

The Ingredients of a Realistic Path Forward to Reduce the Release of Anthropogenic CO₂ to the Atmosphere While Allowing the Long-Term Utilization of Global Fossil Resources

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Presentation to the
13th Annual CCUS Conference
Pittsburgh, Pennsylvania
May 1, 2014

Or ...

Can We Have Our Cake and Eat it Too ?



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Is There a Future for CCS ?

If so, How do We Get There? (Realistically)

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Outline of Talk

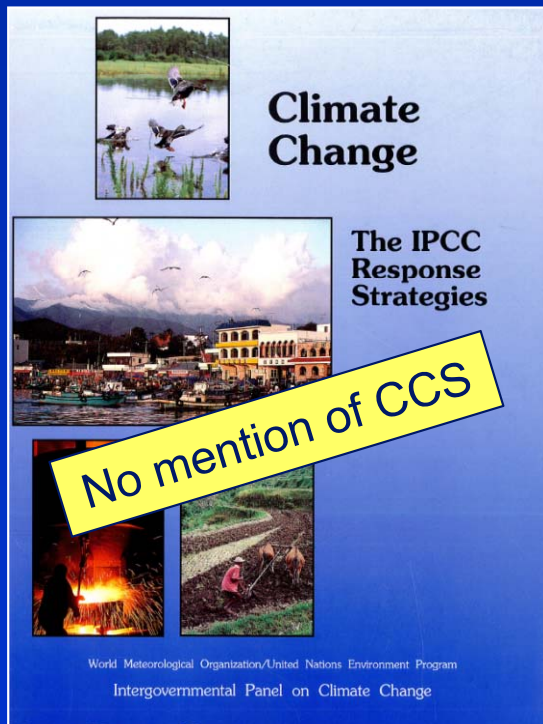
- A brief retrospective on CCS
- The good news
- The not-so-good news
- A path forward

A brief retrospective on CCS
(1990 – present)

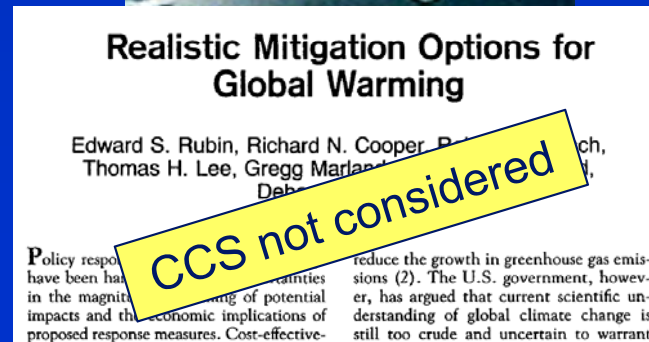
Early-Mid 1990s

CCS: A technical curiosity

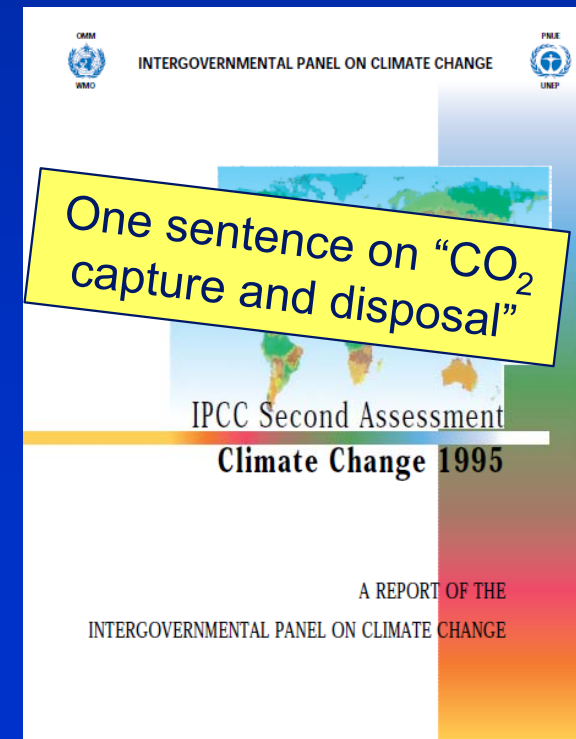
1990



1992



1995



Mid-Late 1990s

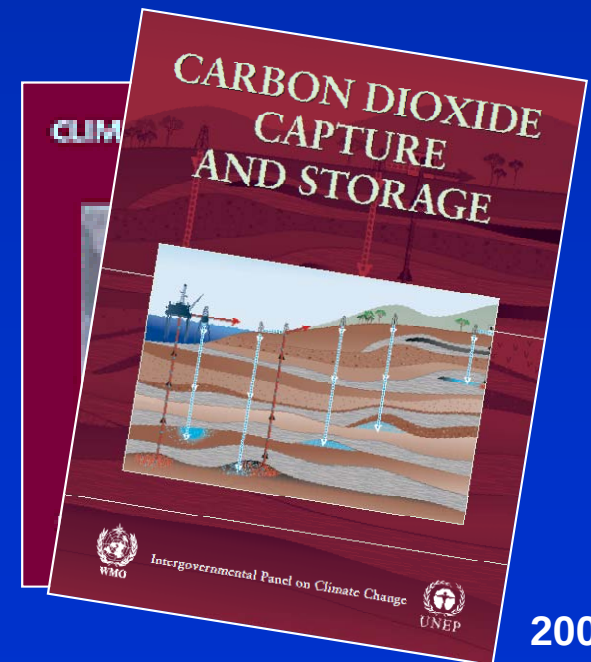
Deserves a closer look

- Growing concerns about climate change (Kyoto Protocol)
- New studies of CCS for coal-fired power plants show greater potential than before (especially for IGCC)
- Growing consensus among analysts that CCS could improve the cost-effectiveness of mitigation strategies
- USDOE announces new initiative on CCS

Early-Mid 2000s

Let's see what it can do

- DOE's Carbon Sequestration Program grows
- Original FutureGen project announced (2003); CSLF formed to promote CCS worldwide
- 3rd IPCC assessment found that: "Physical removal and storage of CO₂ is potentially a more viable option than at the time of the SAR."
- IPCC commissions a "Special Report on Carbon dioxide Capture and Storage" (completed in 2005)



Mid-Late 2000s

Gotta have it !

- Bullish coal outlook in wake of NG price hikes
- Planned demonstrations of CCS at coal plants throughout Europe, North America, Australia
- Carbon pricing in EU; widespread expectation of climate change legislation in the U.S.
- IPCC 4th AR (2007) says CCS is a key component of cost-effective strategies for climate stabilization

Early-Mid 2010s

Retrenchment

- No U.S. climate legislation
- Financial crisis, economic downturn
- Shale gas euphoria
- Cutbacks in CCS demos and budgets; greater emphasis on utilization

Looking toward 2020

A critical period for CCS

- Need successes and growth to preserve and regain global momentum

The Good News

First large-scale power plant demonstrations coming this year

- Sask Power Boundary Dam project (Canada)
 - 110 MW coal-fired unit
 - Post-combustion capture +EOR
 - $\sim 1 \text{ Mt CO}_2/\text{yr}$
-
- Southern Co. Kemper County IGCC project (Mississippi)
 - 582 MW coal-fired unit
 - Pre-combustion capture +EOR
 - $\sim 3.5 \text{ Mt CO}_2/\text{yr}$



Sask Power, 2013

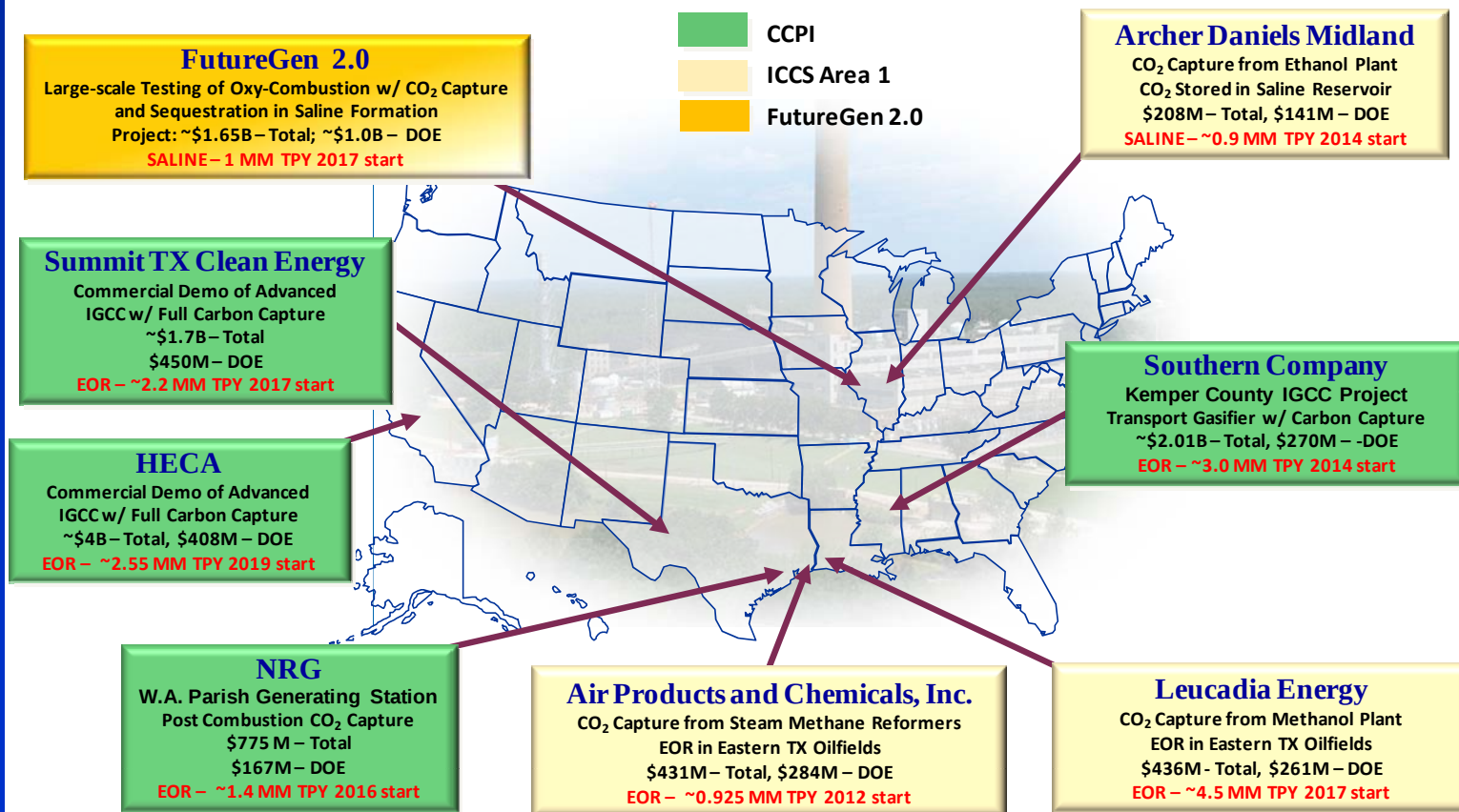


Kemper, 2014

Other Projects Moving Ahead

(Planned projects in the U.S. as of December 2013)

Major CCS Demonstration Projects Project Locations & Cost Share



Source: USDOE, 2013

Two new demonstration projects in the UK recently announced

- Peterhead project
- 385 MW gas-fired unit
- Post-combustion capture + offshore storage
- $\sim 1 \text{ Mt CO}_2/\text{yr}$

(FEED studies)

- White Rose project
- 426 MW coal-fired unit
- Oxy-combustion capture + offshore storage
- $\sim 2 \text{ Mt CO}_2/\text{yr}$

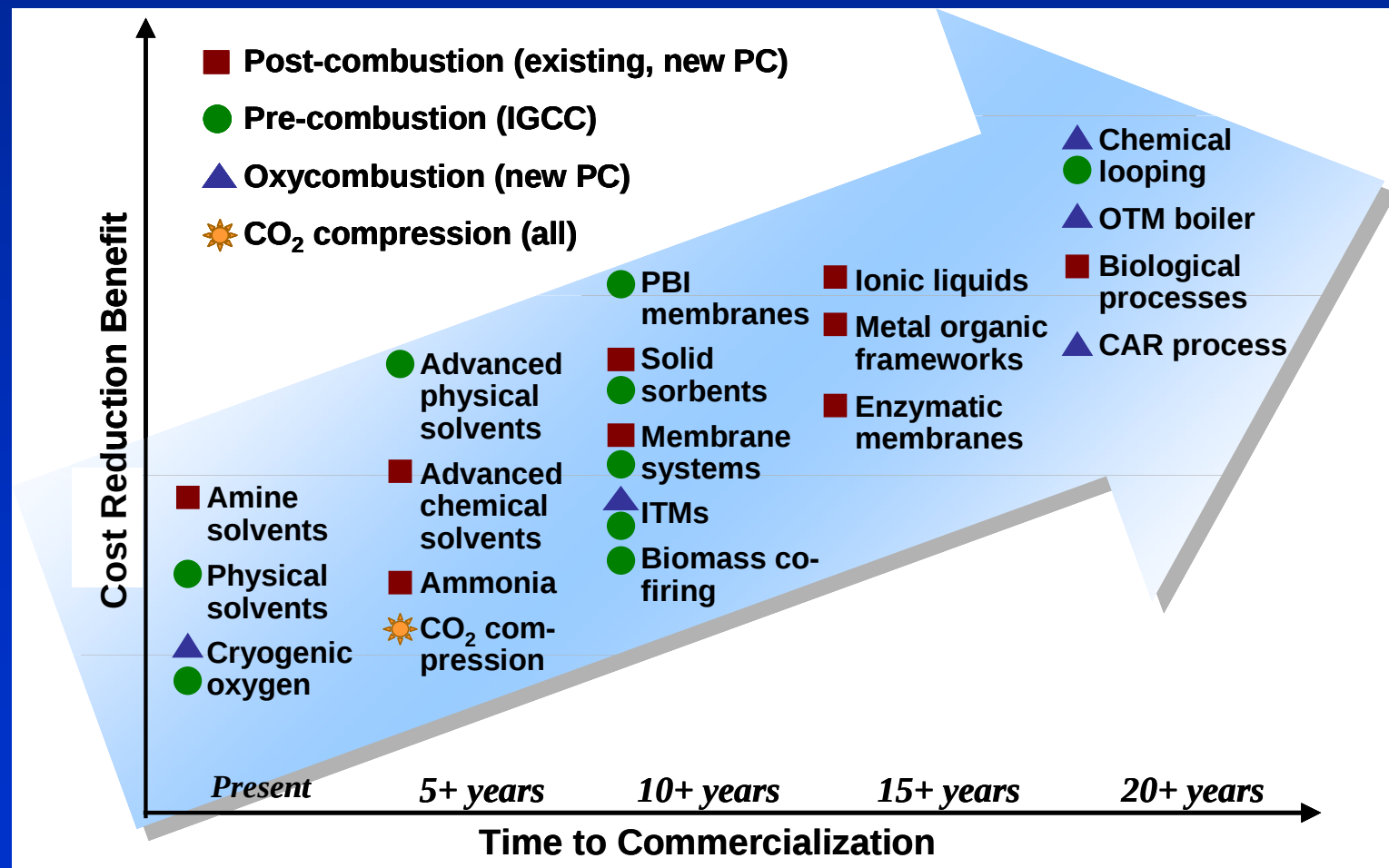


Peterhead, 2014



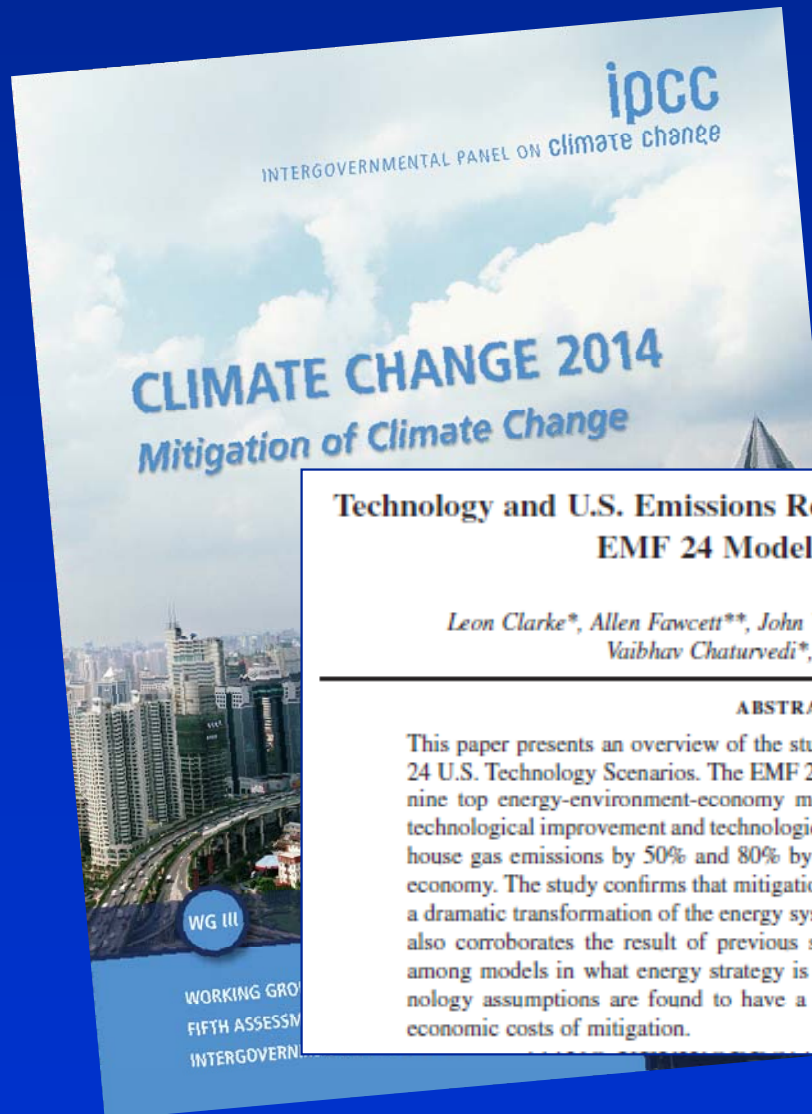
White Rose, 2014

R&D Programs Actively Pursuing Lower-Cost Technologies



Source: USDOE, 2010

New Studies Show Importance of CCS for Climate Change Mitigation



Technology and U.S. Emissions Reductions Goals: Results of the EMF 24 Modeling Exercise

Leon Clarke*, Allen Fawcett**, John Weyant***, James McFarland**,
Vaibhav Chaturvedi*, and Yiyu Zhou*

ABSTRACT

This paper presents an overview of the study design and the results of the EMF 24 U.S. Technology Scenarios. The EMF 24 U.S. Technology Scenarios use nine top energy-environment-economy models to examine the technological improvement and technological availability on reducing greenhouse gas emissions by 50% and 80% by 2050 on the U.S. energy economy. The study confirms that mitigation at the 50% or 80% level requires a dramatic transformation of the energy system over the next 40 years. The study also corroborates the result of previous studies that there is significant uncertainty among models in what energy strategy is considered most cost-effective. Technology assumptions are found to have a large influence on the economic costs of mitigation.

Modeling Optimal Transition Pathways to a Low Carbon Economy in California

California TIMES (CA-TIMES) Model

Prepared for the California Air Resources Board and the California Environmental Protection Agency

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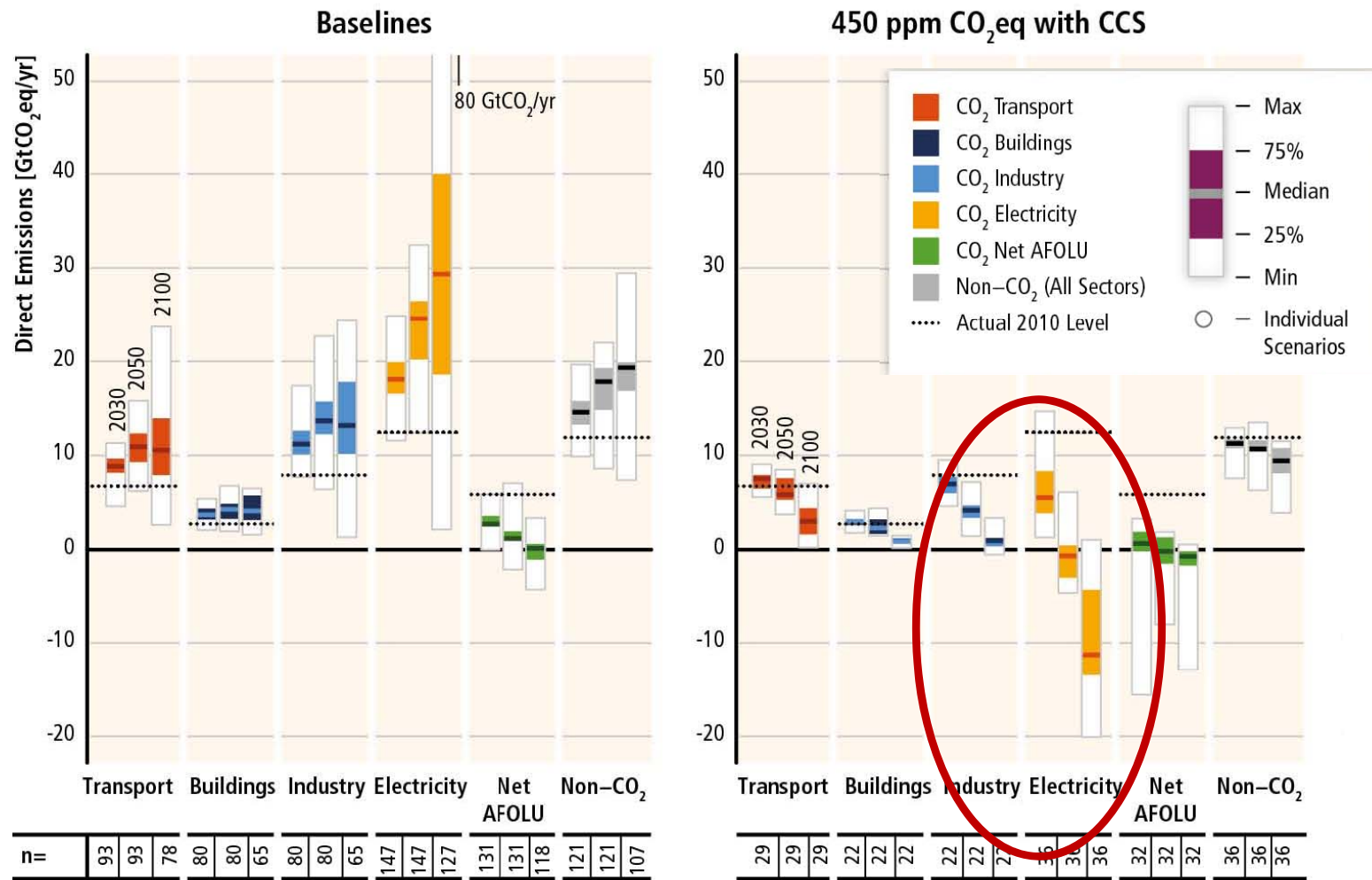
April 2014



The cost-effectiveness of natural gas combined cycle power plants with CO₂ capture and storage in a climate change mitigation strategy

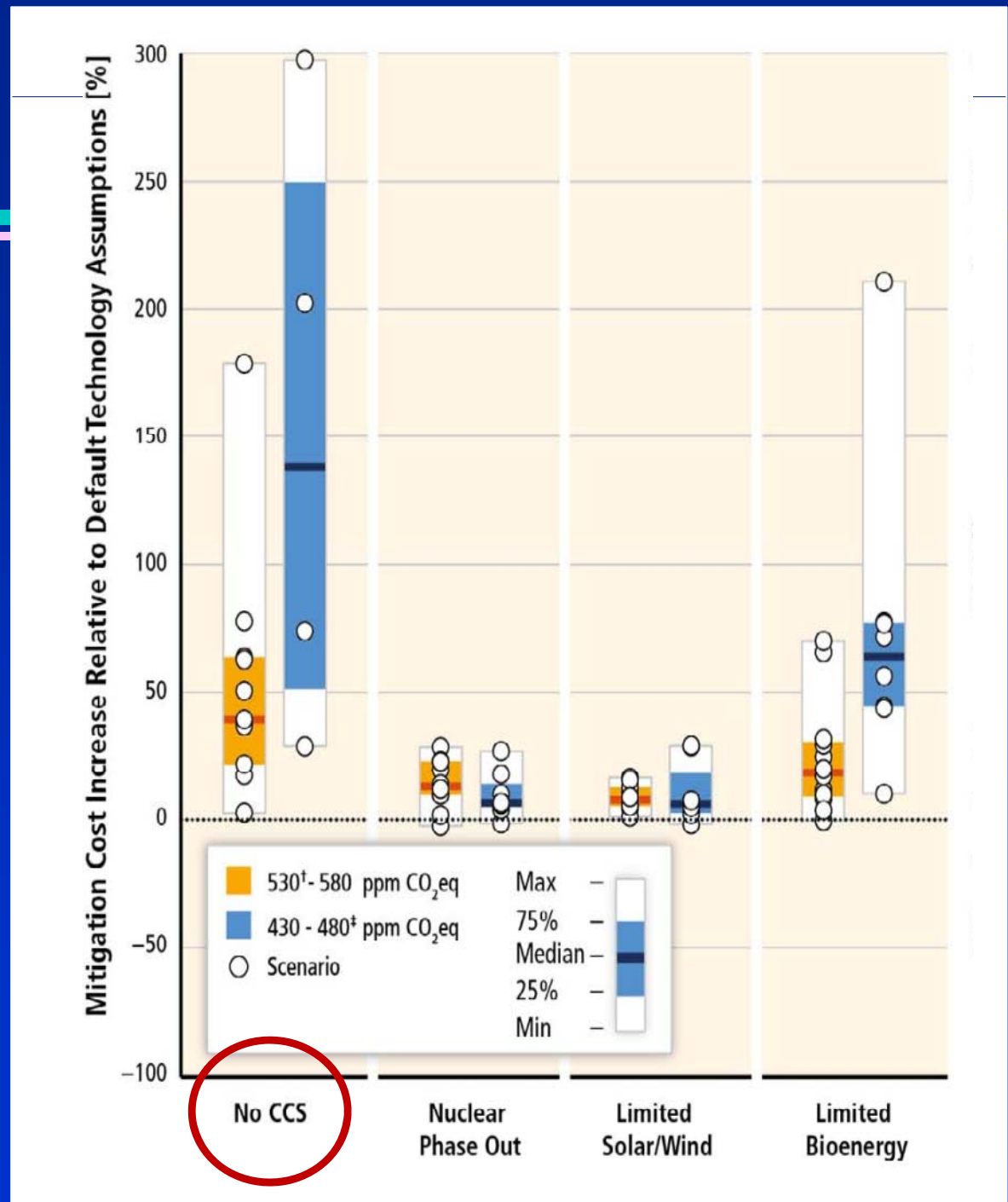
Machteld van den Broek, UU
Niels Berghout, UU
Ed Rubin, Carnegie Mellon University

IPCC affirms CCS as a key component of cost-effective strategies to meet goals

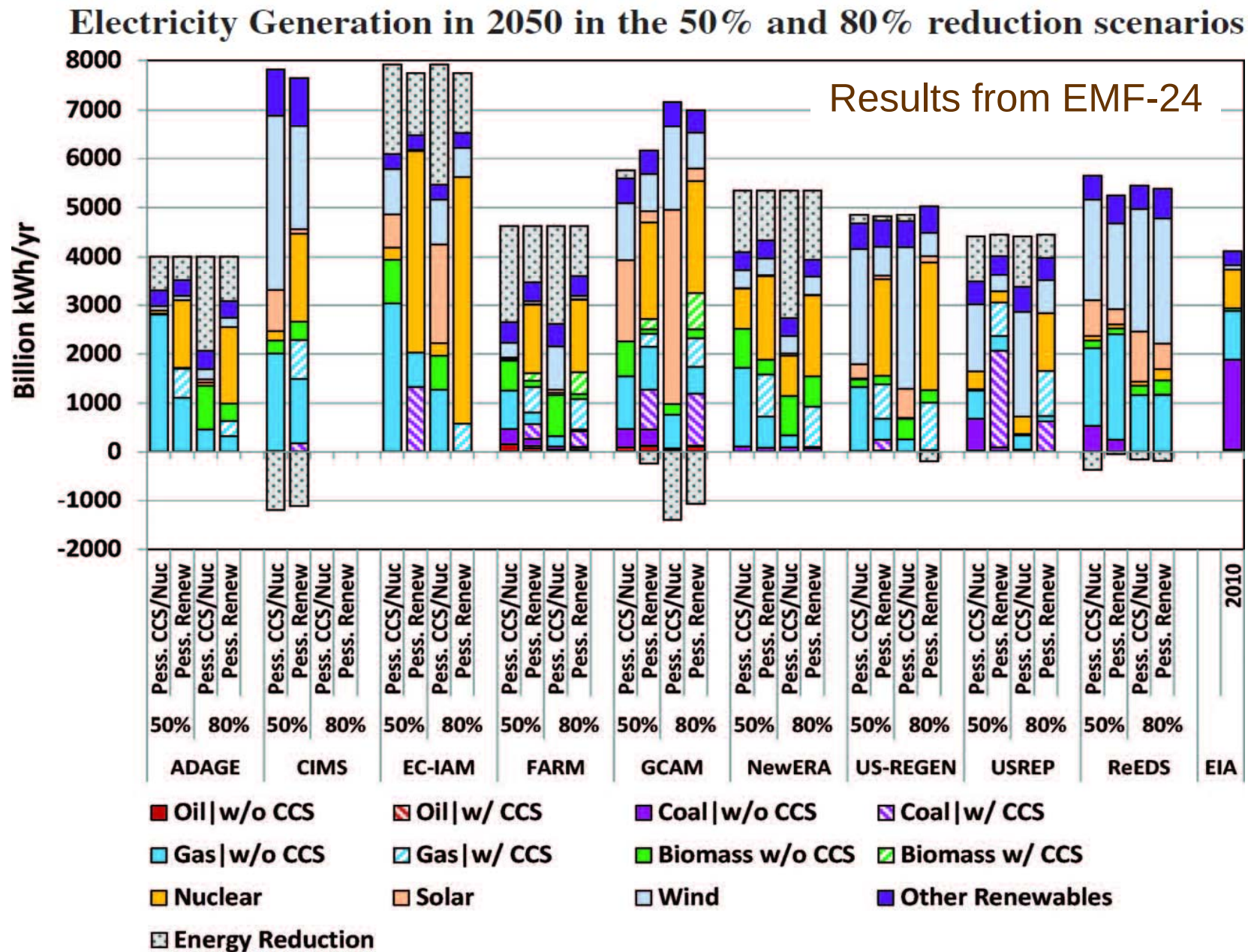


Without CCS...

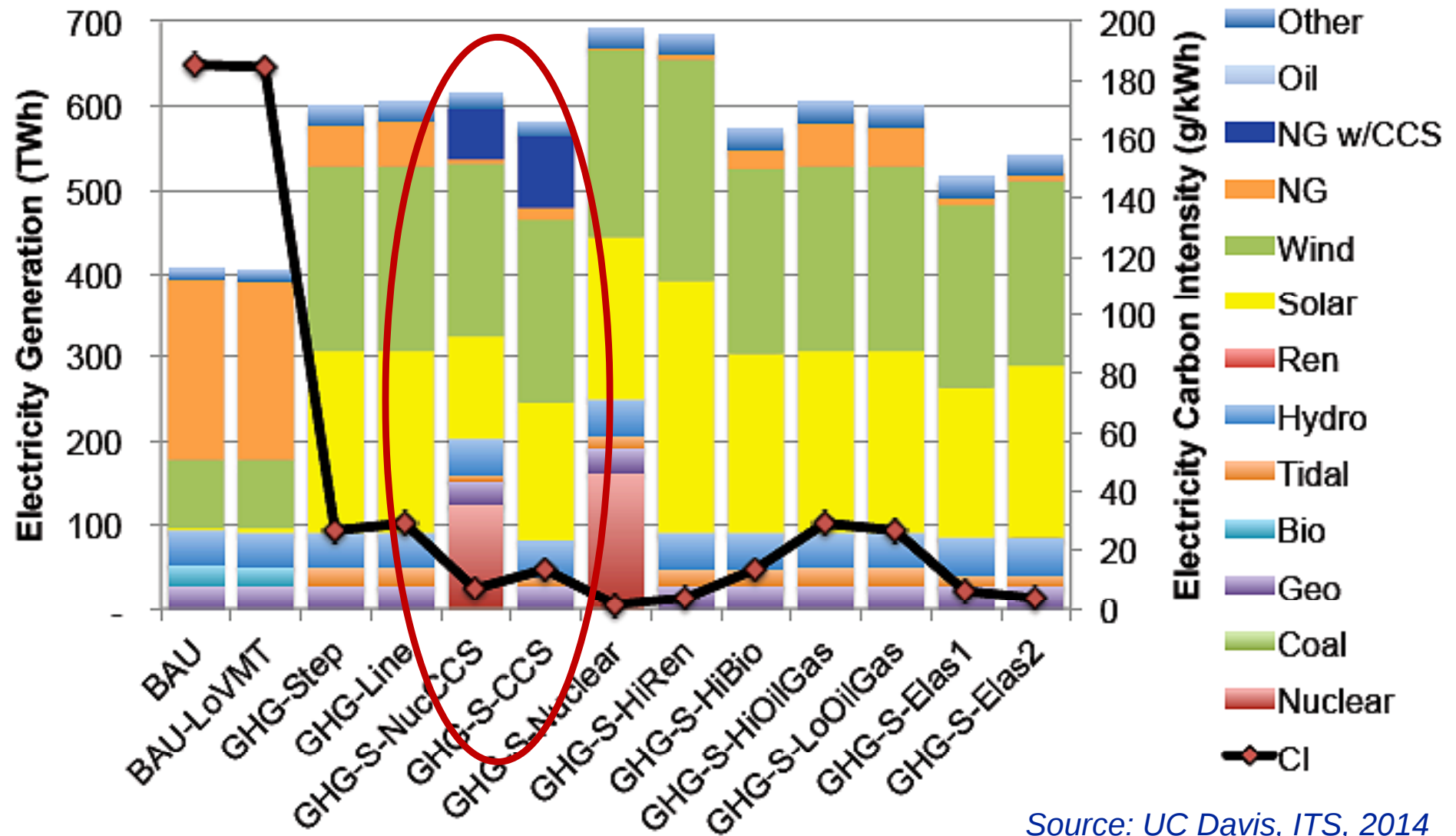
- The cost of mitigating climate change is substantially higher; and ...
- Climate stabilization levels needed may not be achievable



Scenarios for U.S. GHG Reductions



California electricity generation mix and carbon intensity for 2050 scenarios



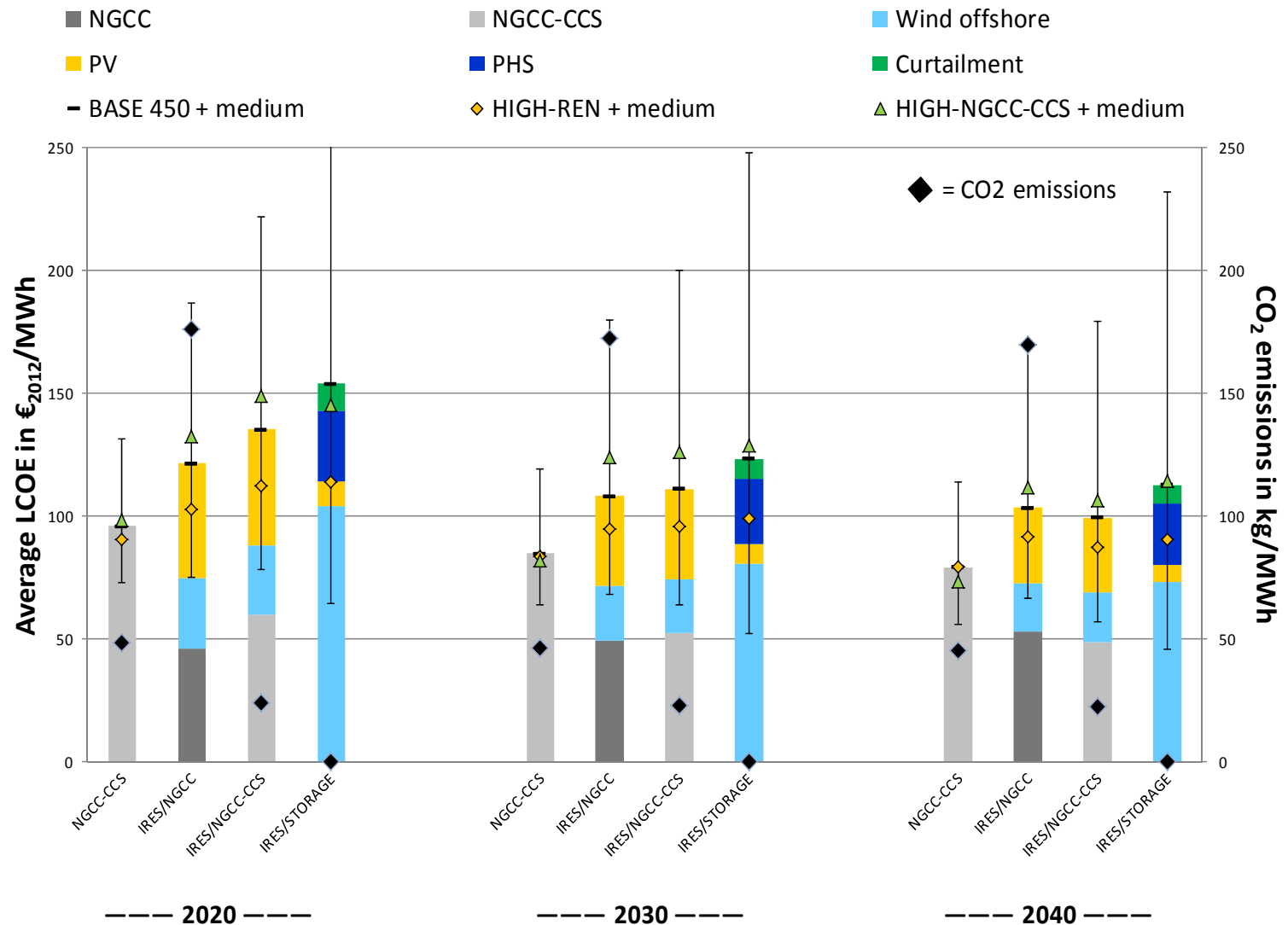
Source: UC Davis, ITS, 2014

Cost-effectiveness of NGCC-CCS vs. Intermittent Renewables for Europe

Results for four stylized electric power systems serving demands under 450 ppm scenarios:

- NGCC-CCS
- IRES+ NGCC
- IRES+ NGCC-CCS
- IRES+ Storage

NGCC-CCS has lowest LCOE and lowest cost of CO₂ avoided thru 2040



The Not-So-Good News

Drawbacks of CCS Technology

- Not yet proven at full-scale power plants
- Legal and regulatory issues remain in some areas (esp. regarding storage sites)
- Varied levels of public acceptance
- It is relatively expensive
 - Utilization for EOR can offset some, but not all, of current CCS costs for power plant projects

A New CCUS Option ☺

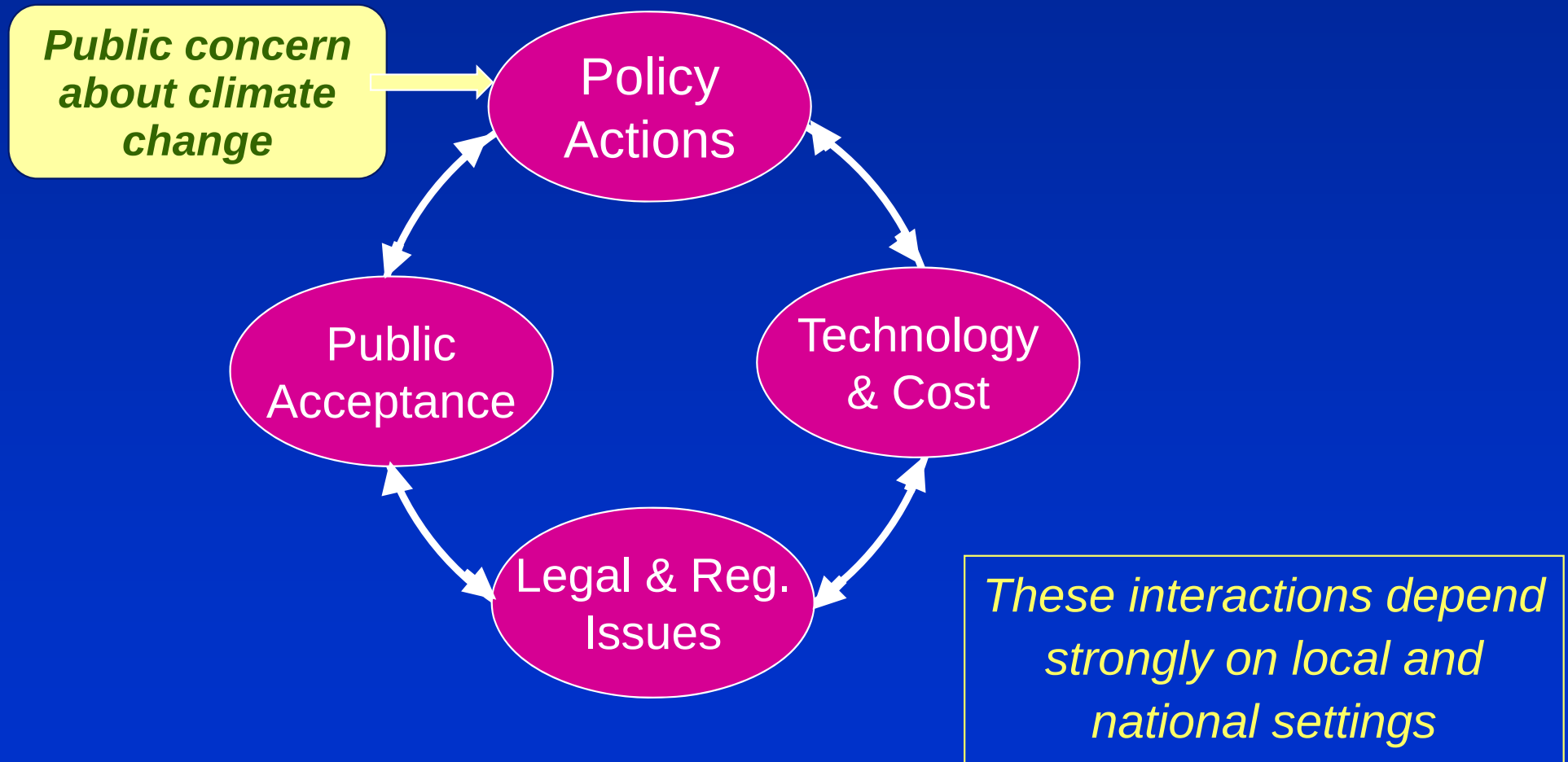


Key Barriers to CCS Deployment

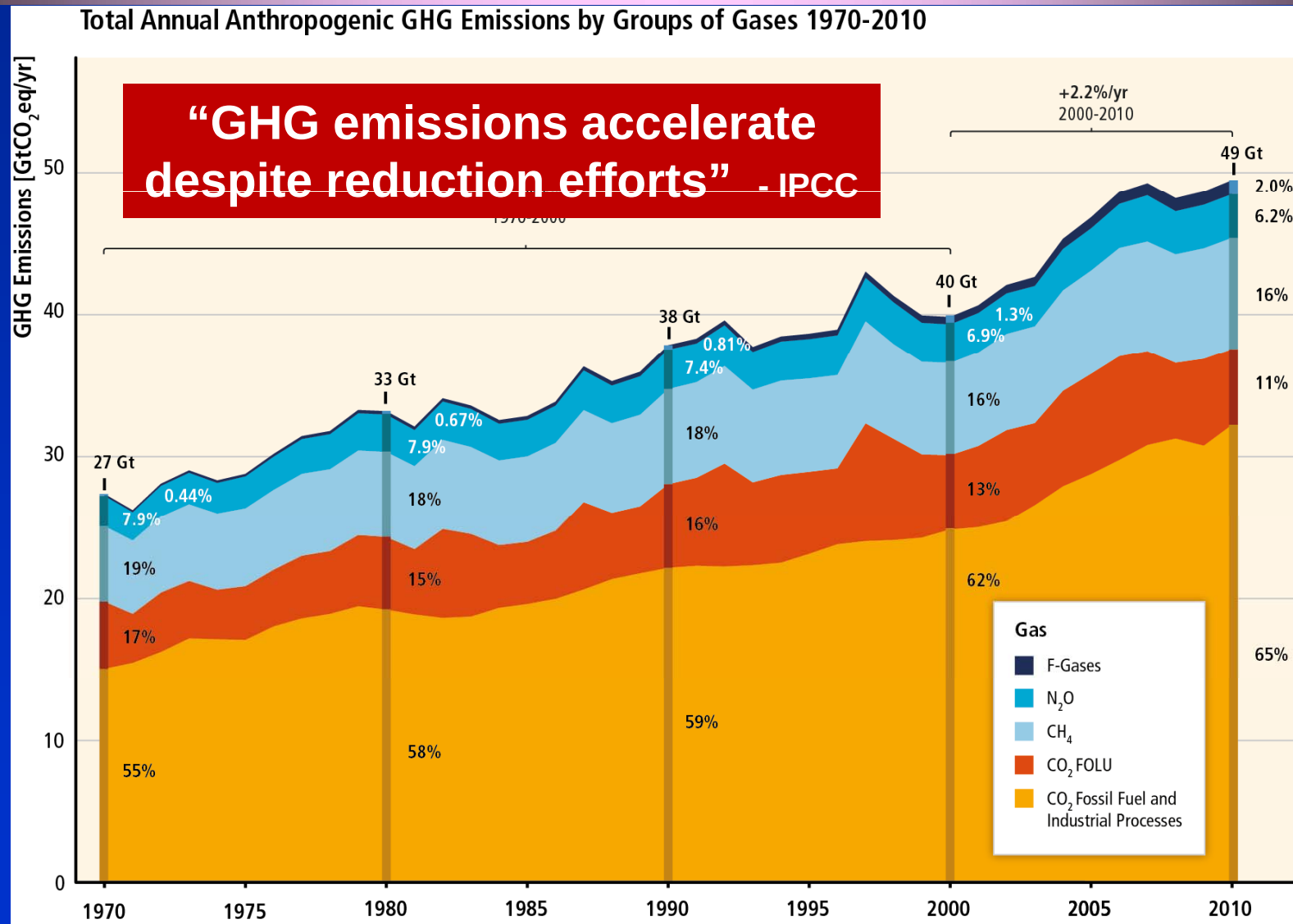
- Policy
- Policy
- Policy

*Without a policy requirement or strong incentive
there is no reason to deploy CCS widely*

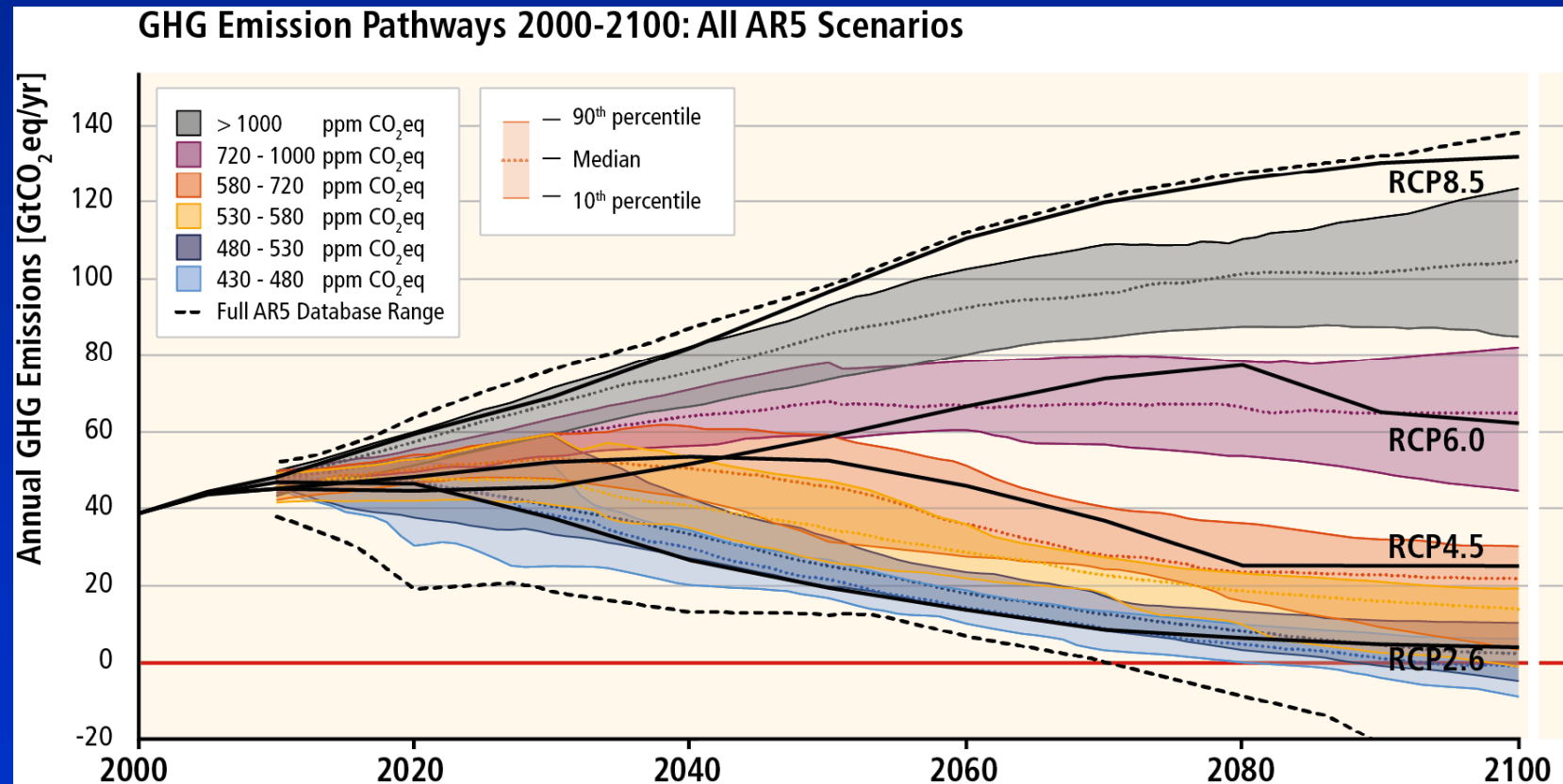
Strong Interactions Between Policy and Other Key Factors



The Climate Problem Hasn't Gone Away



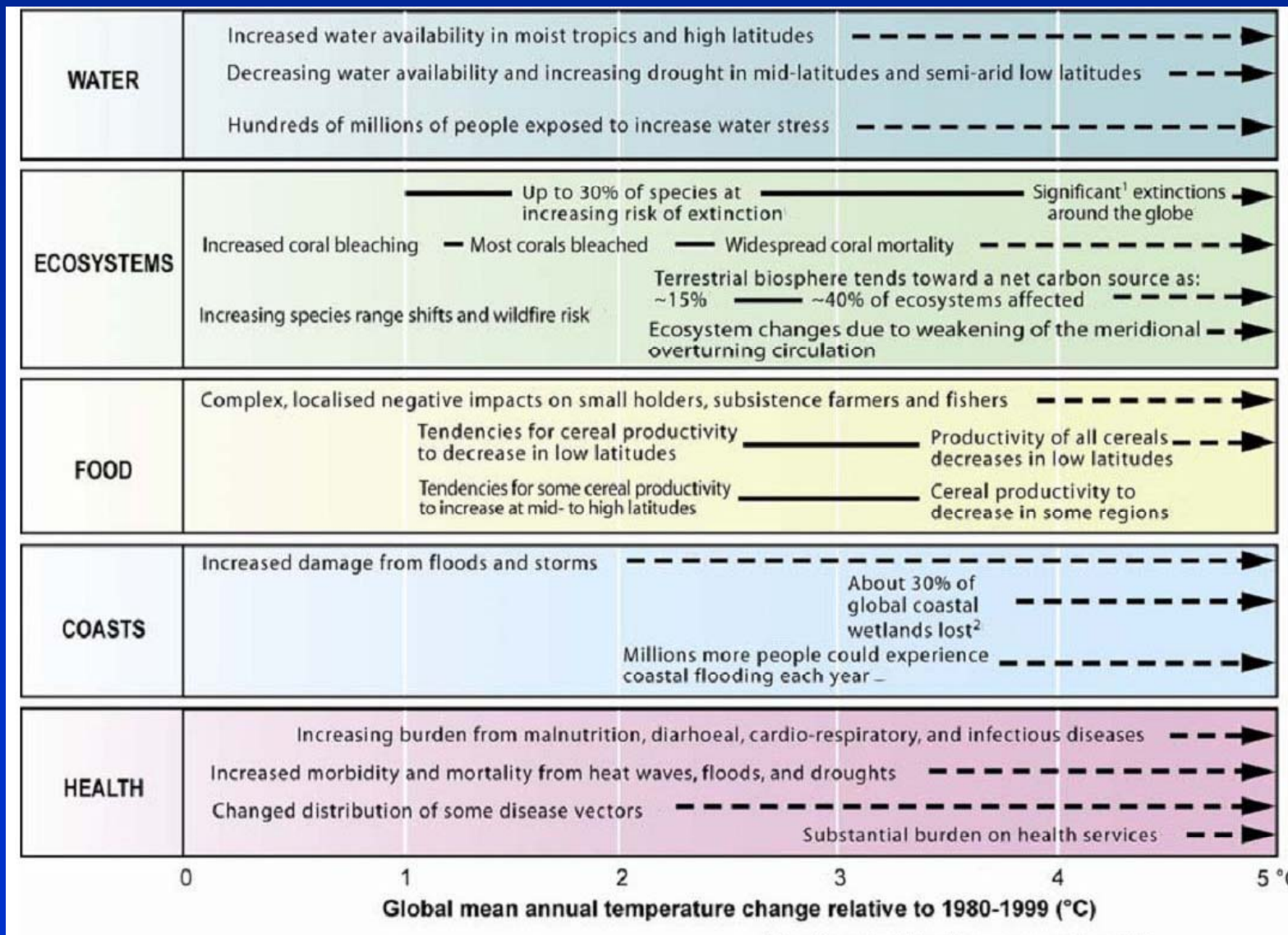
Without mitigation, atmospheric concentrations may more than double before end of century



“Without more mitigation, global mean surface temperature might increase by 3.7° to 4.8°C over the 21st century.” -IPCC

Source: IPCC, WG3, 2014

Impacts grow more severe as global temperature increases



*More extreme events are expected
as atmospheric concentration rises*



This Just In

A-6

PITTSBURGH POST-GAZETTE ■ SUNDAY, APRIL 20, 2014 ■ WWW.POST-GAZETTE.COM

NATIONAL

Political realities slow U.S. effort to enact climate change laws

By Coral Davenport
The New York Times

WASHINGTON—The United States needs to enact a major climate change law, such as a tax on carbon pollution, by the end of this decade to stave off the most catastrophic impacts of global warming, according to the authors of a report released earlier this month by the U.N. Intergovernmental Panel on Climate Change.

But aggressive efforts to tackle climate change have repeatedly collided with political reality in Washington, where some Republicans question the underlying science of global warming and lawmakers' ties to the fossil fuel industry have made them resistant to change. The rise of the Tea Party in recent years has also made a tax increase

— one by President Bill Clinton in 1993 and one by President Barack Obama in 2010 — ultimately failed, contributing to heavy Democratic losses in mid-term elections.

Lawmakers who back such efforts, which represent a threat to the bottom lines of the fossil fuel industry, particularly coal, the nation's top source of carbon pollution, have been criticized by campaigns from Republicans, Tea Party-affiliated "super PACs" like Americans for Prosperity, and the coal and oil industries.

Many members of the Republican Party question the established science that carbon pollution contributes to climate change — and hundreds have also signed on to a pledge promising never to raise taxes.

But there has not been a huge

on coal." The Senate Republican leader, Mitch McConnell, who is running for re-election in the coal-heavy state of Kentucky, has vowed to use every legislative tactic available to block, repeal or delay those rules if Republicans win control of the Senate this fall.

Within that context, many in the Republican establishment think that talking about climate change — and, particularly, any policy endorsing a tax on fossil fuels — would be political suicide for a Republican seeking to win the party's nomination in 2016.

The U.N. report says that if the nation's major economies do not enact steep, fast climate policies well before 2030, in order to cut total global emissions 40 to 70 percent by 2050, the prospects of avoiding a global atmospheric temperature increase of 3.6

quickly push through even more stringent pollution-cutting policies, according to the report's authors.

"We need to increase the slope and the pace of the change," said David Victor, one of the report's authors and an expert on climate and energy policy at the University of California, San Diego. "Accelerating what we're doing in the U.S. will be very important for the next administration."

Despite the history of roadblocks to enacting climate change policy, some experts say they do see some potential for a legislative path to cut U.S. carbon pollution.

One window could open if Congress takes up a comprehensive effort to overhaul the nation's corporate tax code, which could happen after the 2016 presidential election.

pollute.

Historically, California's environmental laws have served as a vanguard and model for national environmental policy. The push for state-level policies could rise, say experts, if there is a significant increase in extreme weather like droughts and flooding, which contribute to higher adaptation costs for state and local governments.

"The question is whether state and local entities want to see action — and if that can then be translated to local action," said Thomas Peterson, founder of the Center for Climate Strategies, a nonprofit group that works on climate policy with state governments.

Last week's report said the impact of climate change was already being experienced, and it followed on earlier scientific

A Path Forward

Ingredients of a Realistic Path Forward for CCS

- Successful startup and completion of planned demonstration projects
- Launching of new projects for “next generation” processes
- Sustained R&D programs worldwide
- Strong policy drivers for CCS
 - Carrots
 - Sticks

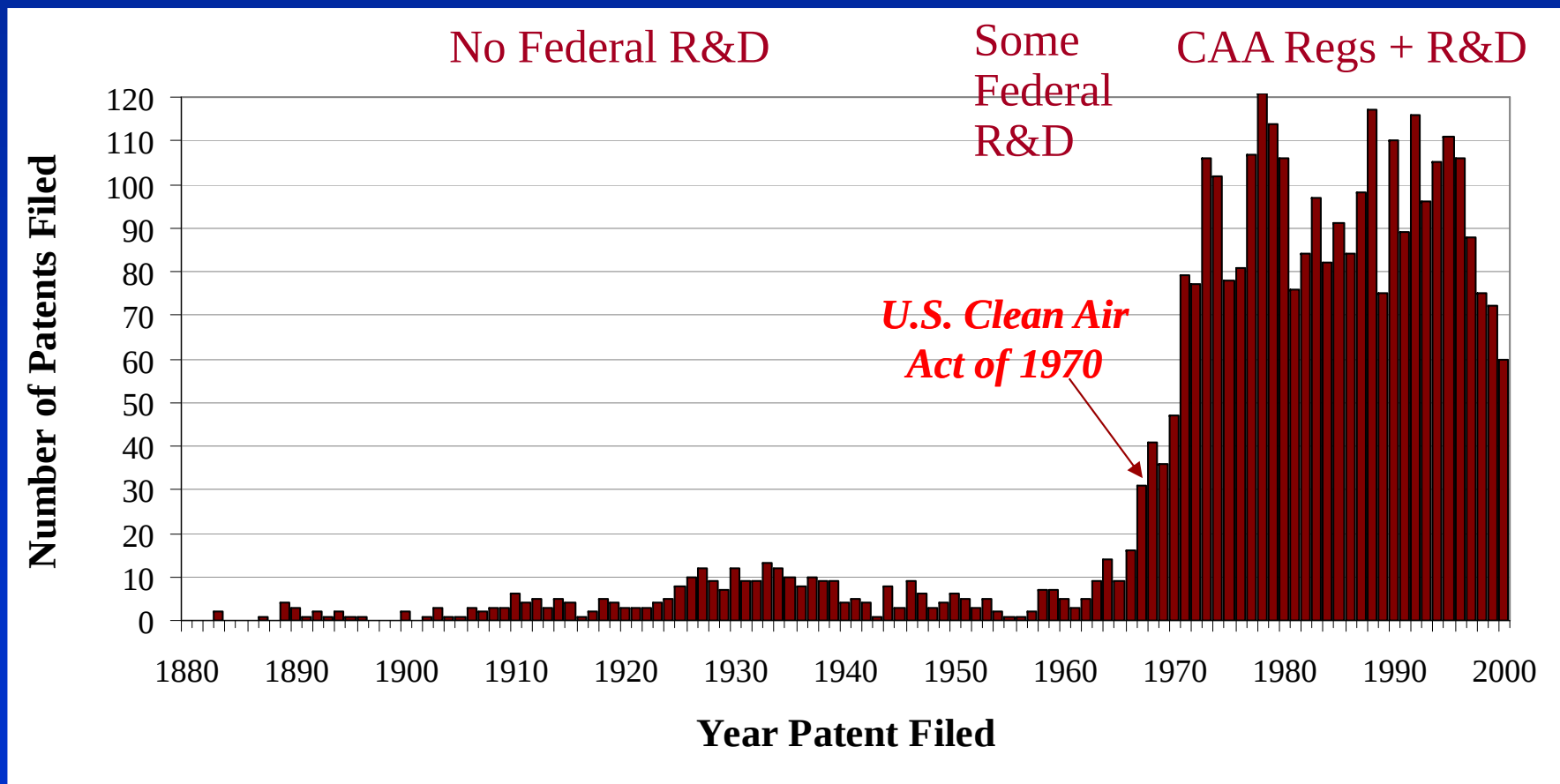
Policy options that can foster CCS and technology innovation

“Technology Policy” Options			Regulatory Policy Options
Direct Gov’t Funding of Knowledge Generation	Direct or Indirect Support for Commercialization and Production	Knowledge Diffusion and Learning	Economy-wide, Sector-wide, or Technology- Specific Regs and Standards
• R&D contracts with private firms (fully funded or cost-shared) • Intramural R&D in government laboratories • R&D contracts with consortia or collaborations	• R&D tax credits • Patents • Production subsidies or tax credit for firms bringing new technologies to market • Tax credits, rebates, or payments for purchasers/users of new technologies • Gov’t procurement of new or advanced technologies • Demonstration projects • Loan guarantees • Monetary prizes	• Education and training • Codification and diffusion of technical knowledge (e.g., via interpretation and validation of R&D results; screening; support for databases) • Technical standards • Technology/Industry extension program • Publicity, persuasion and consumer information	• Emissions tax • Cap-and-trade program • Performance standards (for emission rates, efficiency, or other measures of performance) • Fuels tax • Portfolio standards

Source: NRC, 2010

Inventive activity in SO₂ control soared after CAA requirements

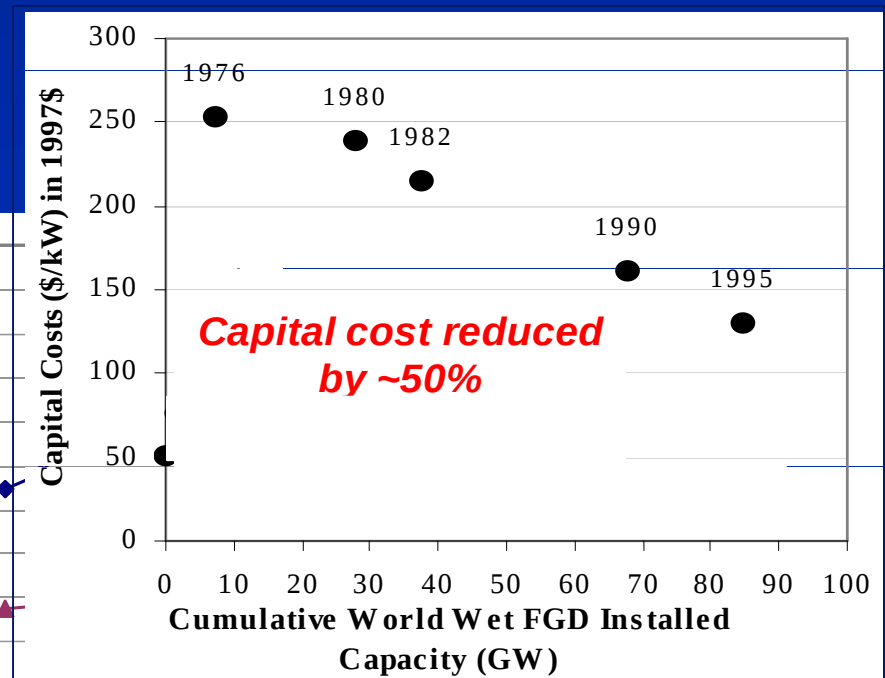
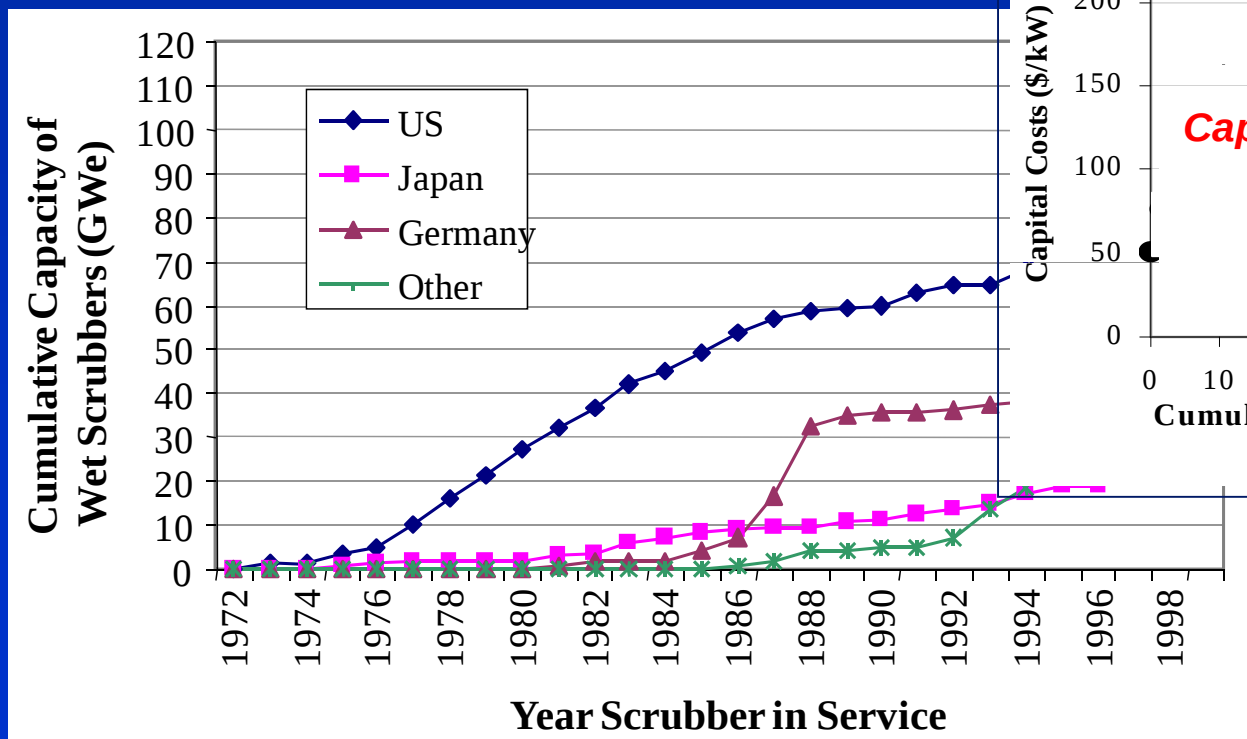
U.S. patenting activity in SO₂ control technology, 1880–2000



Source: Rubin et al. 2007

Trends in FGD Deployment and Cost (1972–2000)

Technology innovations reduced SO_2 capture costs dramatically as global markets grew in response to new policy requirements



Source: Rubin et al. 2007

Could CCS follow a similar path?

Some Recent Developments

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EPA UNVEILS RETOOLED CARBON STANDARDS FOR NEW PLANTS

Sets Separate Rules for Coal and Gas; Lists CCS as 'Best System of Emission Reduction'

Tamar Hallerman
GHG Monitor
9/20/13

The Environmental Protection Agency unveiled a retooled carbon pollution rule for new power plants today that sets separate standards for coal and gas units and provides incentives for plant developers to install carbon capture and storage technology. The rule sets limits for power plants depending on the type of unit:

- Coal-fired units – 1,100 lbs CO₂/MWh over a 12-month operating period;
- Coal-fired units that choose to average their emissions over a seven-year period – 1,000 to 1,050 lbs CO₂/MWh;
- Gas-fired turbines larger than 850 mmBtu/hr – 1,000 lbs CO₂/MWh; and
- Gas-fired turbines smaller than 850 mmBtu/hr – 1,100 lbs/MWh

EPA retooled the standards after receiving what it said were more than 2.5 million public comments on its initial proposal. The agency had previously set a performance standard of 1,000 lbs CO₂/MWh. EPA rescinded that old proposal today in light of the new standard. "We are very confident that the carbon pollution standards that we are proposing today for new power plants will be forward for the next generation of power plants in this country," EPA Administrator Gina McCarthy told reporters.

'Best System of Emission Reduction'

EPA lists CCS as the "best system of emission reduction" in the text of the proposed rule, citing four power plants (Kemper County, Boundary Dam, Texas Clean Energy Project and Hydrogen Energy California) as evidence. The rulemaking states that power plant operators would only need to install "partial" carbon capture in order to capture provides meaningful emission reductions, it has been adequately demonstrated to be technically feasible for deployment and further development of the technology," the rule states. An EPA official said that most coal plants are not meeting the standards.

In order to incentivize developers to install CCS technology, EPA said it would allow plant operators the option to opt out of the standard for CCS. "We understand that CCS may present a challenge out of the gate in terms of whether or not you understand how to operate a plant with CCS, but we think it's a slightly lower standard for the opportunity to have seven years to make the system right for you," McCarthy said. "If it's technically feasible, it's already available and it's being constructed today." The seven year time frame is shorter than the original April 2012 proposal.

The agency will be accepting public comments on the new proposal for 60 days after it is published in the Federal Register. EPA also plans on holding a public meeting on the rule in the near future.

BBC NEWS

SCIENCE & ENVIRONMENT

17 April 2014 Last updated at 12:12 ET

EU green light for UK carbon capture and storage project



By Matt McGrath
Environment correspondent, BBC News

A UK project to capture CO₂ and bury it under the North Sea looks set to receive a 300m-euro boost from the EU.

The European Commission has confirmed that the [White Rose carbon capture and storage](#) (CCS) project is in line to win the cash (equivalent to about £250m).

What is the Future of CCS ?

- Will soon see first large-scale power plant demonstrations, with
- Continued support for R&D; but ...
- Growth will depend on the outlook for strong policy drivers that create markets for CCS
- **WATCH THIS SPACE FOR FUTURE UPDATES**



Thank You

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