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POLICY AND GLOBAL AFFAIRS DIVISION

The Power of Change: Innovation for Development and Deployment of Increasingly Clean Electric Power Technologies

Paul Centolella
Clark Gellings

Committee on Determinants of Market Adoption of Advanced Energy Efficiency and Clean Energy Technologies

2016

Background

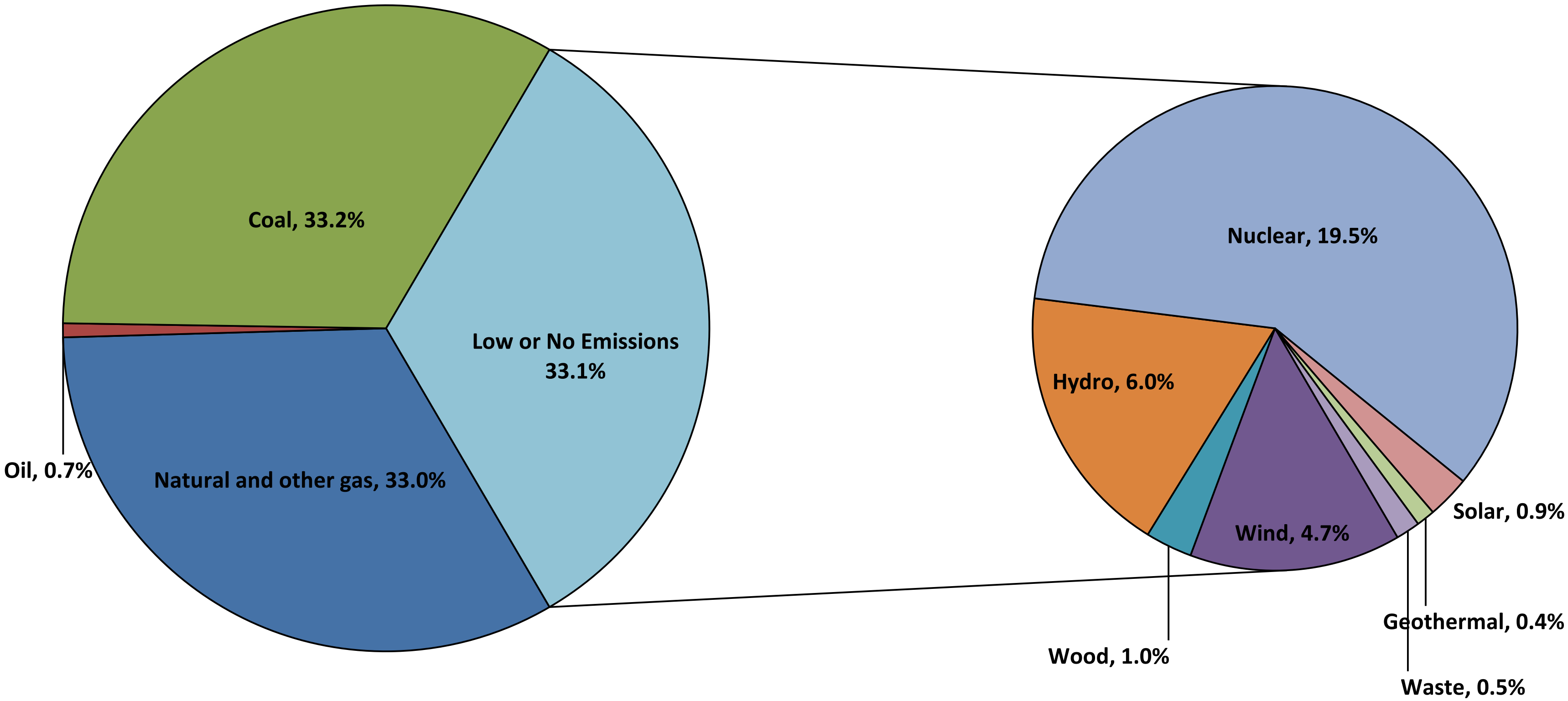
- In 2011, Senators asked DOE to engage the National Academies and study policies that could “recapture our leadership in clean energy”
- DOE tasked the Academies to “determine how federal policies can accelerate the market adoption of advanced energy efficiency and low- or non-polluting energy technologies”
- Committee on Determinants of Market Adoption of Advanced Energy Efficiency and Clean Energy Technology: Members from a variety of backgrounds
- Study funded by DOE with support from the National Academies

Findings and Recommendations

Overarching Recommendations

- U.S. & State Governments should significantly increase their emphasis on supporting innovation in increasingly clean electric power generation technologies.
- Congress should consider an appropriate price on pollution from power production to level the playing field; create market pull; and expand research, development, and commercialization of increasingly clean electric power technologies.

Electricity Generation by Fuel (2015)

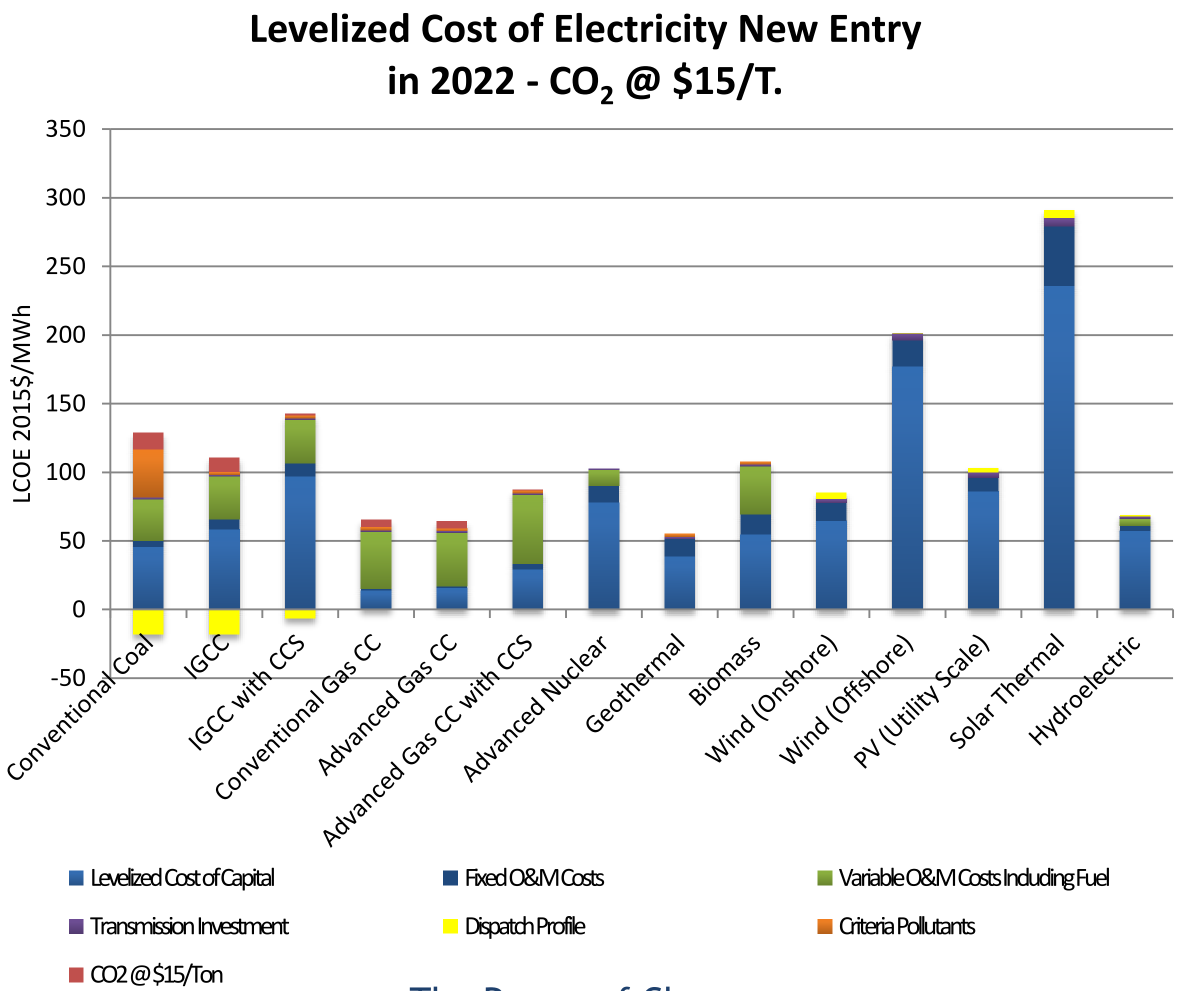


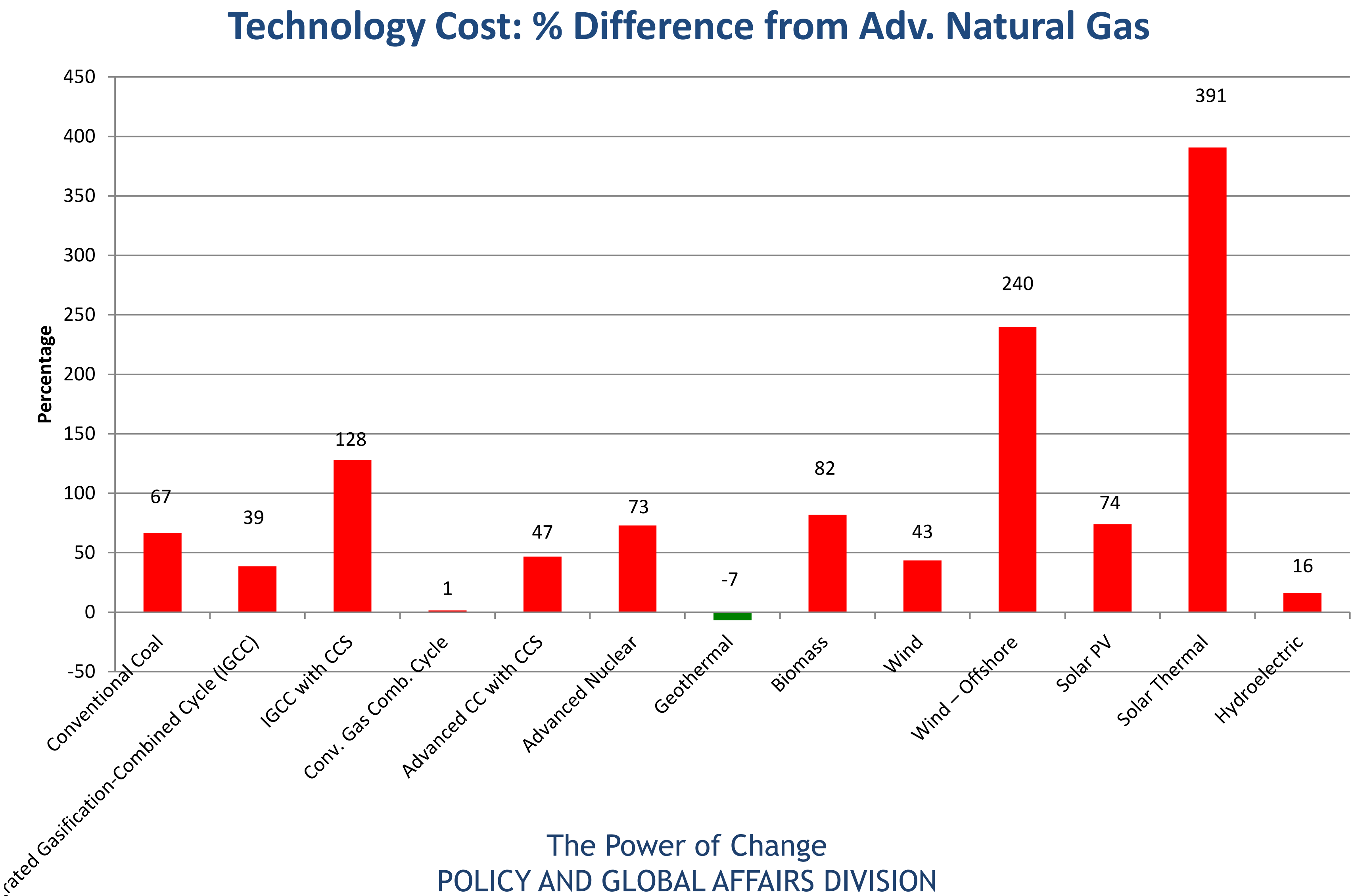
Source: EIA

Failure to Price Pollution Costs

- "[P]ower plant emissions of particulates as well as oxides of nitrogen and sulfur still cause harms and contribute to increases in morbidity and mortality. These harms include premature deaths, contributions to illnesses such as asthma, and increased hospitalizations, and electricity prices do not fully incorporate the costs of these harms. Harms from greenhouse gas emissions – to which the power sector is an important contributor, accounting for nearly 40 person of all domestic emissions remain almost completely unpriced and thus above the level they would be if market prices reflected their full costs."
- Inaccurate price is an example of a "market failure" where government action is often justified. In this case, the solution to correct the market failure is intellectually simple but politically difficult: governments can require that market actors price pollution in their decision making."

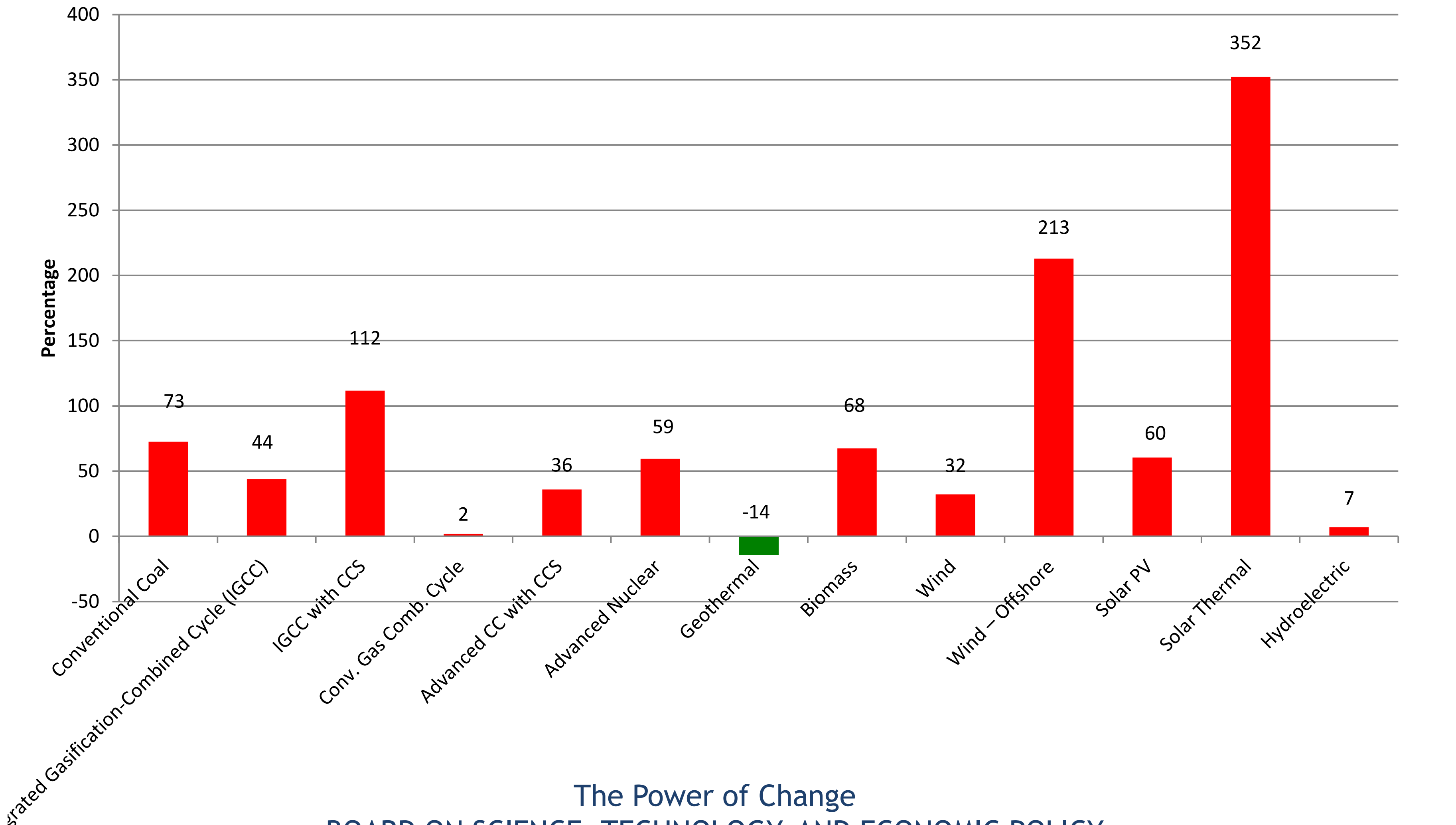
Power Technology Costs based on EIA 2016 AEO





Technology Cost: % Difference from Adv. Natural Gas
Percentage
450
400
350
300
250
200
150
100
50
0
-50
67
39
128
1
47
73
-7
82
43
240
74
391
16
Conventional Coal
rated Gasification-Combined Cycle (IGCC)
IGCC with CCS
Conv. Gas Comb. Cycle
Advanced CC with CCS
Advanced Nuclear
Geothermal
Biomass
Wind
Wind – Offshore
Solar PV
Solar Thermal
Hydroelectric

Technology Cost: % Difference from Adv. Natural Gas (GHGs Priced at $15/T)



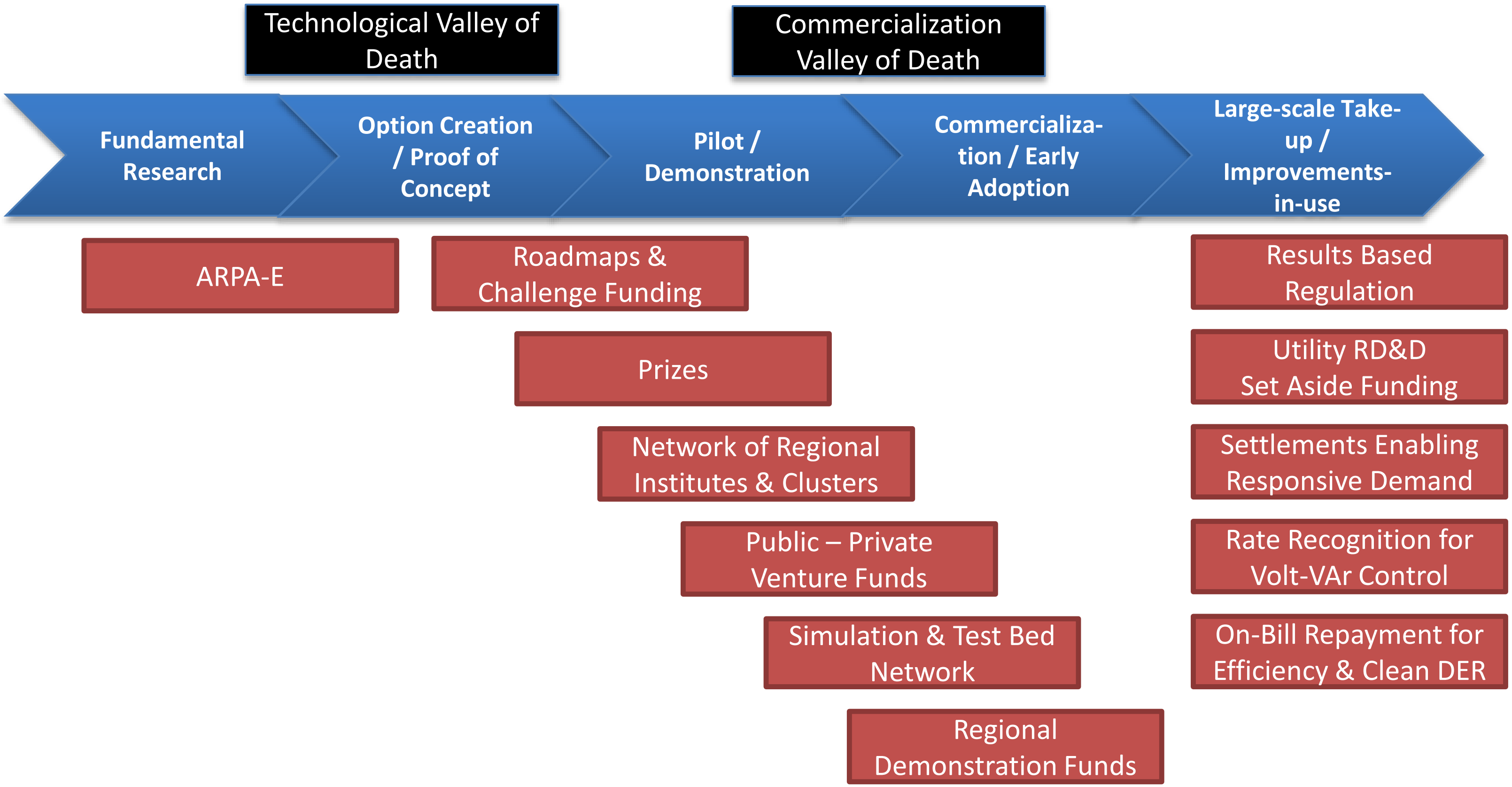
Technological Challenge

- **Recognition that Climate Mitigation is a hard problem:**
  - "…[T]he scale of the climate challenge is so large that it necessitates a significant switch to increasingly clean power sources. In most of the United States, however, even with a price on pollution, most increasingly clean technologies would lack cost and performance profiles that would result in the levels of adoption required. In most cases, their levelized costs are higher than those of dirtier technologies, and there are significant challenges and costs entailed in integrating them into the grid at high levels."
  - "Effective mitigation of climate risks may require a transition to low-carbon energy technologies on a global scale and possibly within a compressed time frame."
- **Finding: "***Evidence suggests that policies focused disproportionately on subsidizing deployments of increasingly clean technologies will not produce the large, timely, cost-effective improvements in the cost and performance of these technologies required to address pollution problems. Rather what is required to achieve these improvements in currently available technologies and to create new, as yet unknown breakthrough technologies is a major investment in innovation."*

Strengthening Energy Innovation Process

- **Finding:** Market failures and nonmarket barriers exist at all stages of the innovation process.
- **Finding:** Regional efforts that leverage regional energy markets and initiatives by states, universities, entrepreneurs and industry can complement federal actions to help bridge funding and commercialization gaps.
- **Finding:** The development of affordable clean technologies that can be rapidly deployed in both developed and developing economies will be enhanced by public / private collaborations and international partnerships.
- **Recommendation:** DOE should direct funds to a broader portfolio of projects than will ultimately prove viable and should tolerate the inevitable failure of some experiments, while winnowing at each stage.

Candidate Solutions



Modernizing the Power System

- **Finding:** It will be necessary to redesign business models and regulatory incentives for a customer-driven model.
- **Recommendation:** DOE should develop information and tools that facilitate state regulatory consideration & implementation of regulatory models to meet current challenges.
- **Recommendation:** States should implement policies designed to support Innovation, such as evaluating approaches to set aside funds for state or regional innovation programs.
- **Recommendation:** DOE should undertake a multiyear R&D program to ensure timely development of the capabilities needed for effective Distribution System Operators (DSO) and Customer Energy Service Providers.
  - Required DSO capabilities include: architecture, control systems, operational modeling, interoperability standards, cyber-security, distribution level markets, and distribution planning models that facilitate regulatory review

The Role of Energy Efficiency

Finding: A price that includes full social costs might spur efficiency in the long run, however, prices may be insufficient to overcome all market and behavioral failures.

- **Recommendation:** DOE should continue to set new appliance standards at maximum technologically feasible and economically justified levels.
- **Recommendation:** DOE should continue to collaborate with standards organizations in developing model codes and compiling best practices for improving building efficiency and the operation of building systems.
- **Recommendation:** Governments and the private sector should take steps to remove barriers to, provide targeted support for, place a high priority on the development and deployment of all cost-effective efficiency measures.

Recognition of an on-going need for program evaluation and innovation:

“The advent of AMI, platform markets, data analytics, and ‘intelligent efficiency’ providers that leverage increased data availability could help change the fragmented efficiency landscape.”

- **Recommendation:** DOE should increase investments in innovative efficiency technologies, improve forecasts of energy savings, and obtain data to develop behavioral interventions.

Technology Readiness Levels (TRLs)

Technology Readiness Levels – In Brief

1. Exploratory research
2. Concepts formulated
3. Concepts validated
4. System validated in lab
5. Early demonstration
6. Early field demo
7. Demo of complete system
8. Early commercial development
9. Wide-scale commercial deployment

The Key Technologies

The committee provided TRLs on five technology categories:

- Renewable power generation
- Advanced pollution control technologies of fossil fuel power generation
- Advanced nuclear power
- The Grid (transmission and distribution)
- Efficient electric technologies for buildings and industry

Concluding Remarks

- Clean technologies are too expensive to compete, especially given low natural gas prices.
- Better technology is needed for power generation, pollution control, end use, grid integration and storage.
- Evolving better technology will require a massive innovation effort.

Additional Notes

Committee Members

- Charles “Chad” Holliday, National Academy of Engineering (NAE), Chairman of Royal Dutch Shell, PLC, *Chair*
- Jerome “Jay” Apt, Professor Tepper School of Business, Co-Director, Electricity Industry Center, Carnegie Mellon University
- Frances Beinecke, President (ret.), Natural Resources Defense Council
- Nora Brownell, Co-Founder, ESPY Energy Solutions; former FERC and Pennsylvania Public Utility Commissioner
- Paul Centolella, President, Paul Centolella & Associates; Senior Consultant, Tabors Caramanis Rudkevich; former Ohio Public Utility Commissioner
- David Garman, Principal and Managing Partner (ret.), Decker Garman Sullivan; former Under Secretary of Energy
- Clark Gellings (NAE), Independent Consultant; Fellow (ret.), Electric Power Research Institute
- Bart Gordon, Partner, K&L Gates LLP; former U.S. Representative, Tennessee, U.S. House of Representatives

Committee Members (cont'd)

- William Hogan, Raymond Plank Professor of Global Energy Policy, Harvard Electricity Policy Group, Harvard Kennedy School of Government
- Richard Lester, Japan Industry Professor, Department of Nuclear Science and Engineering; Associate Provost, Massachusetts Institute of Technology
- August "Bill" Ritter, Co-Founder, Center for the New Energy Economy, Colorado State University; former Governor of Colorado
- James Rogers, President and CEO (ret.), Duke Energy
- Theodore Roosevelt, Managing Director and Chairman, Clean Tech Initiative, Co-Chair Military Services Network, Barclays Bank
- Peter Rothstein, President, NECEC
- Adm. Gary Roughhead (Ret.), Annenberg Distinguished Fellow, Hoover Institution, Stanford University
- Maxine Savitz (NAE), General Manager for Technology Partnerships (ret.) Honeywell, Inc.
- Mark Williams, (deceased)

Congressional Letters to Secretary Chu

"The National Academies has an unequalled reputation for providing the government with independent, objective, and thorough advice since 1863. Following in this tradition, the STEP board's study will provide administrators, legislators, and other decision-makers with key information to understand market issues, what public good will come from federal policies, and what initiatives the federal government may undertake, at the legislative or agency level, to catalyze the deployment of new energy technologies." – Letter from Lisa Murkowski & Jeff Bingaman (May 17, 2011)

"The United States must adopt a sustainable set of policies to recapture our leadership in clean energy. Yet there is growing debate and doubt about the ability of the federal government, in cooperation with the private sector, to meet this imperative." – Letter from Senators Coons, Bingaman, Murkowski, Kerry, Durbin, Sherrod Brown, Lieberman, Murray, Scott Brown, Akaka, Feinstein, Wyden, Collins, Stabenow, Shaheen, Udall, Reed, Blumenthal, Lautenberg, Bennet, Pryor, Franken, Boxer, Cardin, Tester, Menendez, and Whitehouse (January 6, 2012)

Technology readiness levels

Technology Category	1	2	3	4	5	6	7	8	9
	Technology Readiness Level[a]								
Renewable Power Generation									
1: Electric energy storage			■	■	■	■	■	■	■
2: Hydro and marine hydrokinetic power[b]				■	■				■
3: Advanced solar photovoltaic power[c]					■	■			
4: Advanced concentrating solar power						■	■	■	■
5: Advanced solar thermal heating					■	■	■	■	
6: Advanced biomass power				■	■			■	■
7: Engineered/enhanced geothermal systems			■	■		■			
8: Advanced wind turbine technologies		■			■	■			
9: Advanced integration of distributed resources at high percent						■	■	■	■
Advanced Fossil Fuel Power Generation									
10: Carbon capture, transport, and storage							■	■	■
11: Advanced natural gas power and combined heat and power (CHP)[c]				■	■	■	■	■	■
12: Water and wastewater treatment				■	■				■
Nuclear Power Generation									
13: Advanced nuclear reactors	■	■	■	■	■	■	■	■	■
14: Small modular nuclear reactors	■	■	■	■	■	■	■	■	■
15: Long-term operation of existing nuclear plants	■	■	■	■	■	■	■	■	■

(Continued)

Technology readiness levels (continued)

Technology Category	Technology Readiness Level[a]								
	1	2	3	4	5	6	7	8	9
Electricity Transmission and Distribution									
16: Advanced high-voltage direct current (HVDC) technologies							■		
17: Reducing electricity use in power systems									■
18: Smart-grid technologies (grid modernization)				■	■	■	■	■	■
19: Increased power flow in transmission systems			■	■	■	■	■	■	■
20: Advanced power electronics						■	■		
Energy Efficiency									
21: Efficient electrical technologies for buildings and industry	■	■	■	■	■	■	■	■	■

[a]Technology readiness levels are shown on a scale of 1 to 9, where 1 is the least ready. Most of the technology categories shown include technologies with varying readiness levels. A shaded box below a TRL number indicates there is at least one technology at that TRL.

[b]The committee identified barriers at lower TRLs for hydropower technologies but was unable to make specific level assignments.

[c]For concepts beyond three junctions.