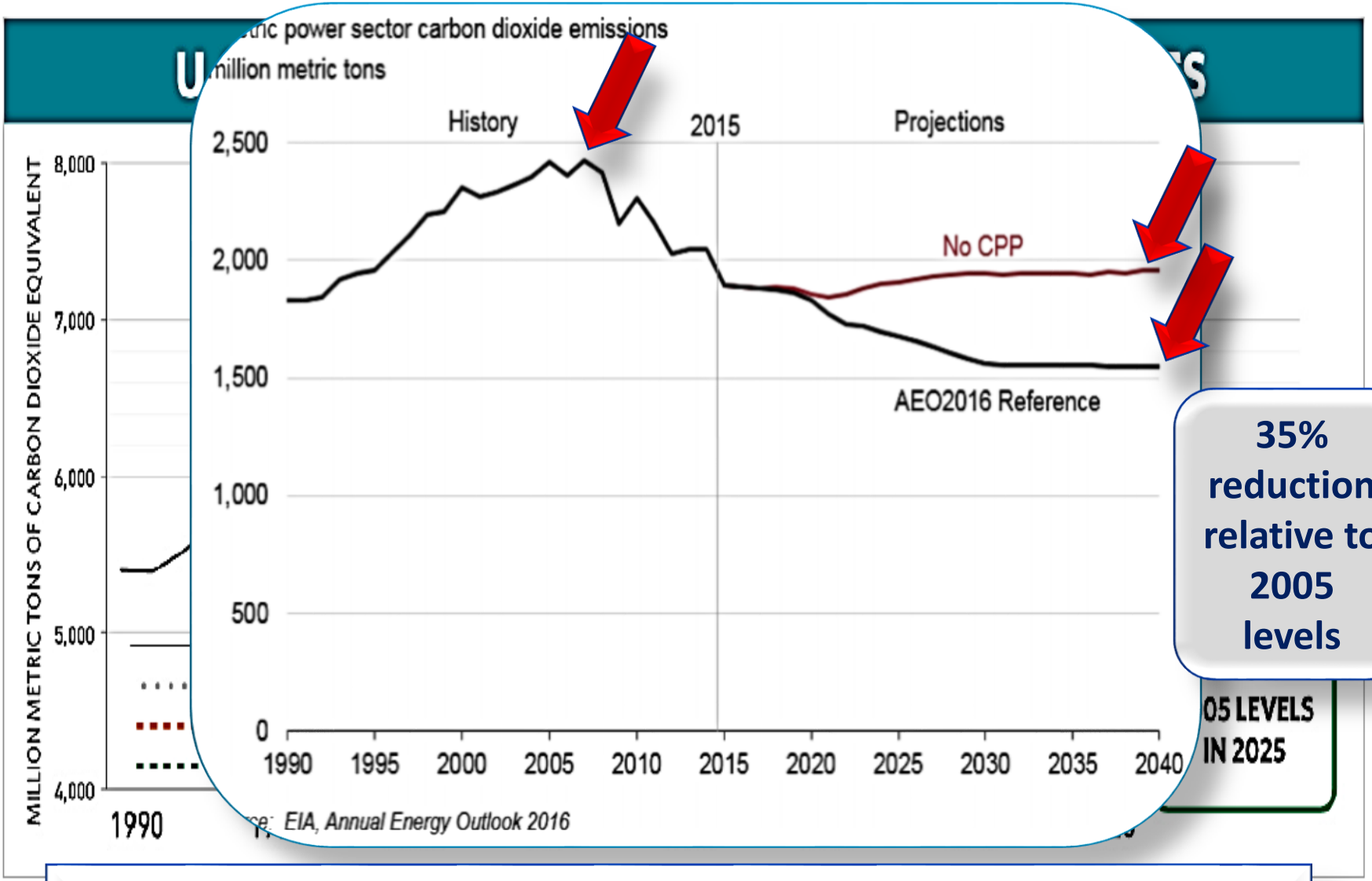
US Energy Trends/Changes

US on Pathway for Significant Reductions in Power Sector GHG Emissions



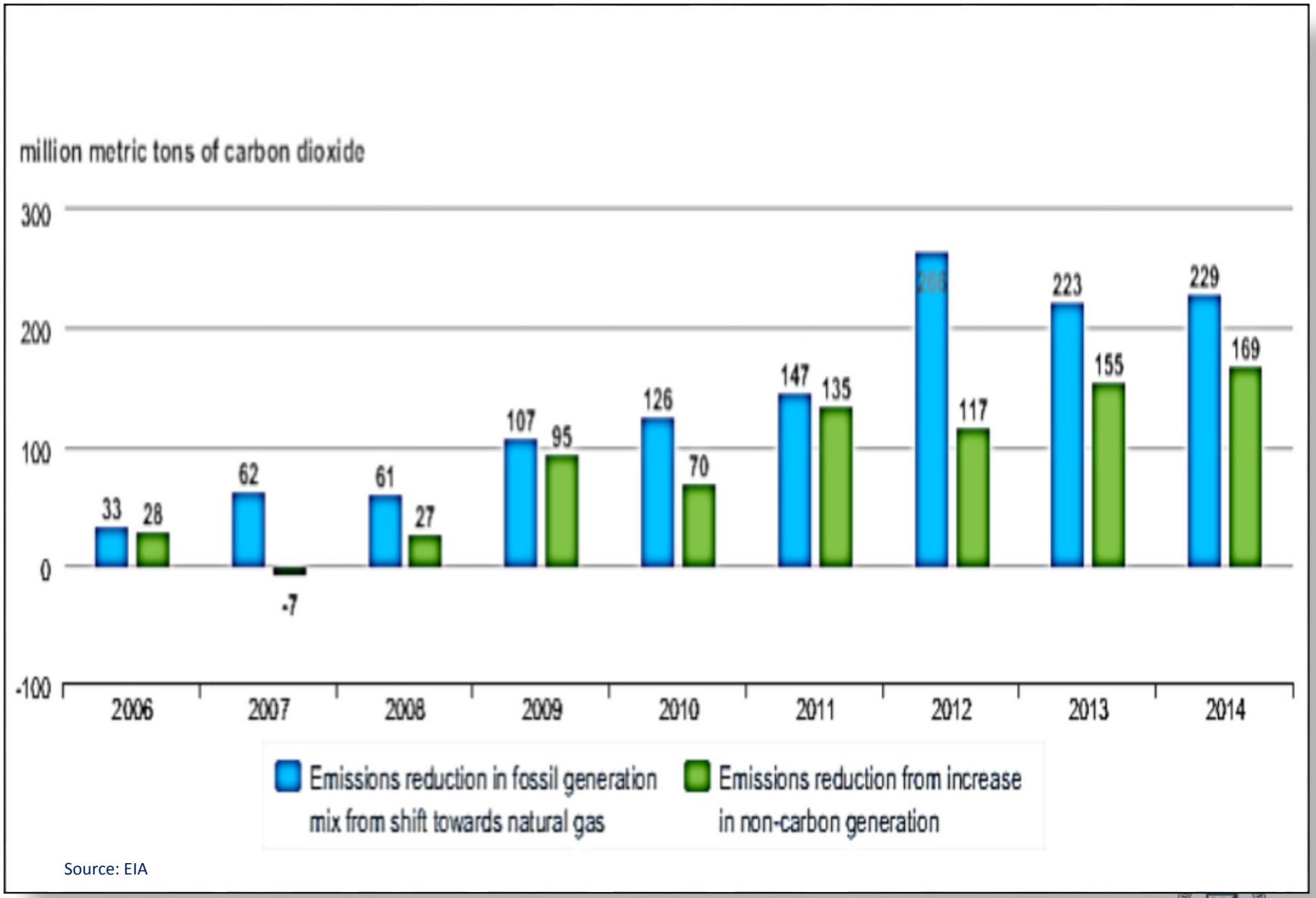
A continuation and acceleration of these trends, in addition to other existing policies and measures, will help the U.S. achieve the goals outlined in its nationally determined contribution to the UNFCCC process.

US on Pathway for Significant Reductions in Power Sector GHG Emissions



A continuation and acceleration of these trends, in addition to other existing policies and measures, will help the U.S. achieve the goals outlined in its nationally determined contribution to the UNFCCC process.

Fuel Switching And CO_2 Emissions Reductions



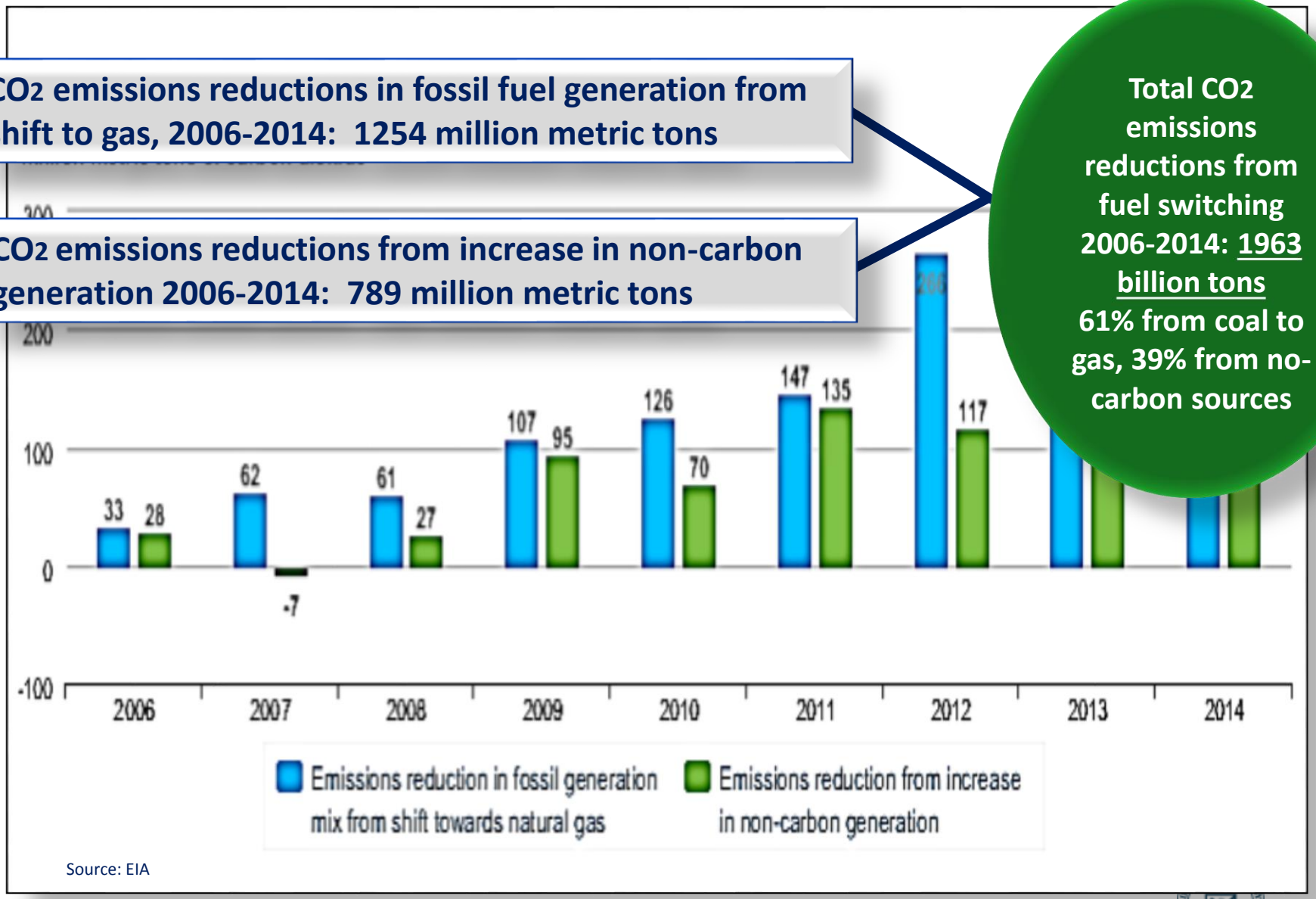
Source: EIA

Fuel Switching And CO_2 Emissions Reductions

CO_2 emissions reductions in fossil fuel generation from shift to gas, 2006-2014: 1254 million metric tons

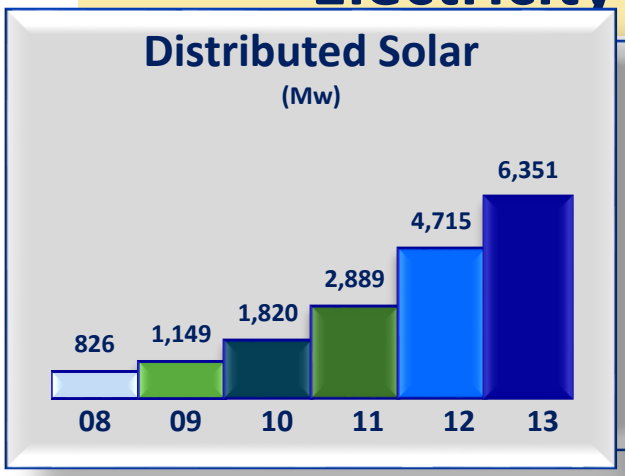
CO_2 emissions reductions from increase in non-carbon generation 2006-2014: 789 million metric tons

Total CO_2 emissions reductions from fuel switching 2006-2014: 1963 billion tons
61% from coal to gas, 39% from no-carbon sources

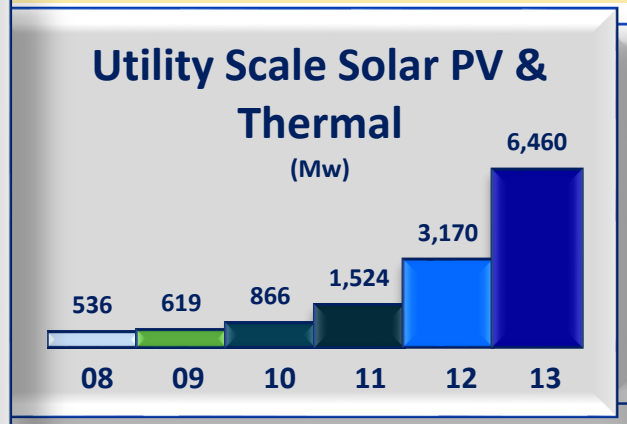


Source: EIA

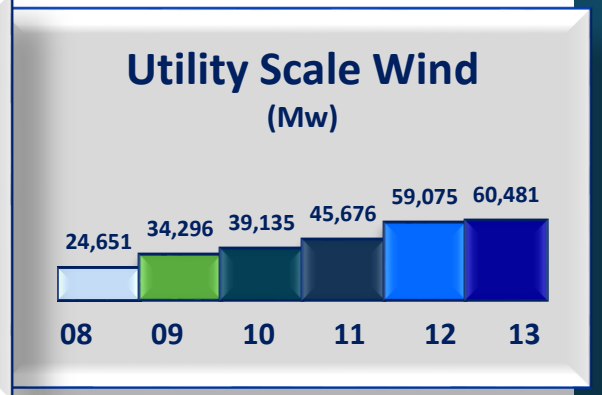
Renewables Capacity Increasing, Costs Declining, Electricity Demand Flat or Decreasing



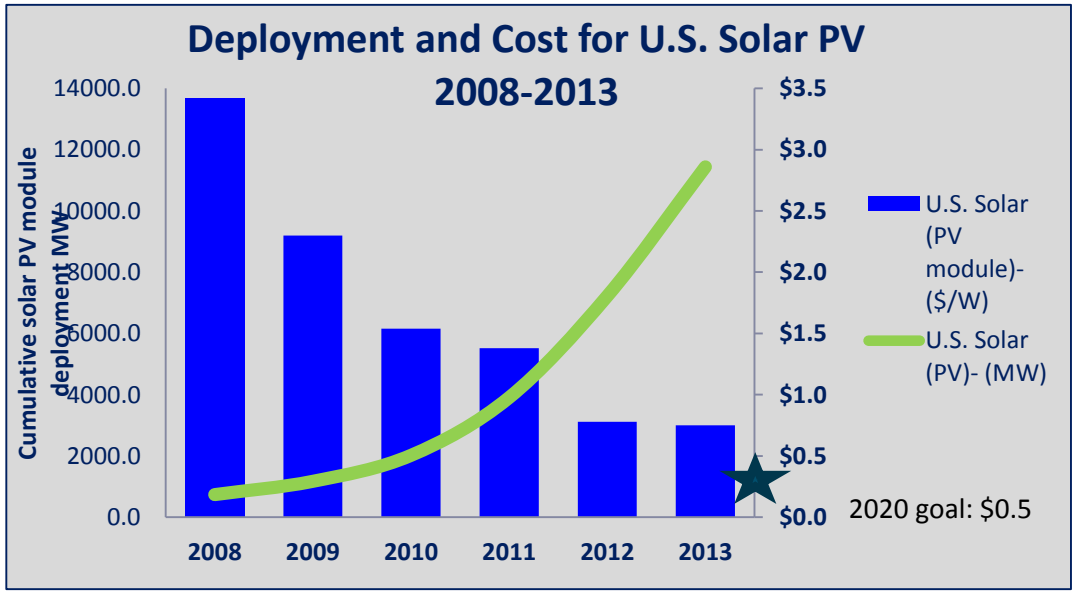
Distributed Solar, 2008-2013 :
769 % increase in capacity



Utility Scale Solar, 2008-2013 :
1200 % increase in capacity



Utility Scale Wind, 2008-2013 :
245 % increase in capacity



Sources: Department of Energy, Office of Energy Efficiency and Renewable Energy analysis, GTM, SEIA, LBNL, NREL

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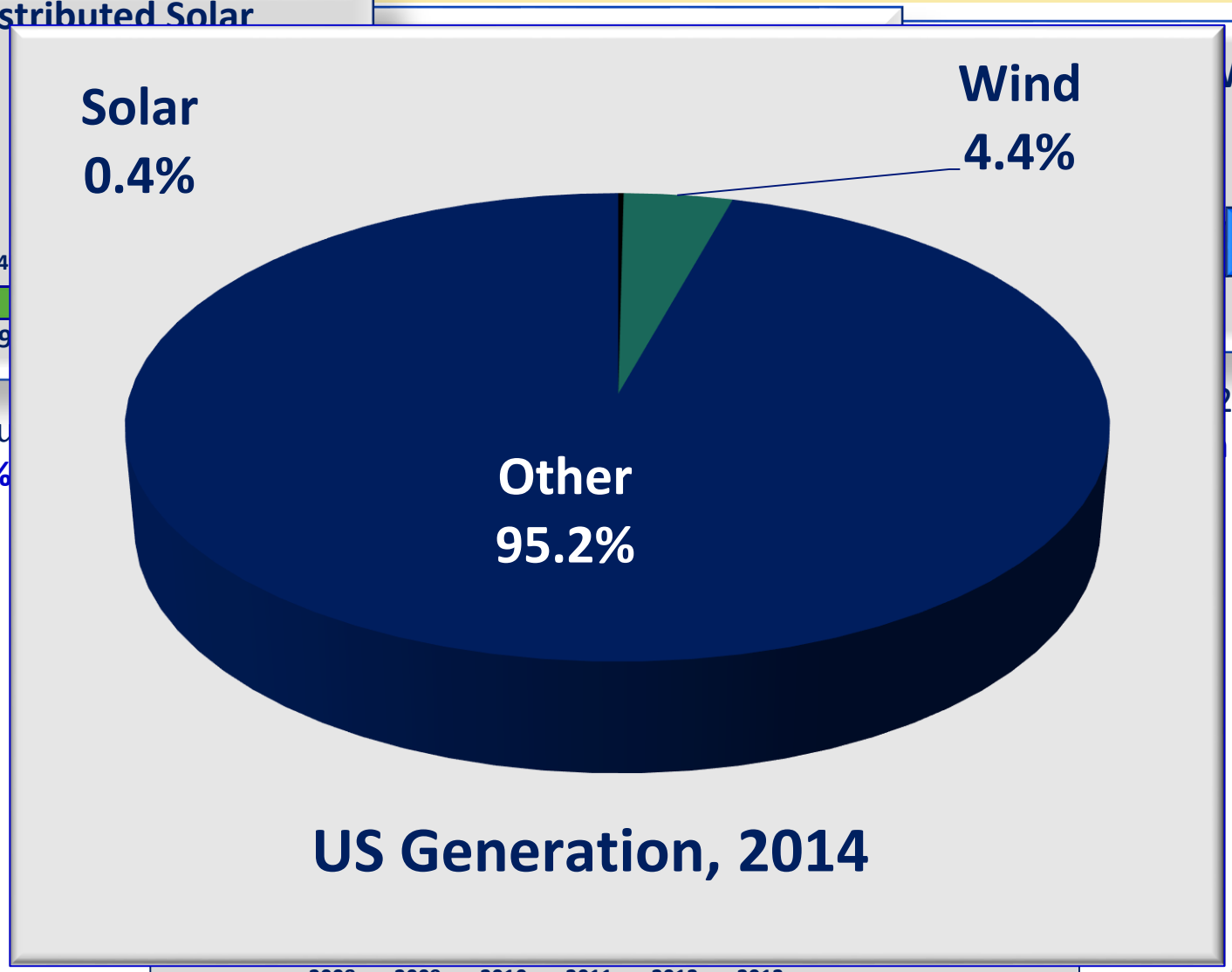

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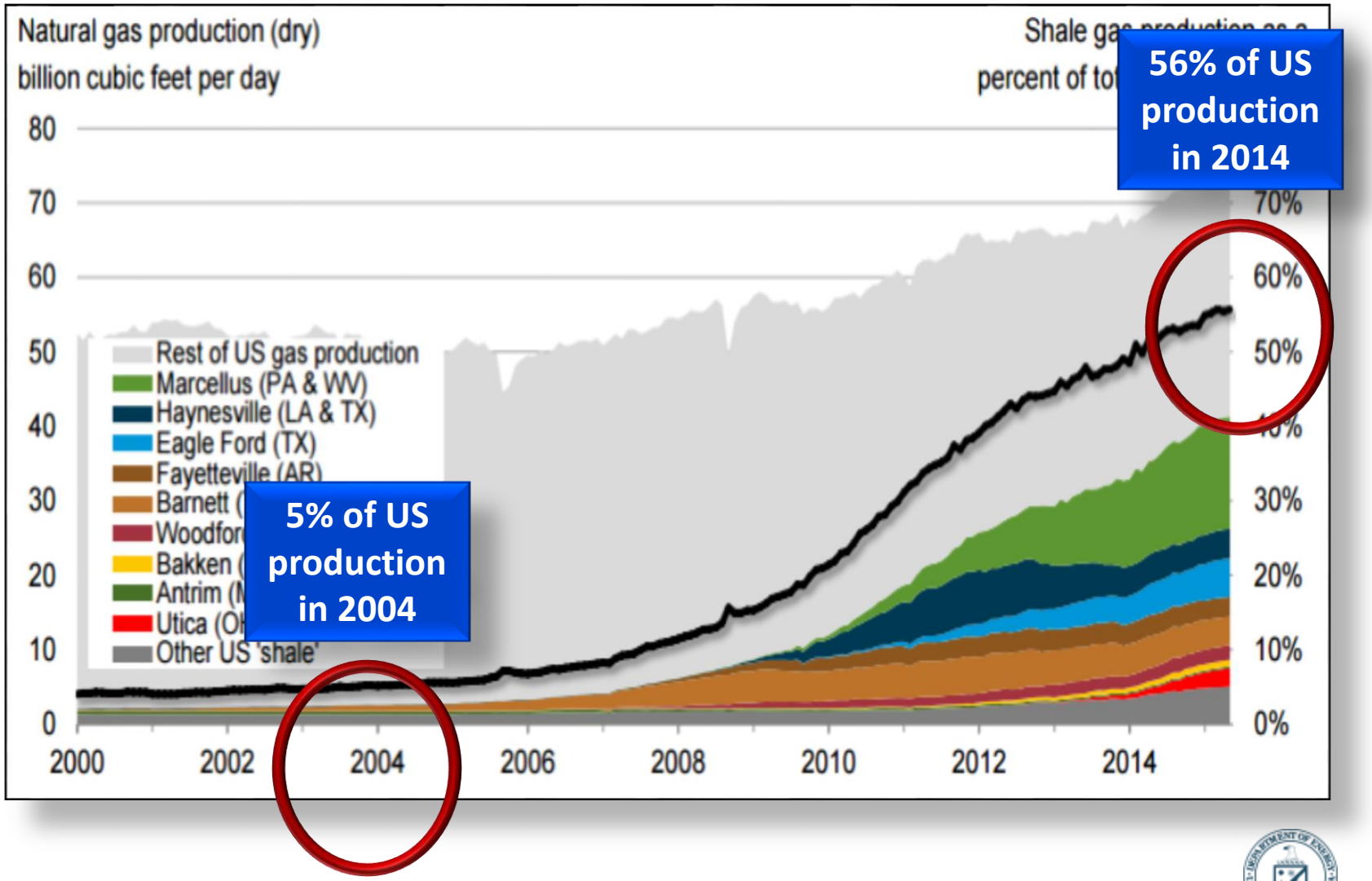
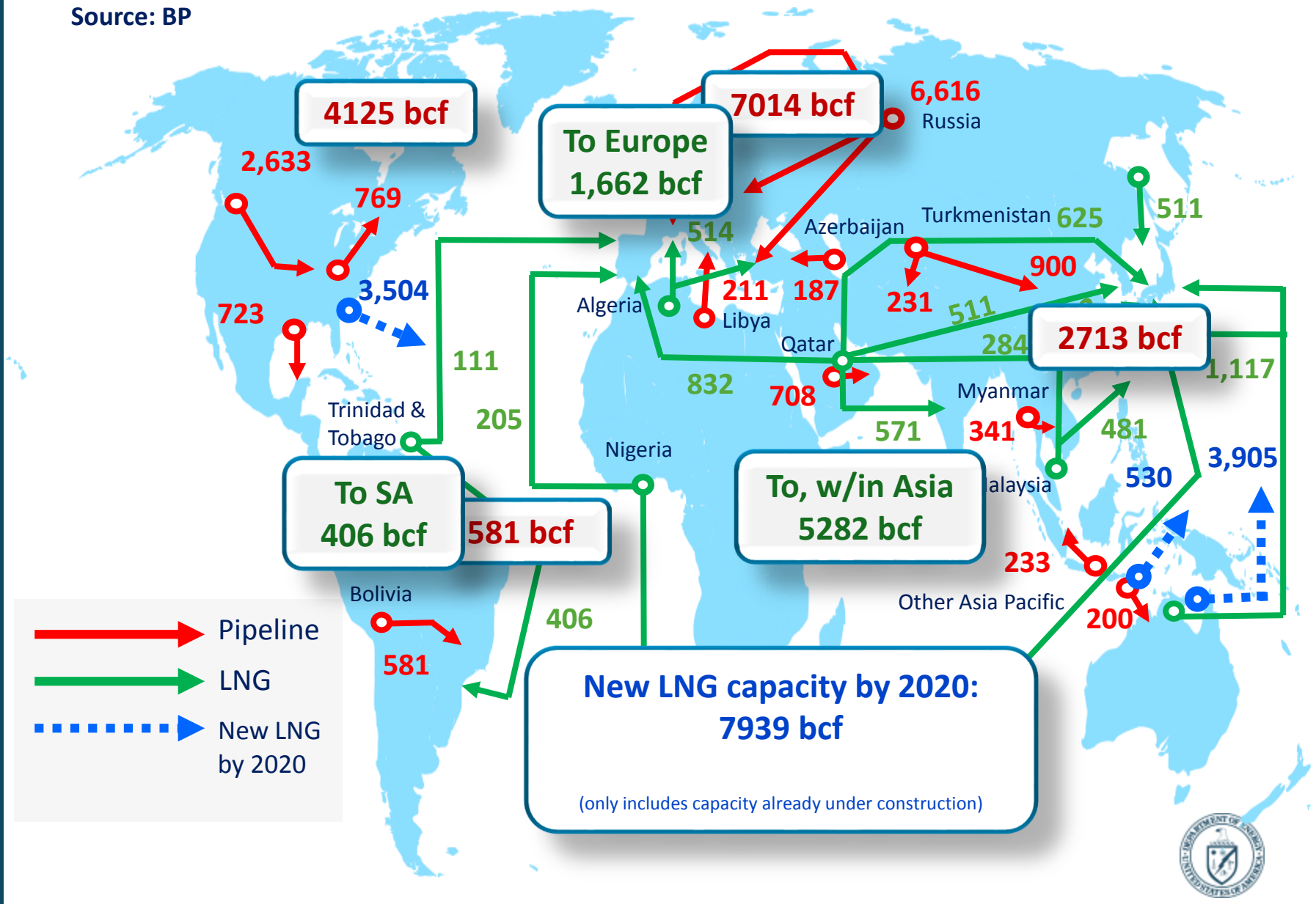
US Shale Gas Production Has Changed Energy Profile



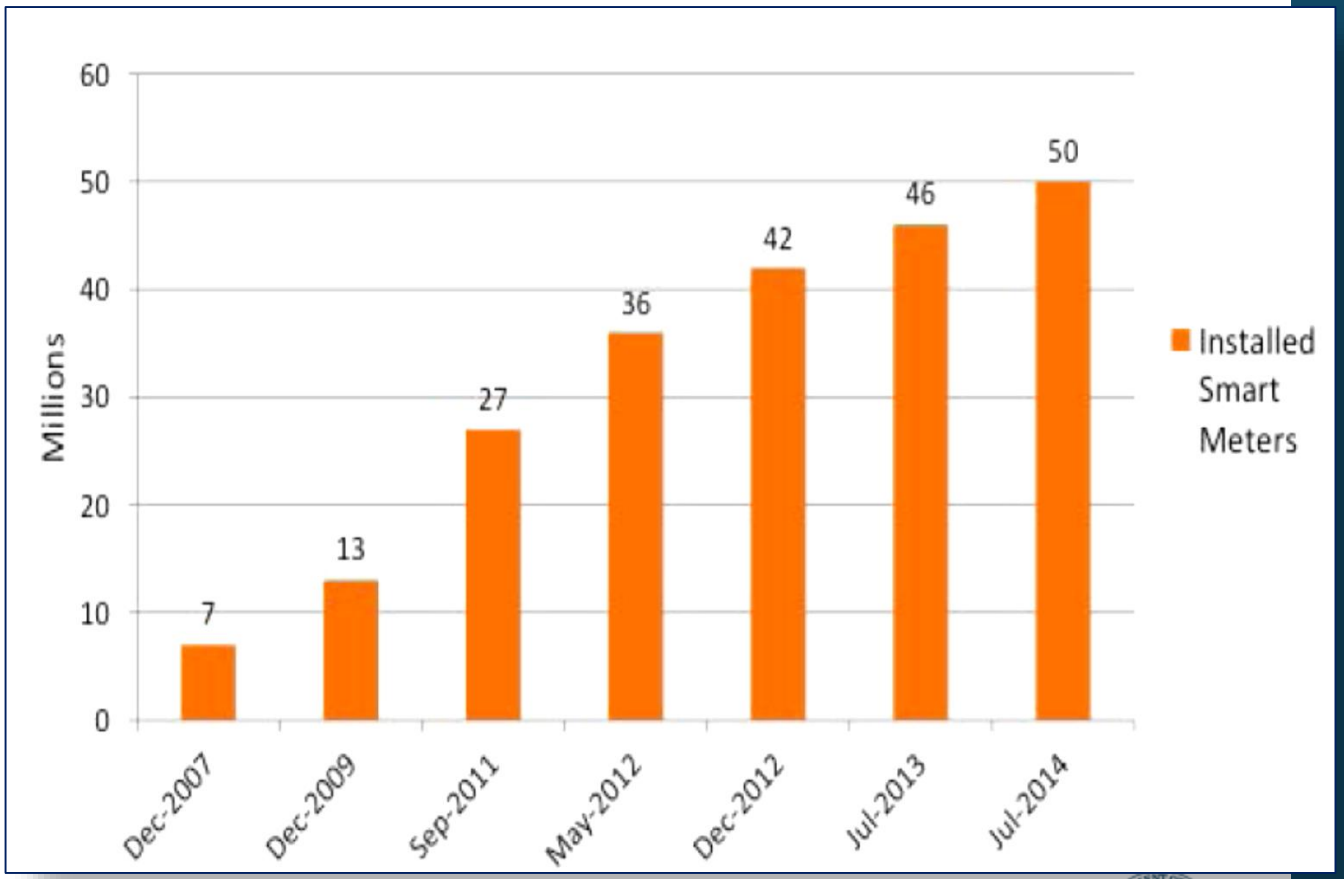
Source: EIA

Significant New LNG Export Capacity By 2020

(Billion Cubic Feet)



Installed Smart Meters: 50 Million US Homes



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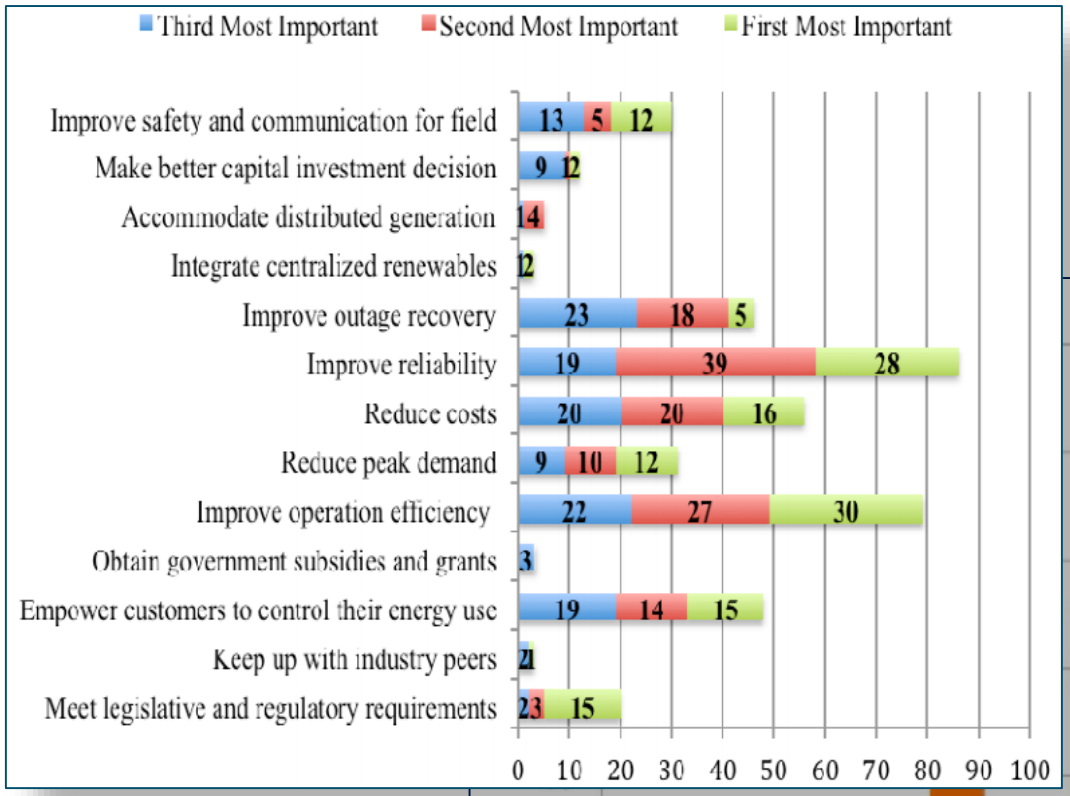
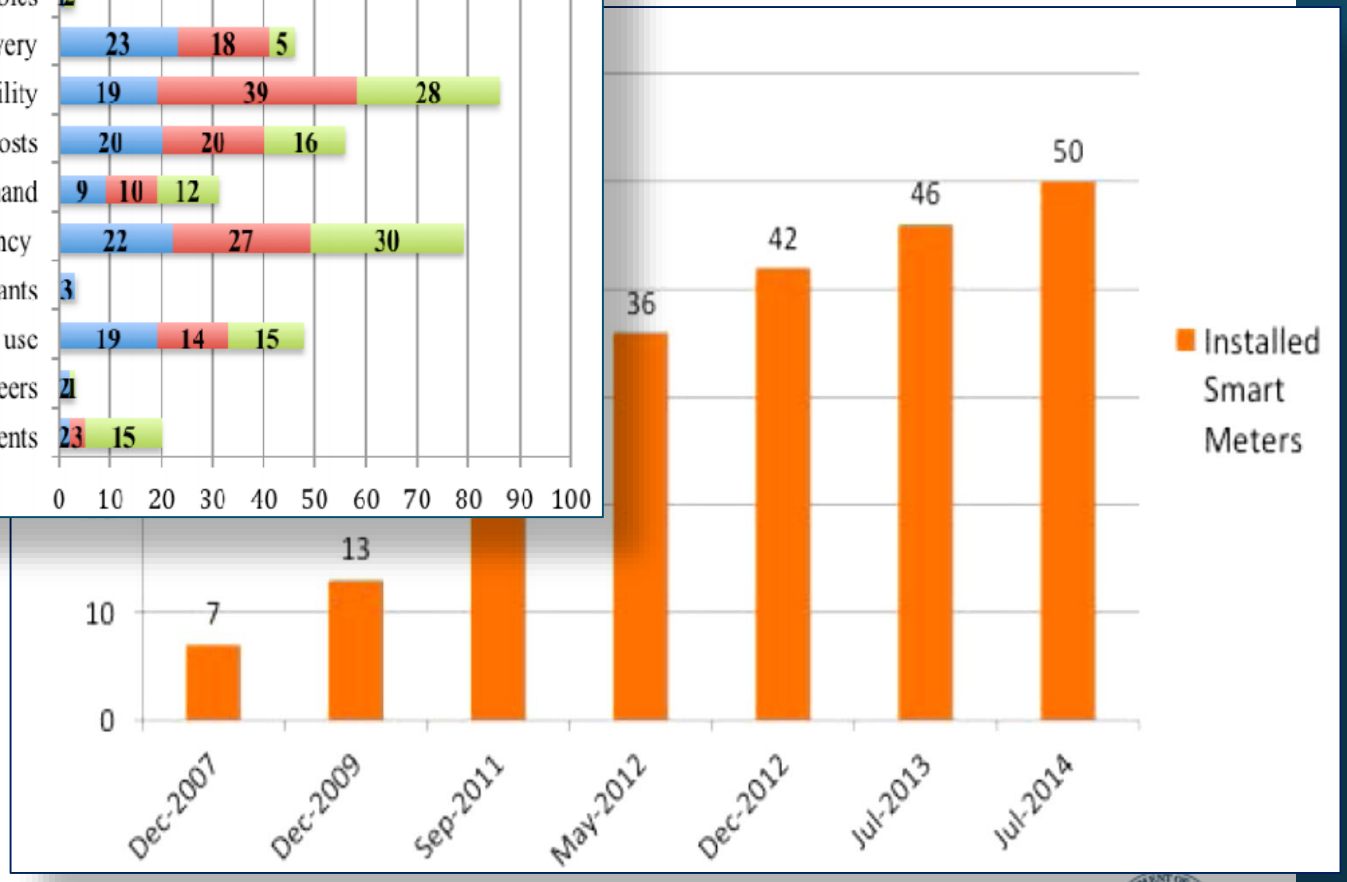




On the Electric Grid and National & Energy Security

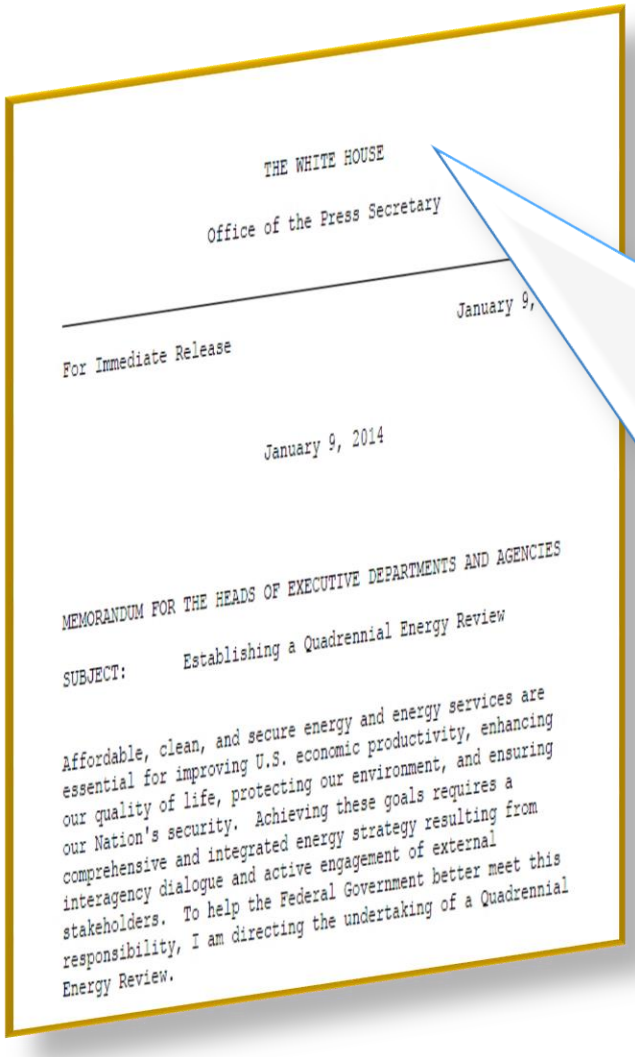
Admiral Mike Rogers, NSA Director, before the House Select Intelligence Committee, 11/14, Cyber-threats: The Way Forward –

"There shouldn't be any doubt in our minds that there are groups out there that have the capability to shut down, forestall our ability to operate our basic infrastructure whether it's generating power, or moving water or fuel."

The Center for Naval Analysis, in November, 2015 --

"Reliable electricity underpins every facet of our lives. The design of the grid and its inherent vulnerabilities, are known to our enemies, foreign and domestic."

President Obama Directs the QER



THE WHITE HOUSE

Office of the Press Secretary

January 9,

For Immediate Release

January 9, 2014

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

SUBJECT: Establishing a Quadrennial Energy Review

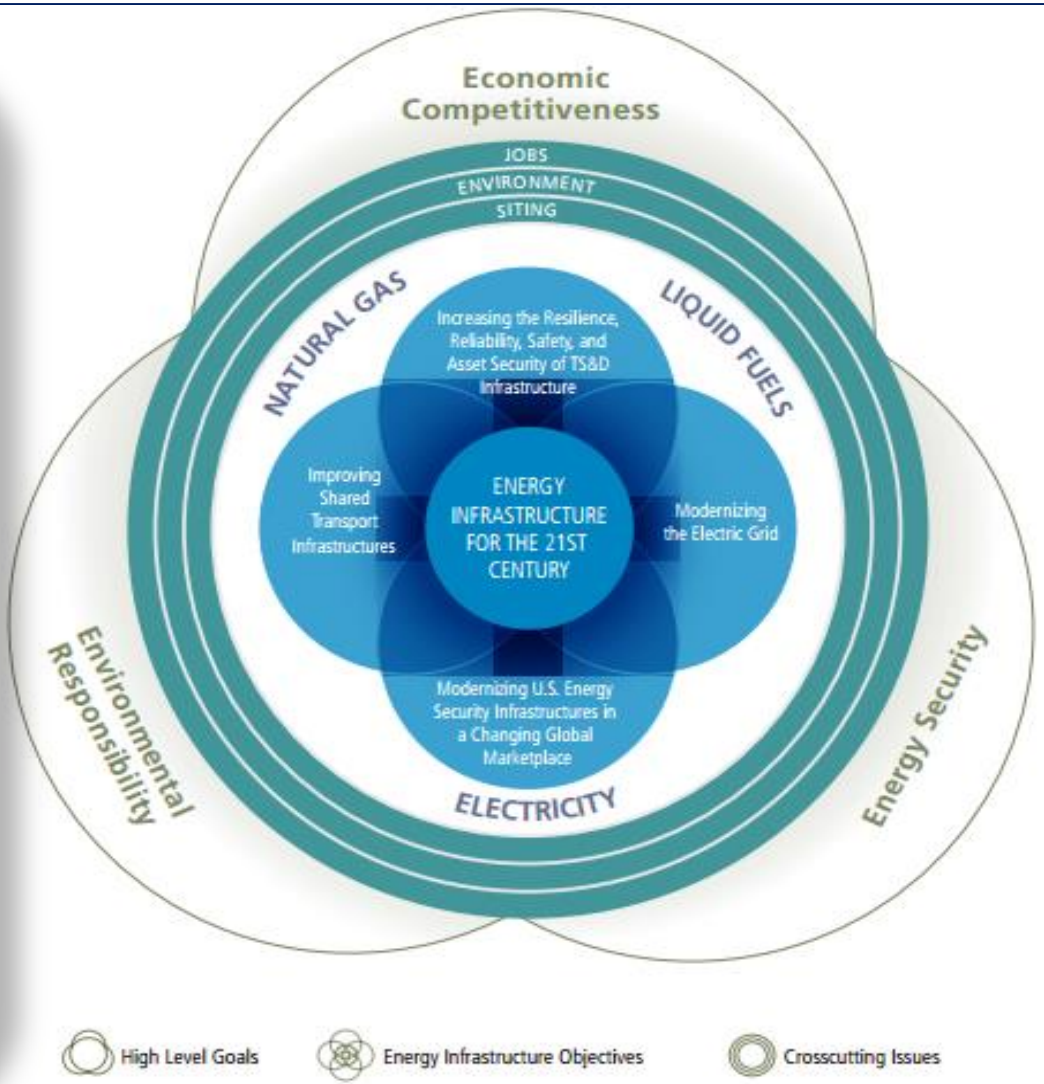
Affordable, clean, and secure energy and energy services are essential for improving U.S. economic productivity, enhancing our quality of life, protecting our environment, and ensuring our Nation's security. Achieving these goals requires a comprehensive and integrated energy strategy resulting from interagency dialogue and active engagement of external stakeholders. To help the Federal Government better meet this responsibility, I am directing the undertaking of a Quadrennial Energy Review.

- January 2014 Presidential Memorandum established the Quadrennial Energy Review
- White House Domestic Policy Council and Office of Science and Technology Policy co-chair a QER Task Force comprised of 22 Federal agencies
- The Department of Energy serves as the Secretariat of the Task Force
- **Enables the Federal government to translate policy goals into a set of analytically based, integrated actions**
- First installment released by Vice President Biden and Secretary Moniz in April 2015

QER 1.1: TS&D Infrastructure

The first installment of the QER analyzed transmission, storage, and distribution infrastructure (TS&D) and focused on eight topic areas:

- Increasing resilience, reliability, safety, and asset security
- Modernizing the electric grid
- Modernizing U.S. energy security infrastructures
- Improving shared transport infrastructures
- Integrating North American energy markets
- Addressing environmental aspects of TS&D infrastructure
- Enhancing employment and workforce training
- Siting and permitting of TS&D infrastructure



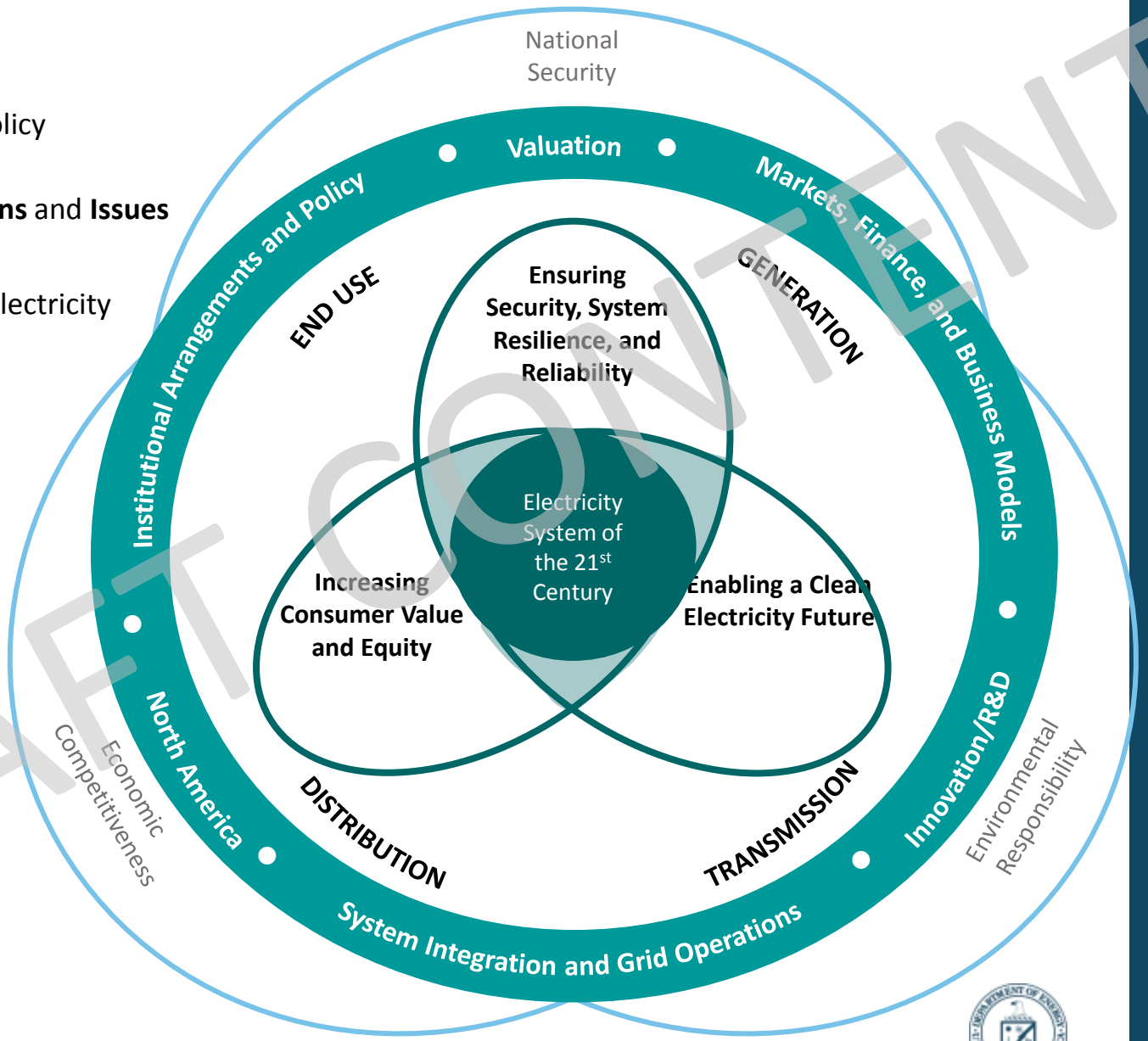
QER 1.2: Electricity from Generation to End Use

High Level **Goals**

Electric System Policy **Objectives**

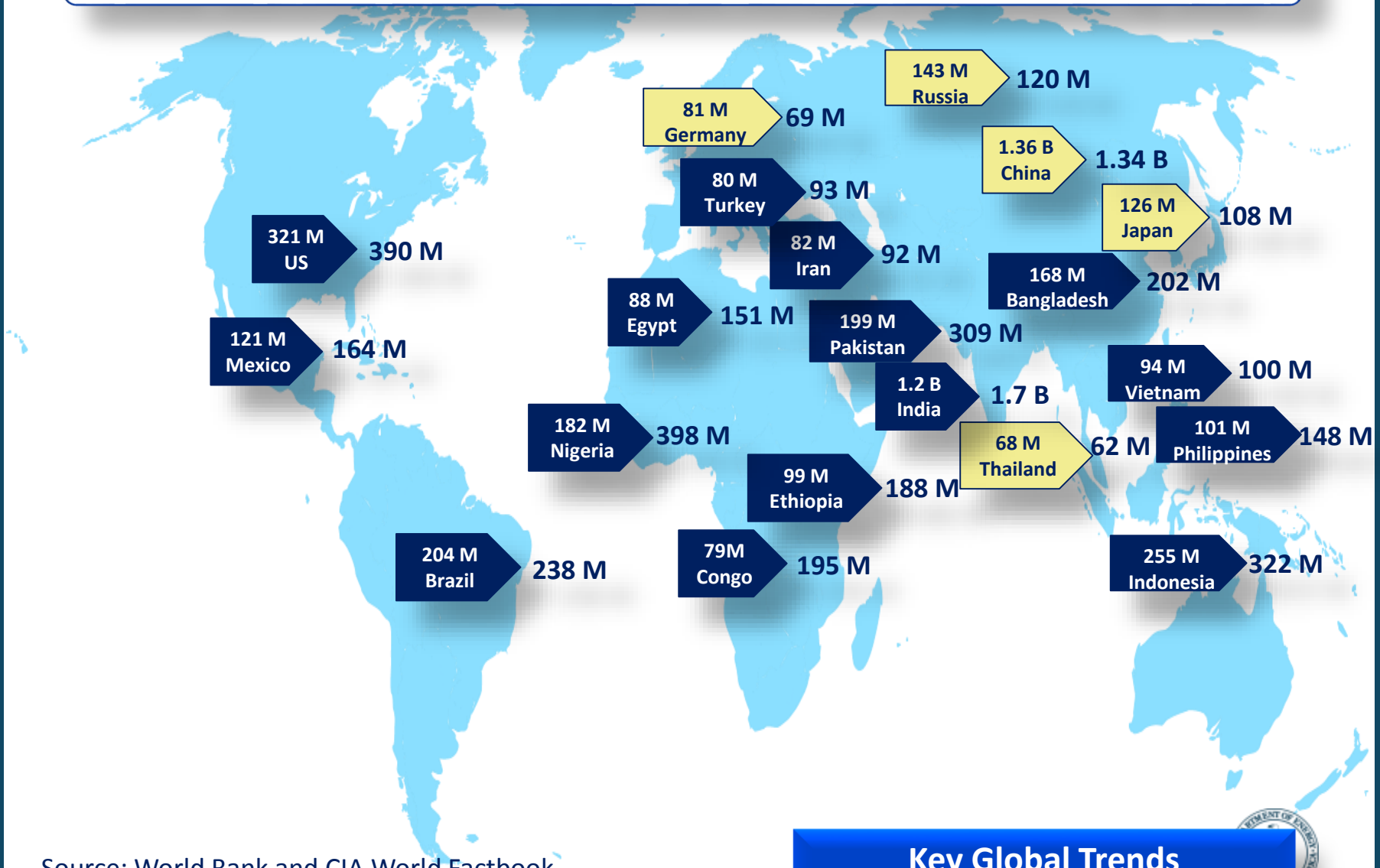
Crosscutting **Means** and **Issues**

Elements of the Electricity System



20 Most Populous Nations in 2015/2050

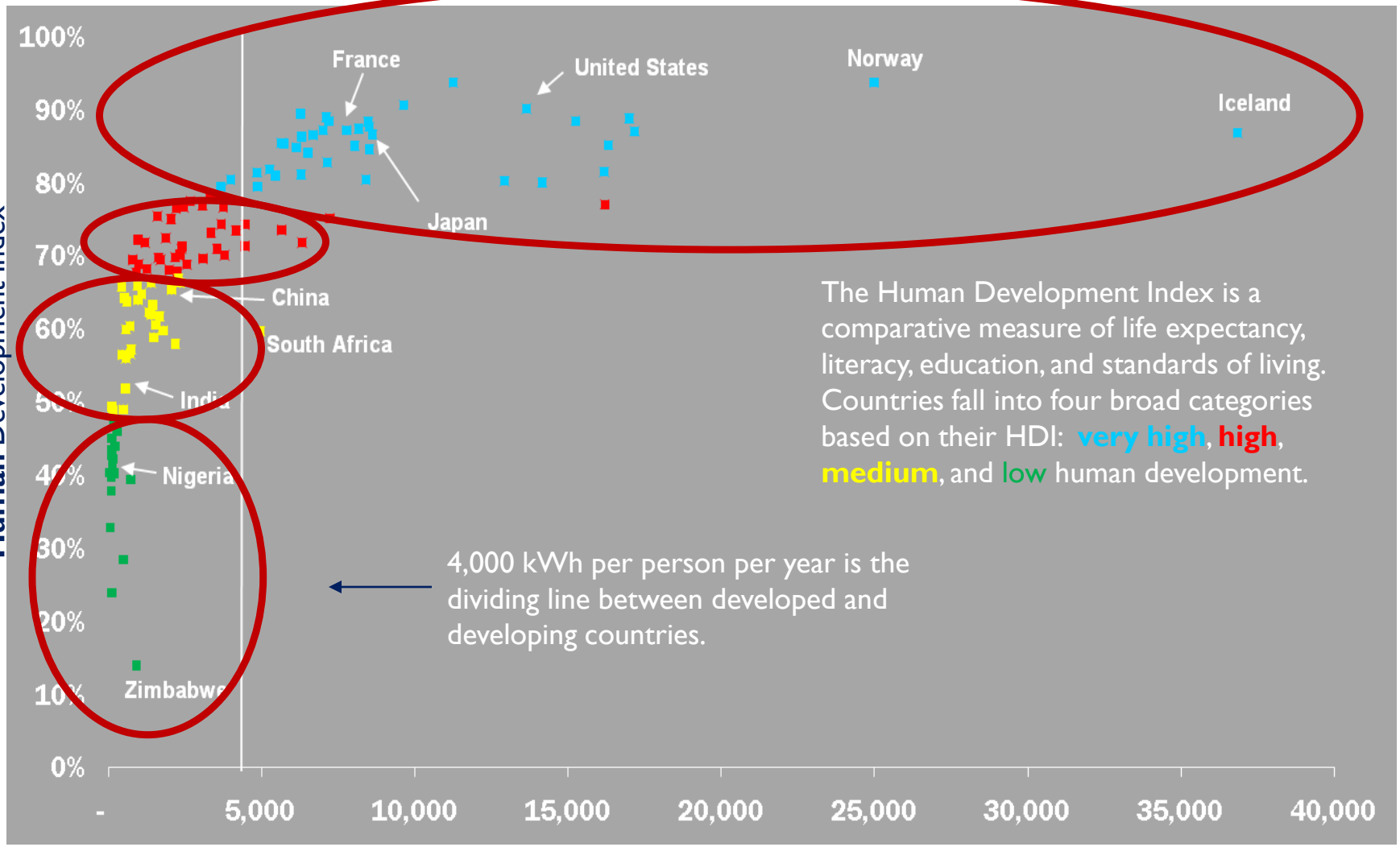
These countries will see a 24 percent increase in population by 2050



Source: World Bank and CIA World Factbook

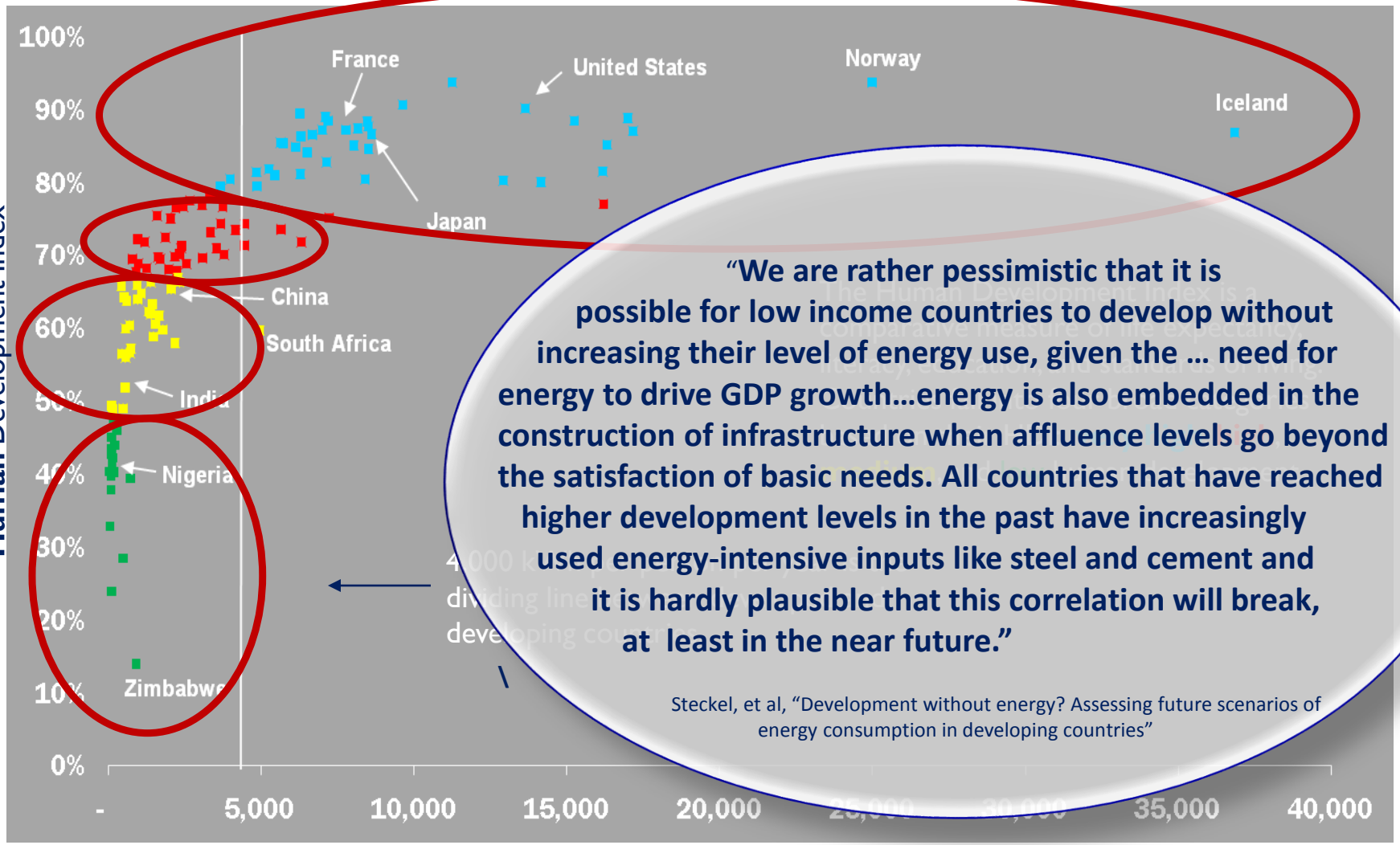
Key Global Trends

Annual Per Capita Electricity Consumption



Source: Human Development Index – 2010 data United Nations; Annual Per Capita Electricity Consumption (kWh) - 2007 data World Bank. Updated: 4/11

Annual Per Capita Electricity Consumption

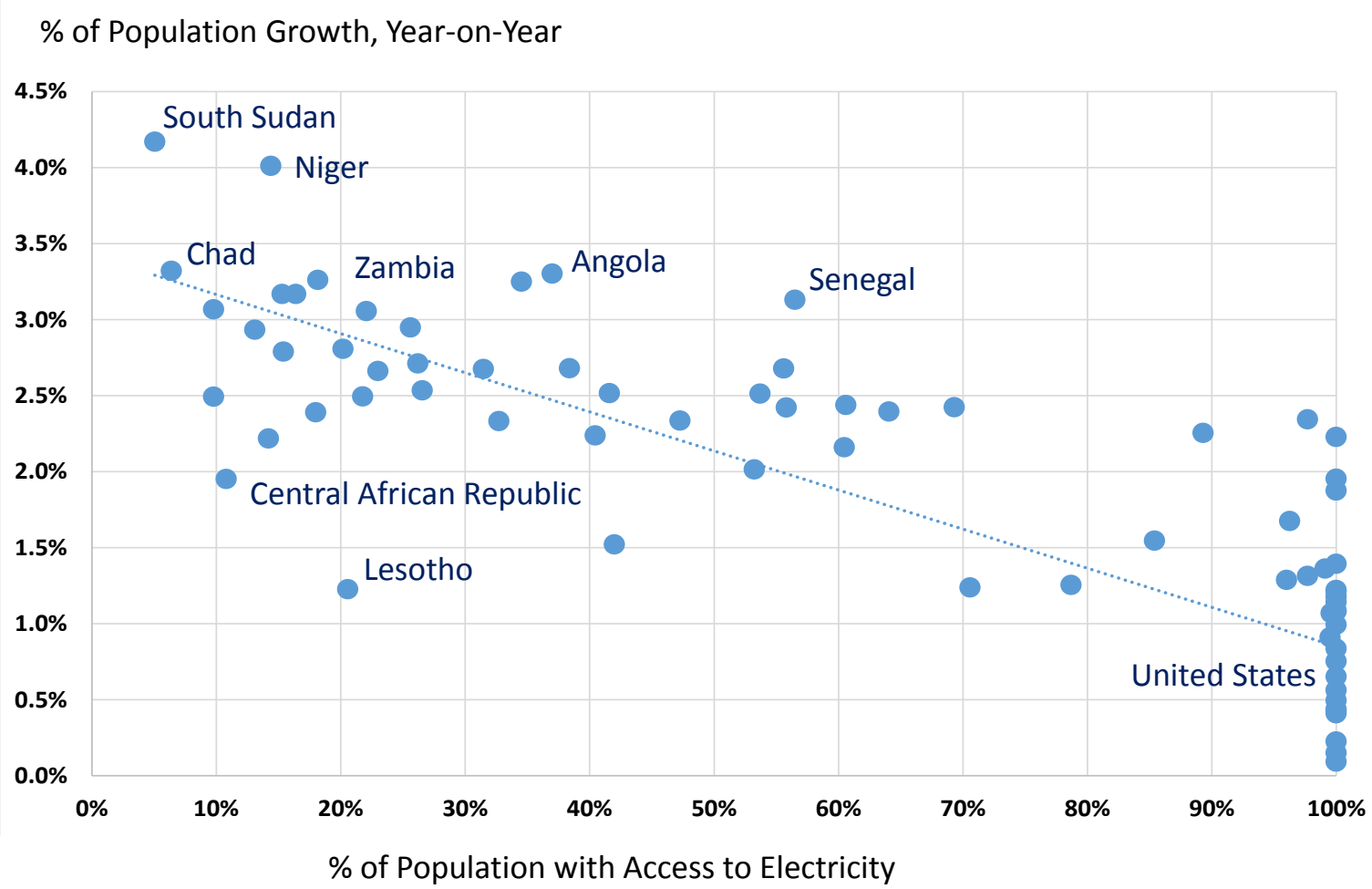


"We are rather pessimistic that it is possible for low income countries to develop without increasing their level of energy use, given the … need for energy to drive GDP growth…energy is also embedded in the construction of infrastructure when affluence levels go beyond the satisfaction of basic needs. All countries that have reached higher development levels in the past have increasingly used energy-intensive inputs like steel and cement and it is hardly plausible that this correlation will break, at least in the near future."

Steckel, et al, "Development without energy? Assessing future scenarios of energy consumption in developing countries"

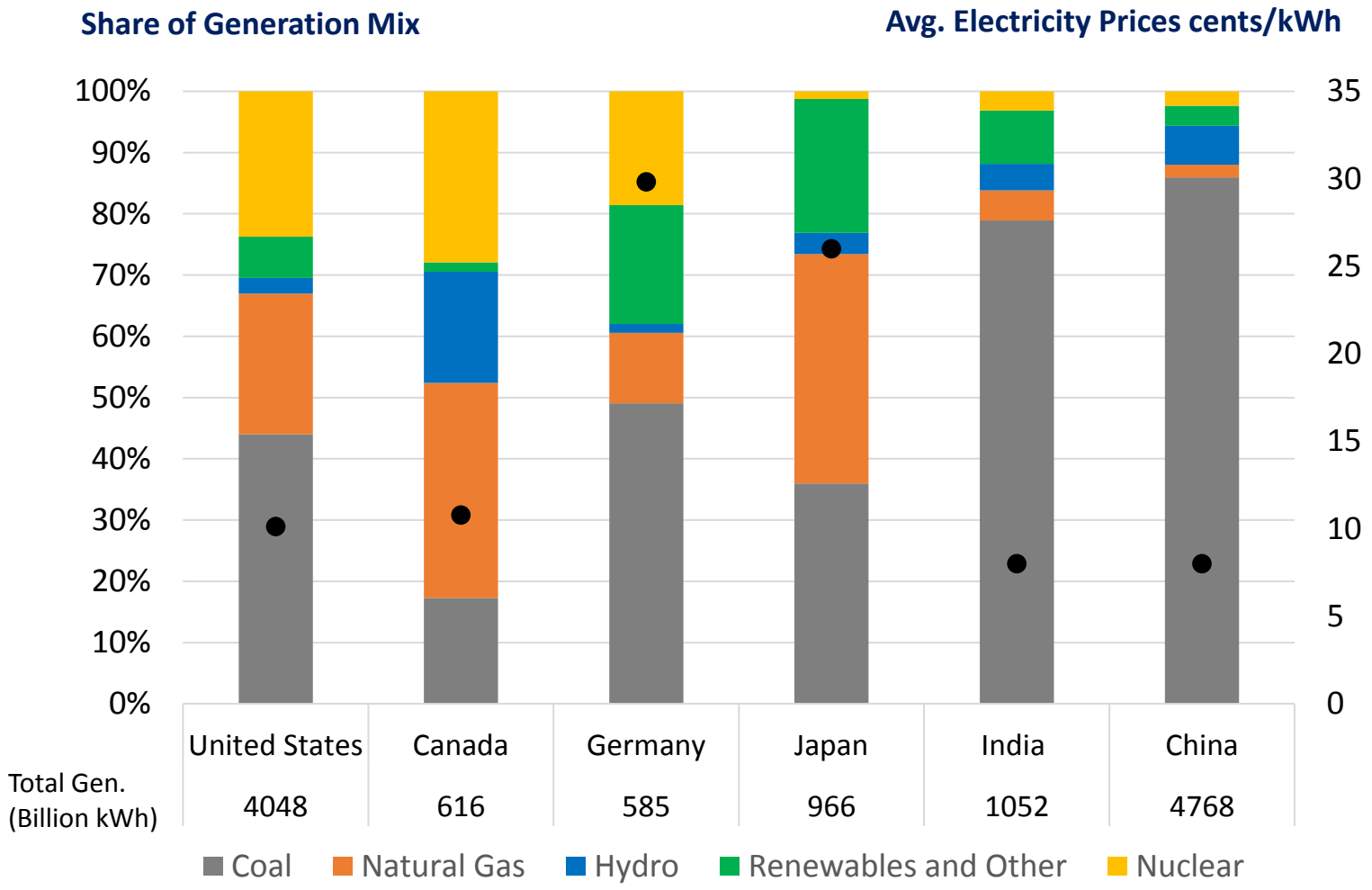
Source: Human Development Index – 2010 data United Nations; Annual Per Capita Electricity Consumption (kWh) - 2007 data World Bank. Updated: 4/11

Populations Growing in Countries with Limited Access to Electricity



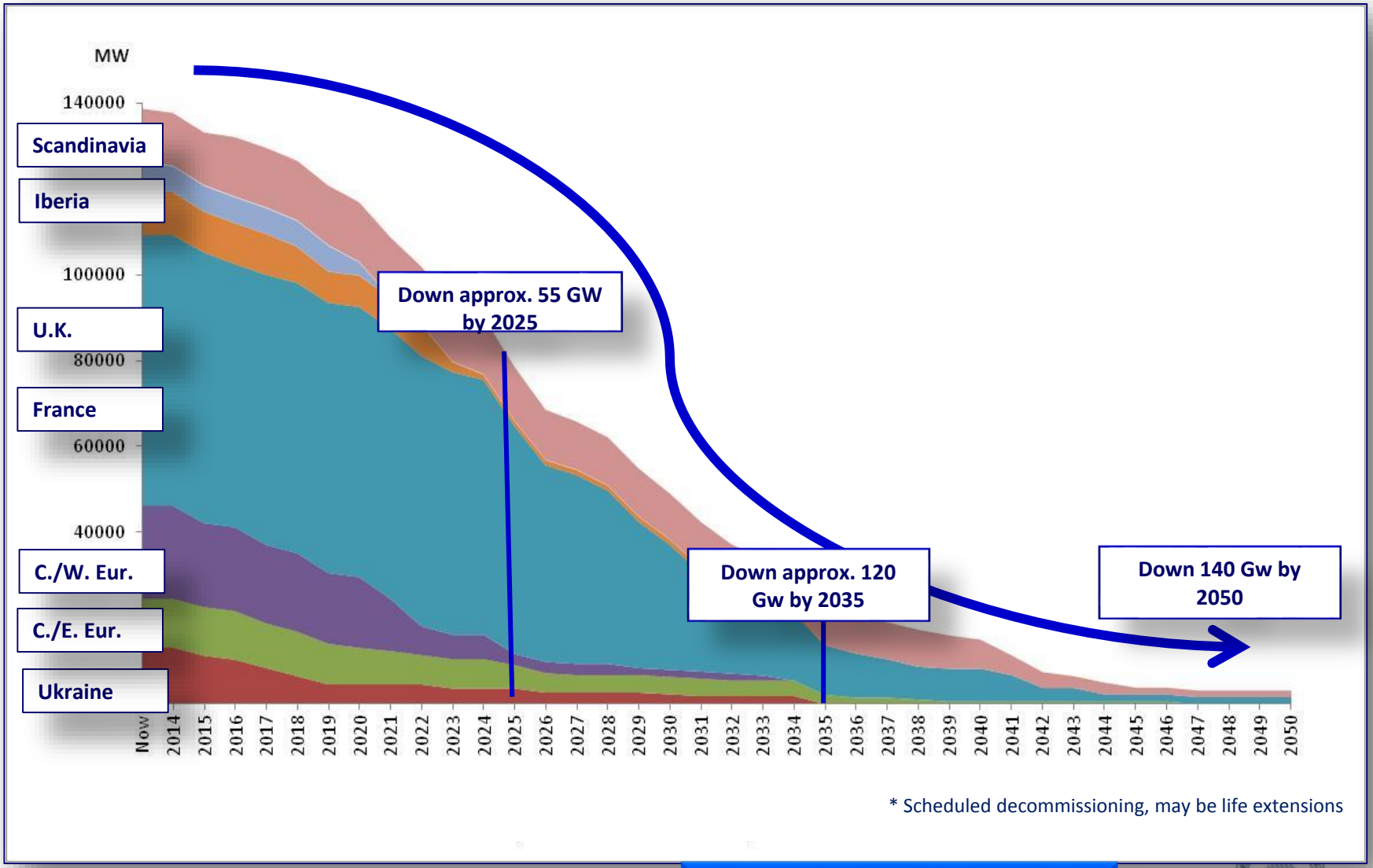
Source: World Bank, 2012 data

Electricity Generation, Select Countries, 2013



Source: LHS: Data from EIA and IEA for 2013; RHS: EIA 2014 (for United States) Eurostat 2014 (for Germany), IEFFA.org 2011 (for India, China, Japan), Electricity.ca 2011 (for Canada)

Decommissioning of Nuclear Plants in Europe: Significant Loss of Carbon-free Generation



* Scheduled decommissioning, may be life extensions

Source: IEA

COP-21 Commitments: Worldwide Driver for Innovation and Clean Energy

India has pledged it would **target 40 percent cumulative installed power capacity from non-fossil fuel sources by 2030** cut the intensity of its carbon emissions by 33 to 35 percent by 2030 from 2005

China aims to achieve a peaking of its CO_2 emissions in 2030. **China also aims to reduce its CO_2 emissions per unit of GDP by 60-65% on 2005 levels by 2030.**

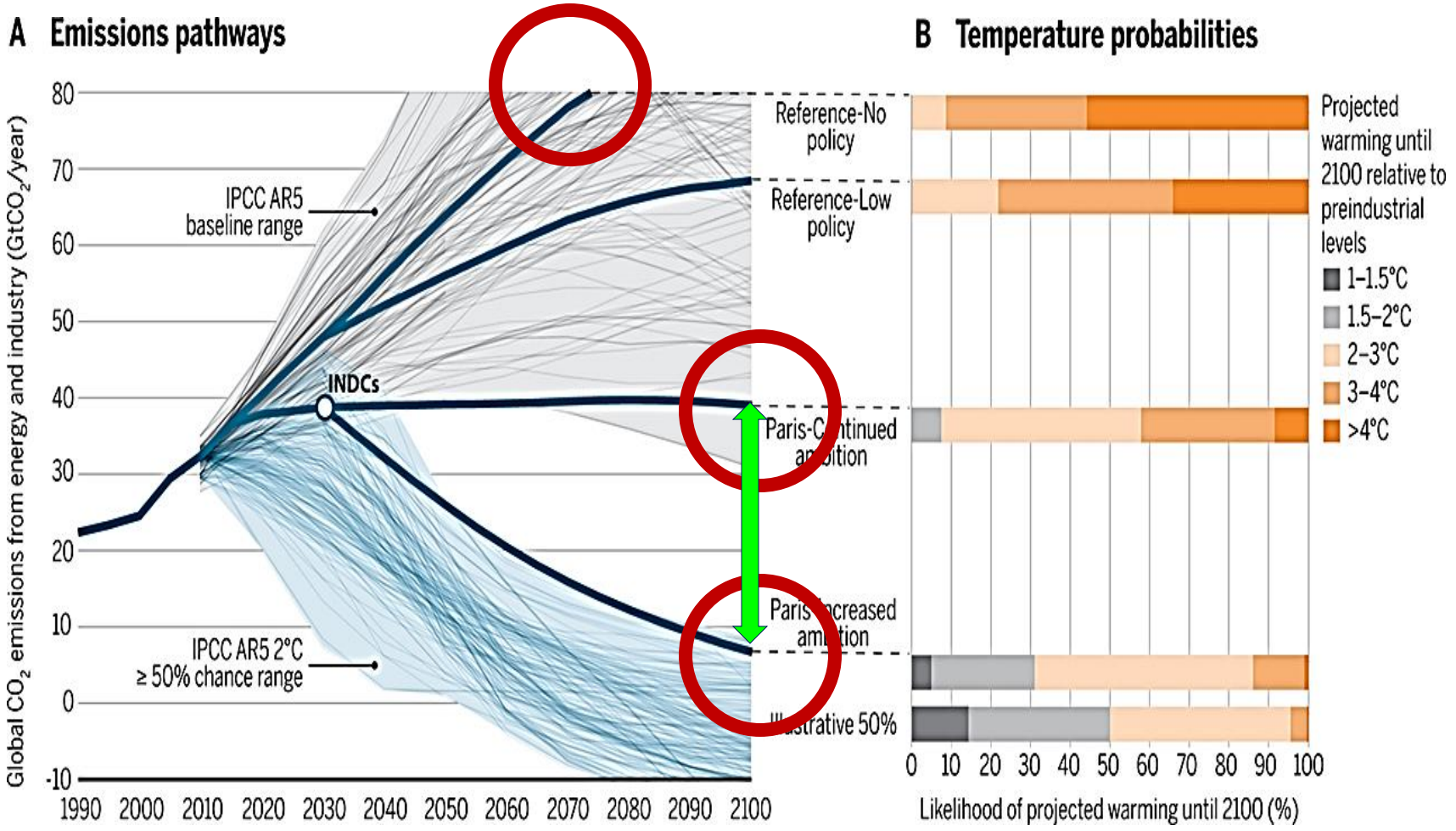
Korea plans to reduce its greenhouse gas emissions by 37% from the business-as-usual (BAU, 850.6 MtCO2eq) **level by 2030 across all economic sectors**.

Japan's INDC, submitted in advance of COP-21 **aims for a 26% reduction of greenhouse gas emissions by 2030 relative to 2013 levels** (ie -18% compared to 1990)

The United States intends to achieve an economy-wide target of reducing its greenhouse gas emissions by 26-28 per cent below its 2005 level in 2025 and to make best efforts to reduce its emissions by 28%.

The EU and its Member States are committed to a binding target of an at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990, to be fulfilled jointly…

Climate Goals/COP 21 Temperature Targets



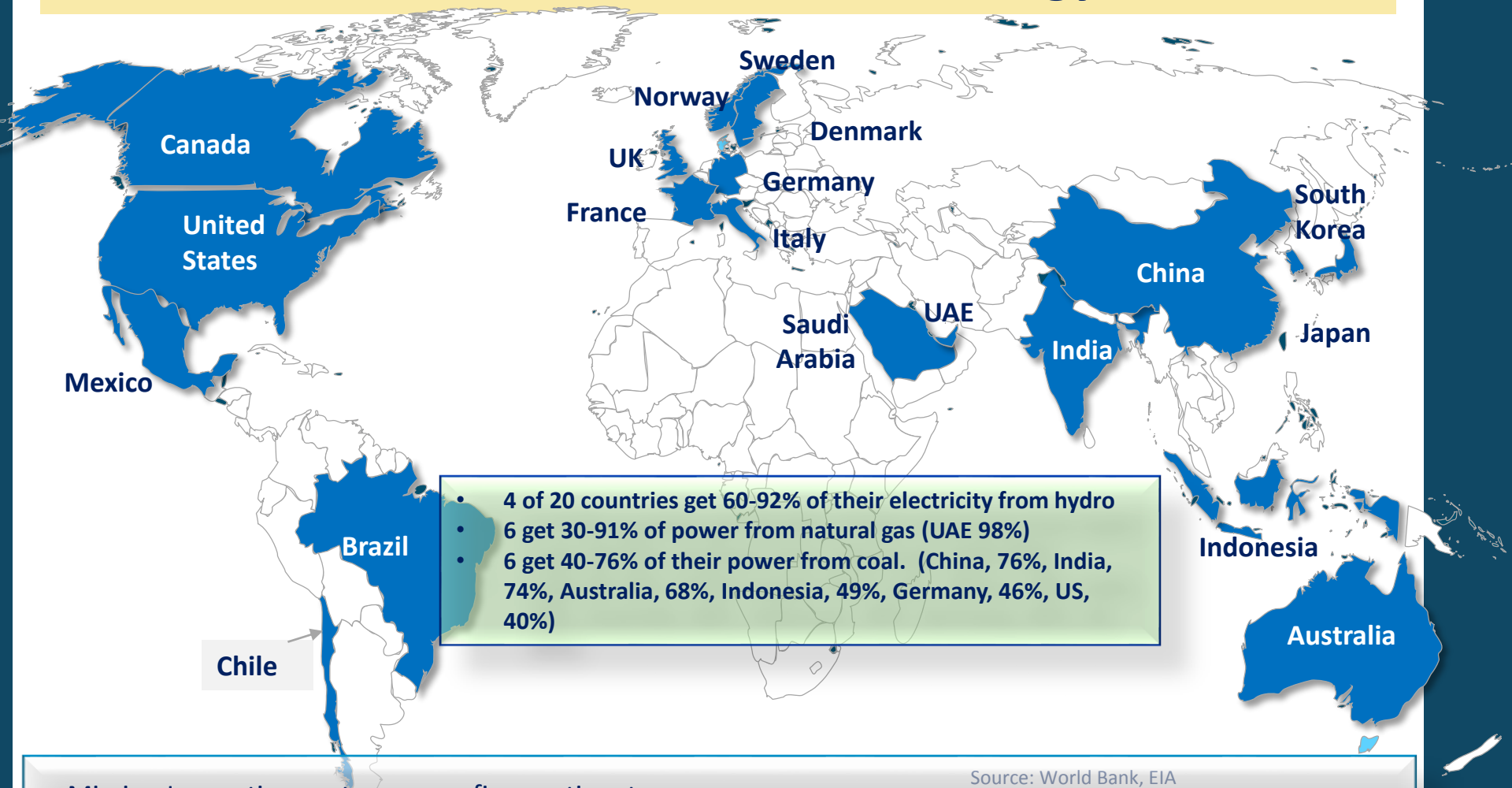
Fawcett et al 2015

Mission Innovation Announced in Paris

- All on One Stage -- Leaders of 20 Countries Representing over 80 % of Global Clean Energy R&D Investment Agreed to Support a *Joint Statement* on Innovation
- Each Country Supported a Doubling of Governmental Clean Energy R&D Investment over Next Five Years (www.mission-innovation.net)
- Gov't Investment was Complemented by a Private Sector Initiative led by Bill Gates, the Breakthrough Energy Coalition (www.breakthroughenergycoalition.com)

26

Mission Innovation: Focus on Clean Energy Innovation



- 4 of 20 countries get 60-92% of their electricity from hydro
- 6 get 30-91% of power from natural gas (UAE 98%)
- 6 get 40-76% of their power from coal. (China, 76%, India, 74%, Australia, 68%, Indonesia, 49%, Germany, 46%, US, 40%)

Source: World Bank, EIA

- Mission Innovation partners span five continents
- They represent nearly 60% of the world's population and include the top five most populous countries in the world
- Coalition emits two-thirds of the world's total greenhouse gas emissions and nearly 3/4ths of the CO2 emissions from electricity
- GDP in these countries represents almost 70% of the global total
- Mission Innovation countries represent over 80% of all government investment in clean energy R&D

Breakthrough Energy Coalition


Mukesh Ambani


John Arnold


Mark Benioff


Jeff Bezos


Alwaleed bin Ttalal


Richard Branson


Ray Delio


Aliko Dangote


John Doerr


Bill Gates


Reid Hoffman


Chris Hohn

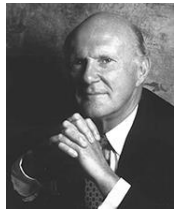

Vinod Khosla


Jack Ma


Patrice Motsepe


Xavier Niel


Hasso Plattner


Julian Robertson


Neil Shen


Simons & Baxter-Simons


Masayoshi Son


George Soros


Tom Steyer


Ratan Tata

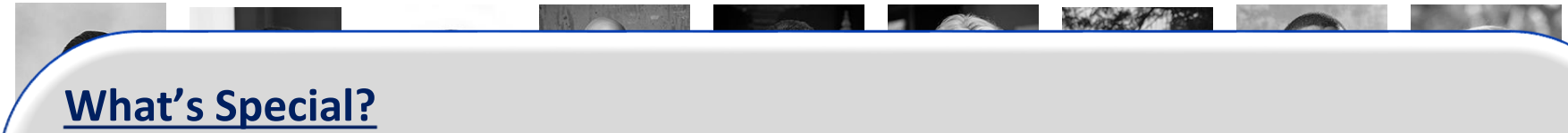

Meg Whitman


Zhang Xin Pan Shiyi


Mark Zuckerberg, Priscilla Chan

- 27 investors & University of California; collective net worth: $300+ billion
- Commitment to invest in innovation emerging from Mission Innovation pipeline
- Long-term, patient, and risk-tolerant capital

Breakthrough Energy Coalition



What's Special?

- 27 (of 28 total) investors pledging personal funds - - BEC says it is designing a new investment fund as its vehicle.
- Investments will be at earlier stage, be end-to-end (e.g. angel investment through commercial deployment) and be more patient.
- BEC committed to investing only in Mission Innovation partnership countries.

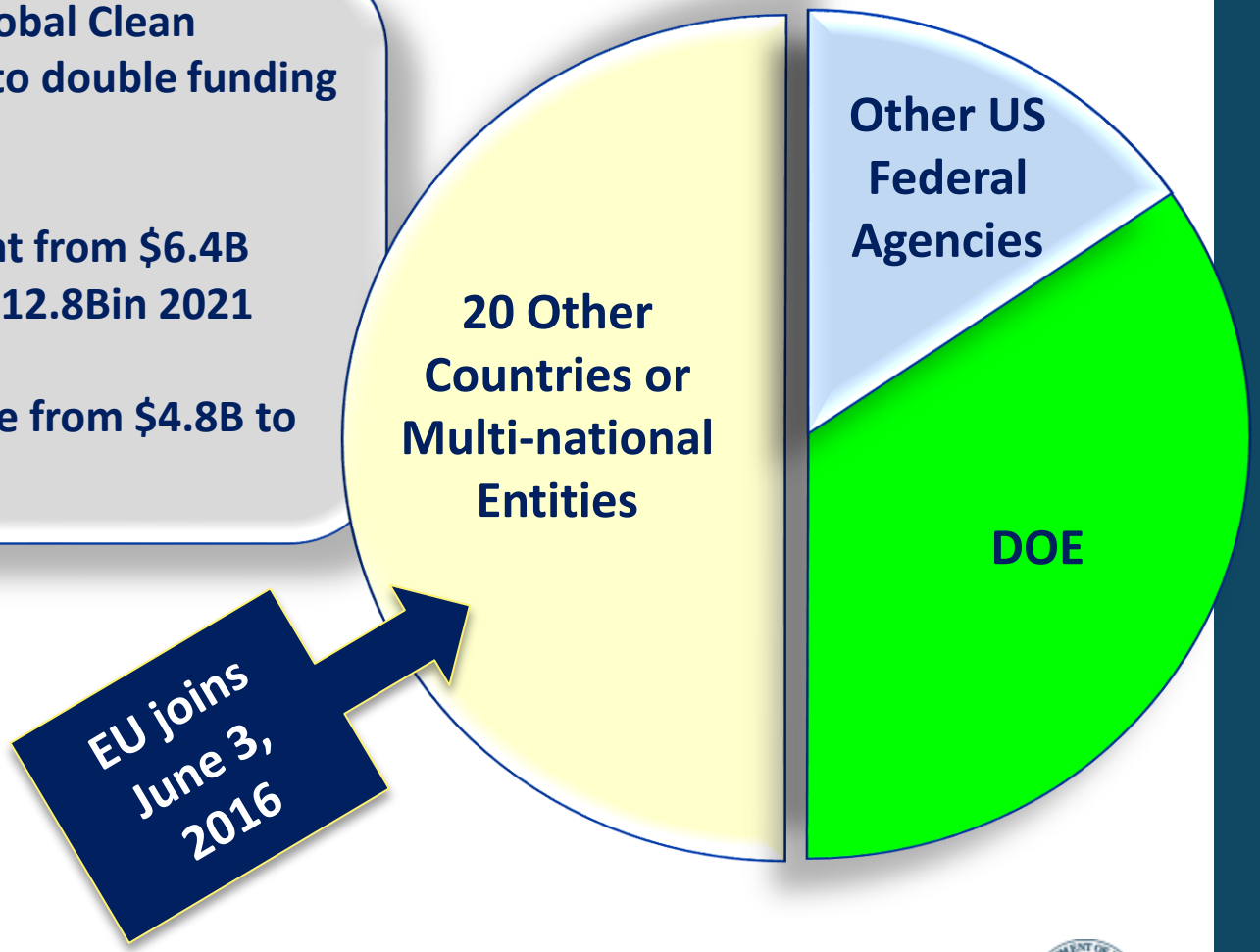
Interface with DOE?

- BEC's efforts are separate from DOE and the federal government
- Existing platforms such as DOE programs, ARPA-E, Clean Energy Investment Center, and Office of Technology Transfers, will provide information about emerging technologies; no preferential access.

- 27 [illegible]
- Commitment to invest in innovation emerging from Mission Innovation pipeline
- Long-term, patient, and risk-tolerant capital

Mission Innovation Launch, Nov. 30, 2015

- 20 countries (80% of Global Clean Energy R&D,) will seek to double funding over 5 years
- U.S.: Double investment from $6.4B baseline in FY 2016 to $12.8Bin 2021
- DOE: $1B (21%) increase from $4.8B to $5.9B in FY 2017

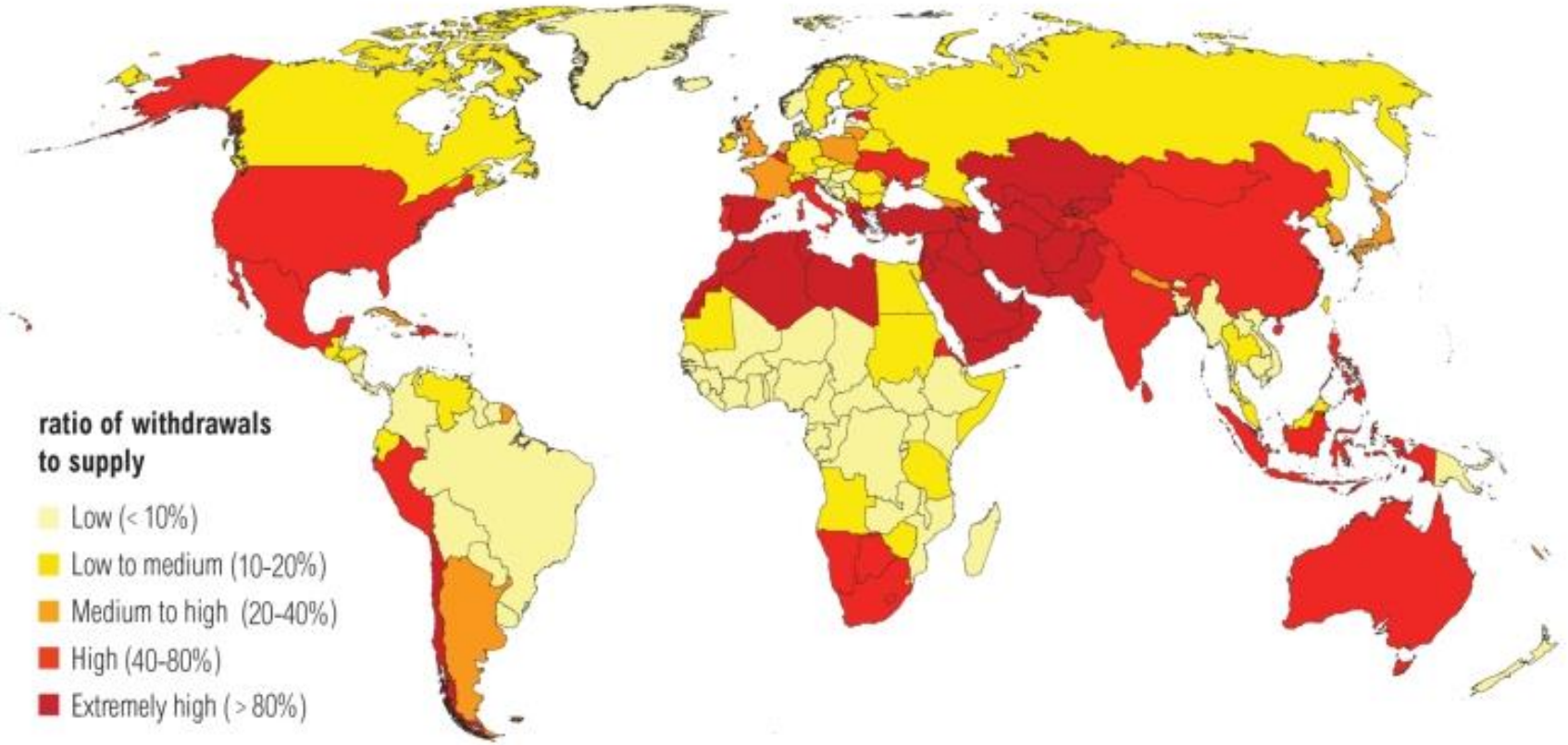


Mission Innovation Clean Energy R&D Funding Increase

Country	Baseline(Million currency as declared, per year)	Baseline (Million US Dollars per year)	Five-Year Target Amount (Million US Dollars per year)
Australia	104 AUD	78	156
Brazil	600 BRL	150	300
Canada	387 CAD	295	590
Chile	4.1856 USD	4	9
China	25,000 RMB	3,800	7,600
Denmark	292 DKK	45	90
European Union	989 EUR	1,111	2,218
France	440 EUR	494	989
Germany	450 EUR	506	1,011
India	4700 INR	72	145
Indonesia	16.7 USD	17	150
Italy	222.6 EUR	250	500
Japan	45,000 JPY	410	820
Kingdom of Saudi Arabia	281.3 SAR	75	150
Mexico	20.71 USD	21	62
Norway	1132 NOK	140	280
Republic of Korea	490 USD	490	980
Sweden	134 SEK	17	33
United Arab Emirates	10 USD	10	34
United Kingdom	200 GBP	290	580
United States	6415 USD	6,415	12,830
TOTAL		14,690	29,516

Global Water Stress, 2040

Currently, 28% of the world lives in water-scarce countries. Experts estimate that by 2080, this number will climb to between 43-50%*



Water Stress by Country: 2040

* World Bank, 2014, Huffman

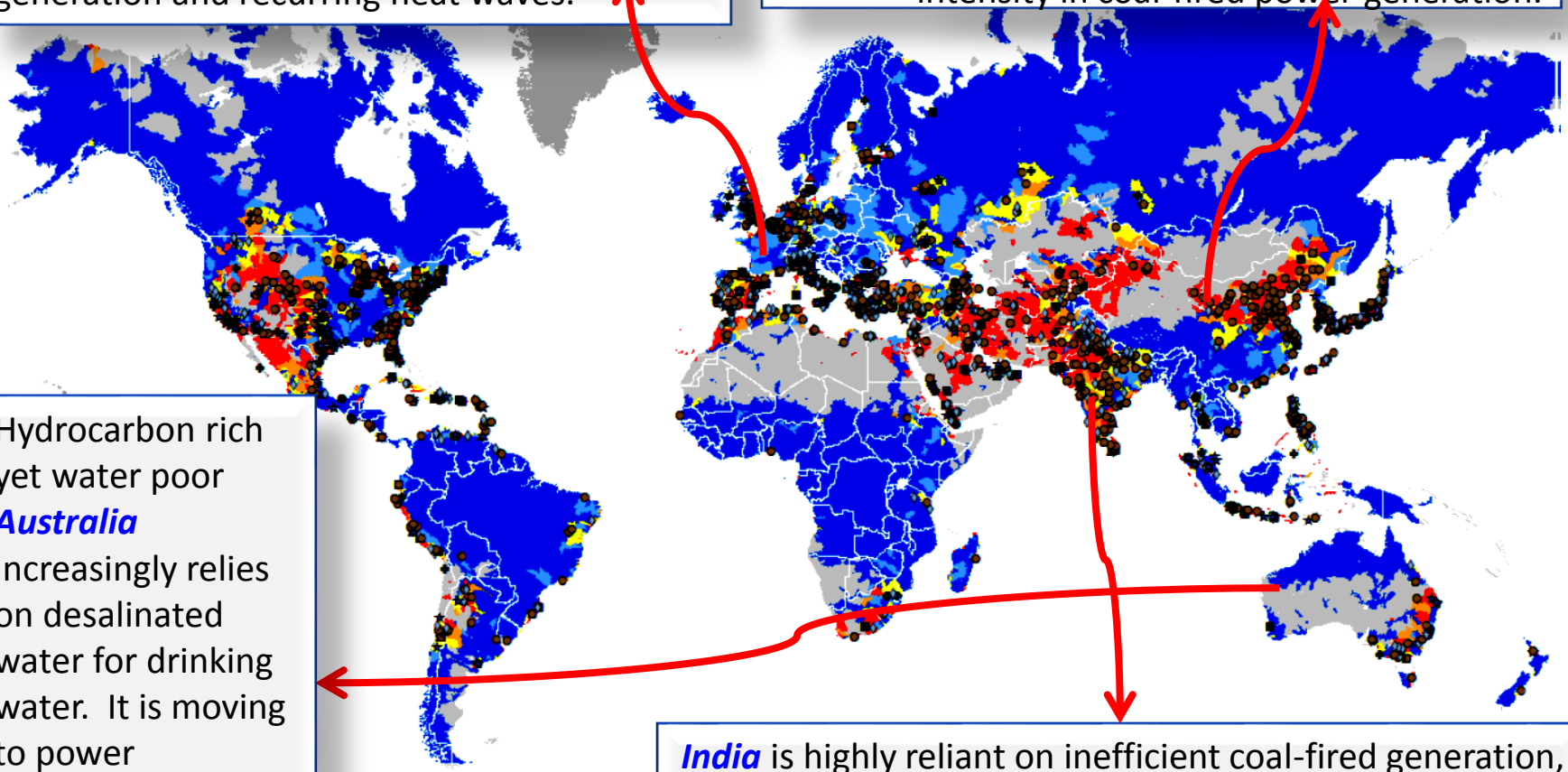
NOTE: Projections are based on a business-as-usual scen

Example: Global Innovation Needs

Mission Innovation Partners & the Water-Energy Nexus

France is particularly vulnerable due to high power sector water dependency from nuclear generation and recurring heat waves.

Coal-rich but water poor, ***China*** is adopting direct and indirect measures to reduce water intensity in coal-fired power generation.



Hydrocarbon rich yet water poor ***Australia*** increasingly relies on desalinated water for drinking water. It is moving to power desalination with renewable power and waste heat.

India is highly reliant on inefficient coal-fired generation, and needs to power remaining 1/3rd of population. The country is improving coal-fired power generation efficiency and reclaiming waste water.

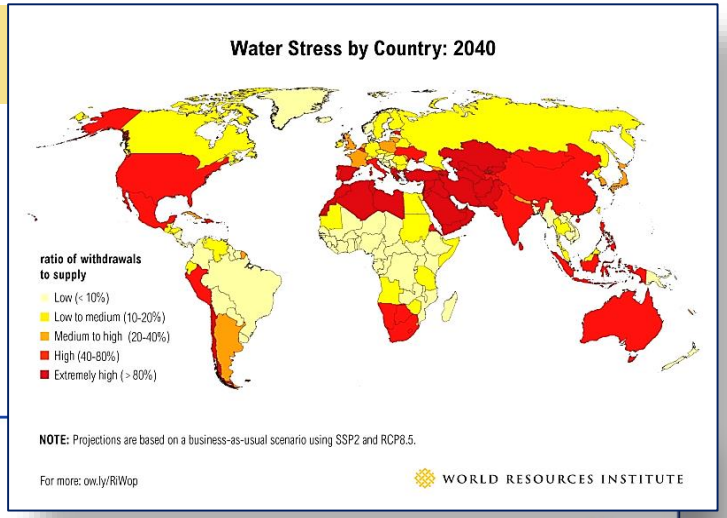
Global Generation Units with Water Stress

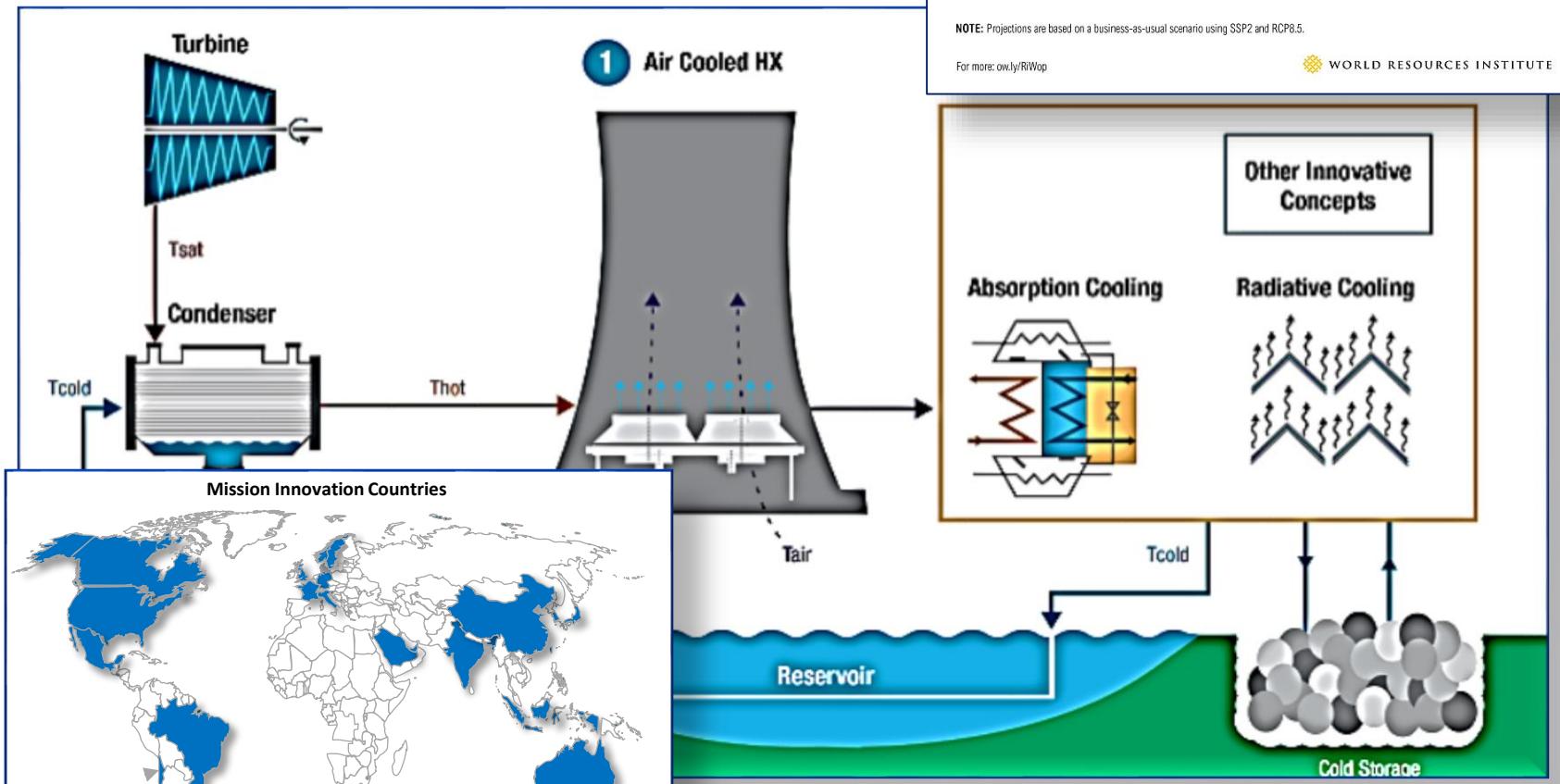
- yellow, orange, and red correspond with medium, high, to extremely high stress levels

Source: GE (2012)

Research in Dry Cooling

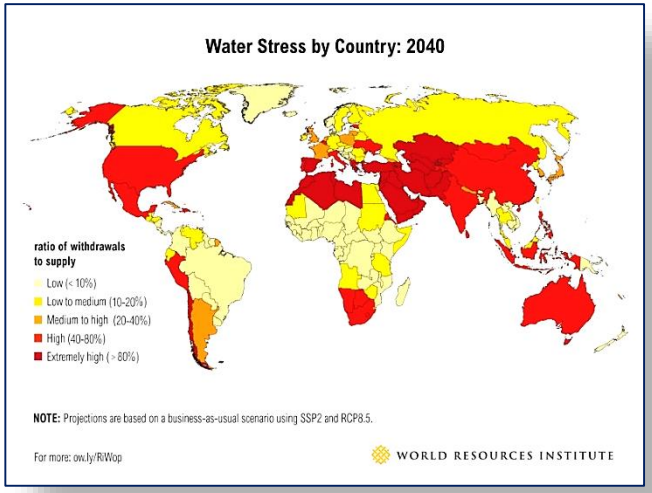
ARPA-E's Advanced Research in Dry Cooling (ARID)

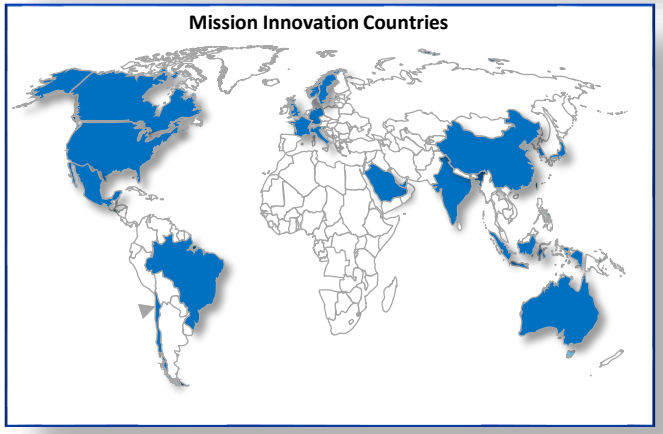


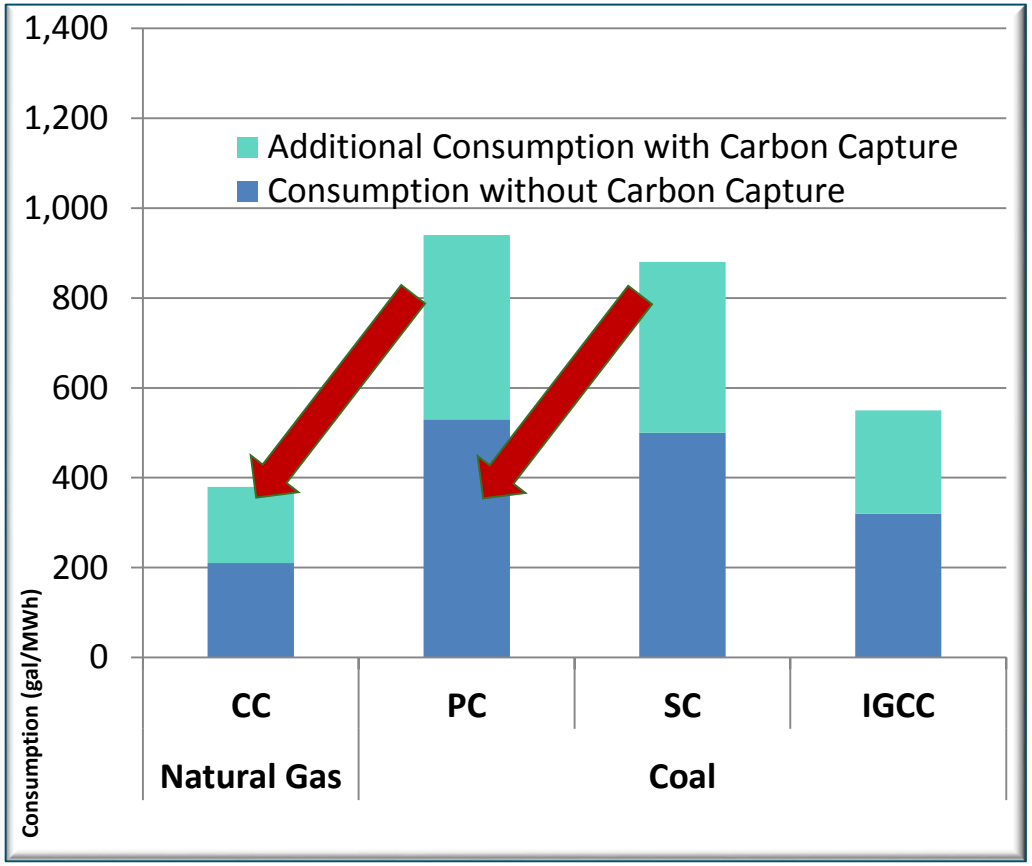


Carbon Capture Technology

Depending on the technology, carbon capture can dramatically increase water requirements for thermoelectric cooling







Capture technology: monoethanolamine

Data source: Meldrum et al. (2013)

Competition Between Policy Goals: Water Requirements, Energy Equity, Climate Mitigation

Cooling System	Advantages	Disadvantages
Once-through	Low water consumption Mature technology Lower capital cost	High water withdrawals Impact on ecosystem Exposure to thermal discharge limits
Wet tower	Significantly lower water withdrawal Mature technology	Higher capital cost relative to once-through Lower plant efficiency, especially when ambient temperatures are high Large land area requirements
Dry	Zero or minimal water withdrawal or consumption	Higher capital cost than wet tower or once through Limited technology experience

Scope of Mission Innovation for U.S. FY 17 President's Budget Request

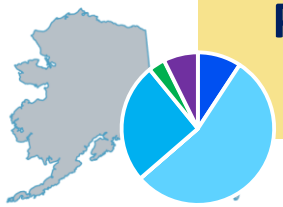
- Mission Innovation consists of early-stage clean energy elements of existing programs that are research, development and demonstration (RD&D) – not deployment
- FY 2016 U.S. government-wide baseline is $6.4 billion and, of this, the U.S. Department of Energy (DOE) baseline is $4.8 billion (75%)

Clean energy technology is any process, product or system of products and processes, that can be applied at any stage of the energy cycle from production to consumption, whose application will reduce net greenhouse gas emissions, and can meet one or more of the following characteristics:

- reduced demand for water resources
- reduced waste
- reduced emissions of other air pollutants
- or reduced concentrations of contaminants in wastewater discharges.

37

Power Generation Sources and Water Withdrawals for Power Generation Vary Greatly by Region



Alaska/Arctic

60 Mgal/day
3,130 gal/MWh

Northwest

PNNL
NETL

200 Mgal/day
370 gal/MWh

North Central

INL
NREL

3,240 Mgal/day
4,370 gal/MWh

Midwest

AM

39,890 Mgal/day
20,630 gal/MWh

West

LBNL
SLAC SNL
LLNL

6,740 Mgal/day
7,010 gal/MWh

Southwest/Central

LANL
SNL

17,510 Mgal/day
9,340 gal/MWh

Northeast

BNL

14,000 Mgal/day
19,160 gal/MWh

Mid-Atlantic

PPL
NETL
NETL

35,320 Mgal/day
17,410 gal/MWh

Southeast

TJ
ORNL
SRNL

40,840 Mgal/day
16,780 gal/MWh

Hawaii

656 Mgal/day
22,097 gal/MWh

KEY (GENERATION SOURCE DATA)

- Coal
- Natural Gas
- Nuclear
- Hydroelectric Conventional
- Non-Hydro Renewables[1]
- Other [2]

[1] Includes Wind, Solar, Biomass, Geothermal

2 Includes Petroleum, Other Fossil Fuel Gases, Pumped Storage, Non-Biogenic Municipal Solid Waste, Batteries, Hydrogen, et al.

KEY (WATER DATA)
Water Withdrawal for Power Generation (Mgal/day)
Water Withdrawal Intensity of Power Generation (gal/MWh)

	Most	Least
Water Withdrawal	Southeast, Midwest	Alaska/Arctic, Northwest
Water Intensity	Hawaii, Midwest	Northwest, Alaska/Arctic

Sources: EIA, 2014 data from "Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)," October 21, 2015. https://www.eia.gov/electricity/data/state/
USGS, EIA data via Maupin, M.A. et al., 2014, Estimated use of water in the United States in 2010: U.S. Geological Survey Circular 1405, 56 p., http://dx.doi.org/10.3133/cir1405

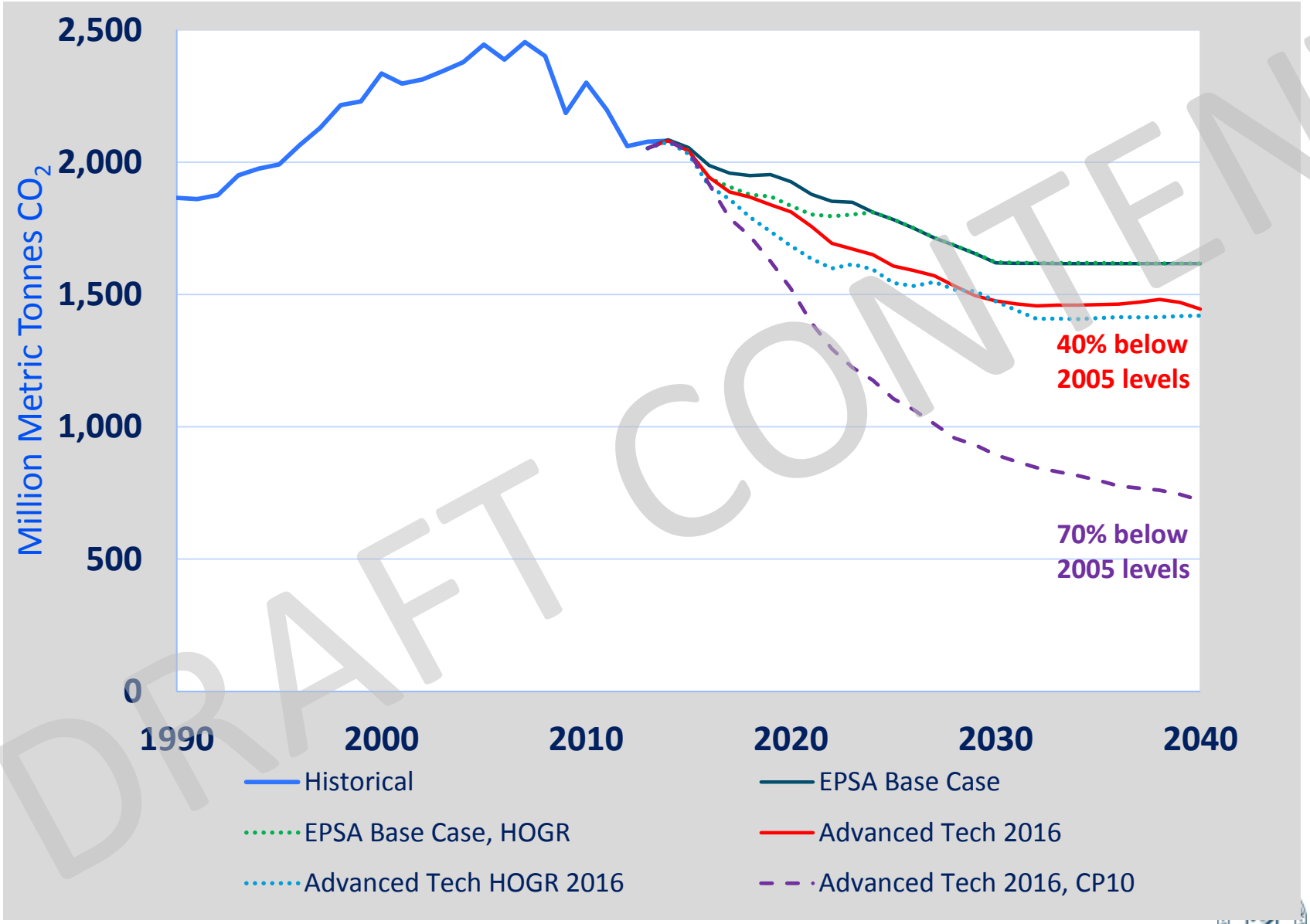
Impacts of Enhanced Investments in Technology

What greenhouse gas reductions would be achieved under current DOE program office goals, including cost and performance goals?

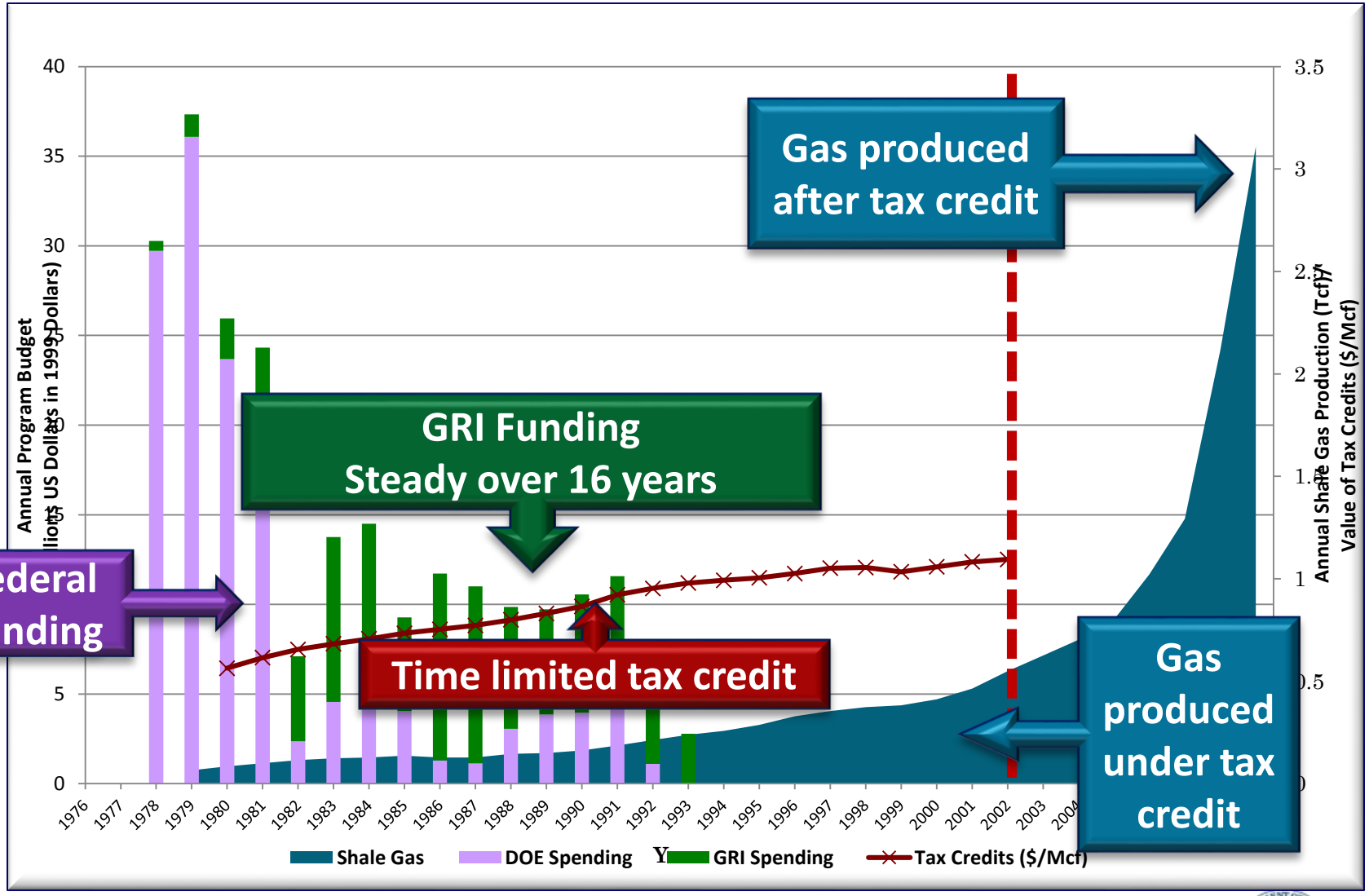
Energy program goals, most recently published in the FY17 budget, include cost and performance targets for future years. Program goals were translated into model inputs.

The Advanced Technology Case represents one potential version of a clean energy technology future based on current RDD&D funding levels and the "technology push" approach to significant GHG emissions reductions from the energy sector.

Power Sector Emissions Under Advanced Tech Cases



Unconventional Gas Development: Lessons Learned



Source: MIT Future of Natural Gas Study