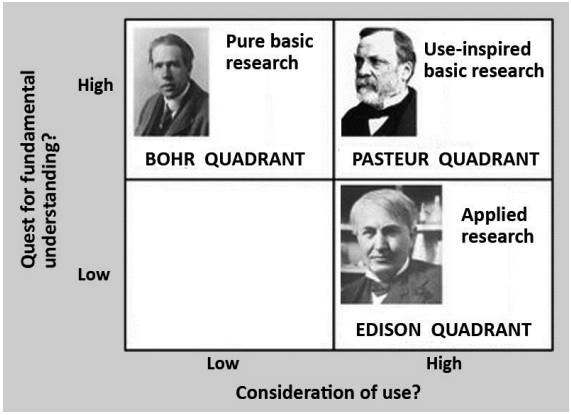
Innovative strategies to strengthen R&D for "clean" electric power – and other sectors

Robert Socolow
socolow@princeton.edu

DOE Cornerstone Workshop
for the Quadrennial Technology Review
Arlington VA
December 4, 2014

Strategy #1: Examine interfaces

Office of Science: Technologists should provide a steady stream of requests for insights. Examples: 1) CO_2 sorbents and membranes; 2) high-T storage materials; 3) plant physiology and high-yield crops.

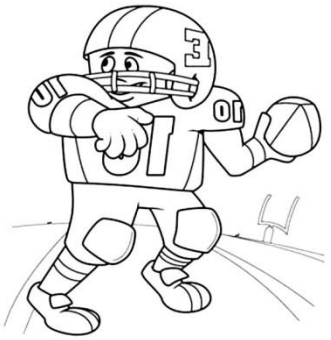


The interface between "systems and grids" (Chapter 5, a different room this morning) and "components" (us). The separation is risky. Overlap areas: 1) storage; 2) smart buildings integrated into smart decentralized and centralized grids; 3) multi-product "power" plants (heat, H_2, H-C fuels).

The *internal* interfaces, especially between renewables and fossil energy. 1) natural gas for firming of intermittent renewables; 2) co-firing biomass and fossil fuel, with CCS.

Strategy #2: The forward pass from policy to technology

Policy will evolve. Technology R&D should anticipate the innovations needed to address 2020 and 2030 policies. Policy throws forward passes to technology, not laterals.



A carbon price of \$100/tCO_2. Mischief with biocarbon (a pull toward the energy sector for everything that grows). EOR when CO_2 storage and extra oil are comparably lucrative. How long does CO_2 need to stay down?

\$15/MMBtu natural gas as well. (International trade. How fast can gas grow?) Topping and bottoming cycles for coal power. Electric heat pumps.

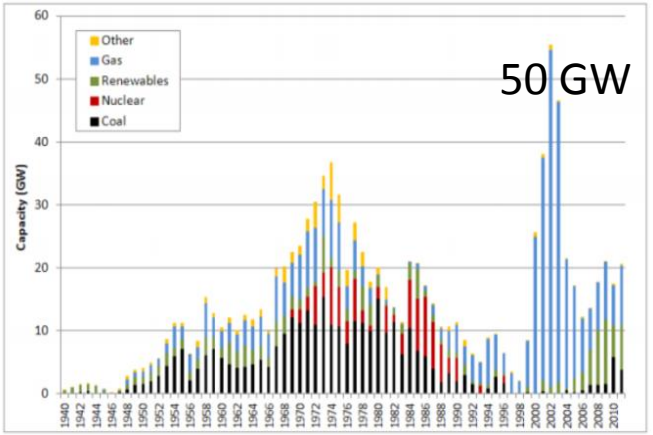
Strict proliferation-resistant nuclear power. Uranium-enrichment and plutonium-separation vigilance.

A 100-year timescale for nuclear waste storage. Advanced dry-cask storage.

Strategy #3: Replacement-facilitation technology (RFT)

Plant replacement will dominate in industrialized countries with aging coal and nuclear plants.

A new research area is Replacement Facilitation Technology (RFT). 2x2 matrix: (Keep the same site or go to a new one) x (Keep the same power plant type or go to a new one).



US power plants

Same-site/same type RFT: Designs to integrate CO_2 capture

New-site RFT: Decommissioning the old site.

Figure 5-1. Historical U.S. Power Plant Capacity Additions, by Technology, 1940-2011

Source: Form EIA-860 (2011)
Note: Renewables include hydro, geothermal, biomass, solar, and wind energy technologies.

Strategy #4: A bold search for efficiency

Electricity demand in WEO-2014 (PWh): total (from coal)				
	2012	2040-BAU	2040-"450"	Δ in 2040
World	22.7 (9.2)	44.0 (17.7)	35.0 (4.6)	-20% (-74%)
US	4.6 (1.3)	5.7 (2.2)	4.0 (0.8)	-14% (-63%)

The cleanest power plant is one that is never built!

Current goals aren't ambitious enough. See Table: 63% reduction in projected 2040 U.S. coal power with aggressive policy, but only 14% reduction in total U.S. electricity demand.

In-plant efficiency: Topping and bottoming cycles, reduced parasitic losses, including at CCS plants.

System efficiency: Technology matched to residential and commercial spot-market pricing.

Shared-savings businesses targeting HVAC, lighting, appliances.

Strategy #5: Use an A and a B team when evaluating climate-change mitigation technology

CO_2 fossil fuel emissions in WEO-2014 ($GtCO_2$): total (electricity)				
	2012	2040-BAU	2040-"450"	Δ in 2040
World	31.6 (13.2)	46.0 (20.9)	19.3 (4.0)	-58% (-81%)
US	5.0 (1.6)	5.4 (1.9)	1.9 (0.1)	-65% (-93%)

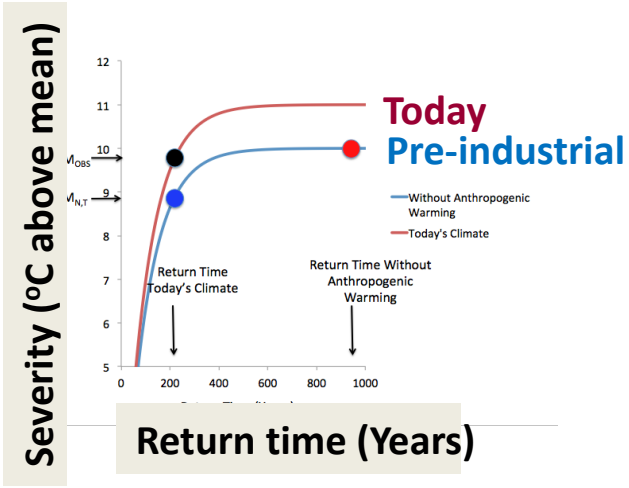
Hugh emissions reductions in WEO-2014! Anticipate what will go wrong when the pace is very fast. There is so much hype!

Renewables at high penetration: intermittency and unpredictability.

Enhanced geothermal: How long can power be produced competitively at one site before the field must be reentered elsewhere?

Biocarbon: land use.

Nuclear power fuel cycle: Proliferation



Source: S. Pacala, private communication