

The Role of Carbon Dioxide Capture and Storage (CCS) in Addressing the Climate Change Challenge

University of Sevilla

May 4, 2016

Overview

What is CCS?

Carbon dioxide (CO₂) capture and storage (CCS) is a process consisting of separation of CO₂ from industrial and energy-related sources, transport to a storage location, and long-term isolation from the atmosphere.

Intergovernmental Panel on Climate Change (IPCC)
Special Report on Carbon Dioxide Capture and Storage

CCS

Sources and Sinks

- Large Stationary Point Sources
 - Power – Coal, Biomass, Natural Gas
 - Industrial –
 - » High Purity - Gas Processing, Ammonia, Ethanol, Hydrogen (Refineries)
 - » Other – Cement, Steel, Refineries
- Sinks
 - Geologic Formations
 - » Proven - Depleted Oil & Gas Reservoirs, Deep Saline Formations
 - » Speculative – Unmineable Coal Seams, Basalts
 - Utilization
 - » Proven – EOR, Commercial Markets
 - » Speculative – Building materials, Chemicals, Fuels

Sleipner (North Sea, Norway), 1996 World's First Commercial CCS Project



Boundary Dam, 2014

World's First CCS Power Plant



Howard Herzog / MIT Energy Initiative

IPCC Assessment Report 5 (AR5)

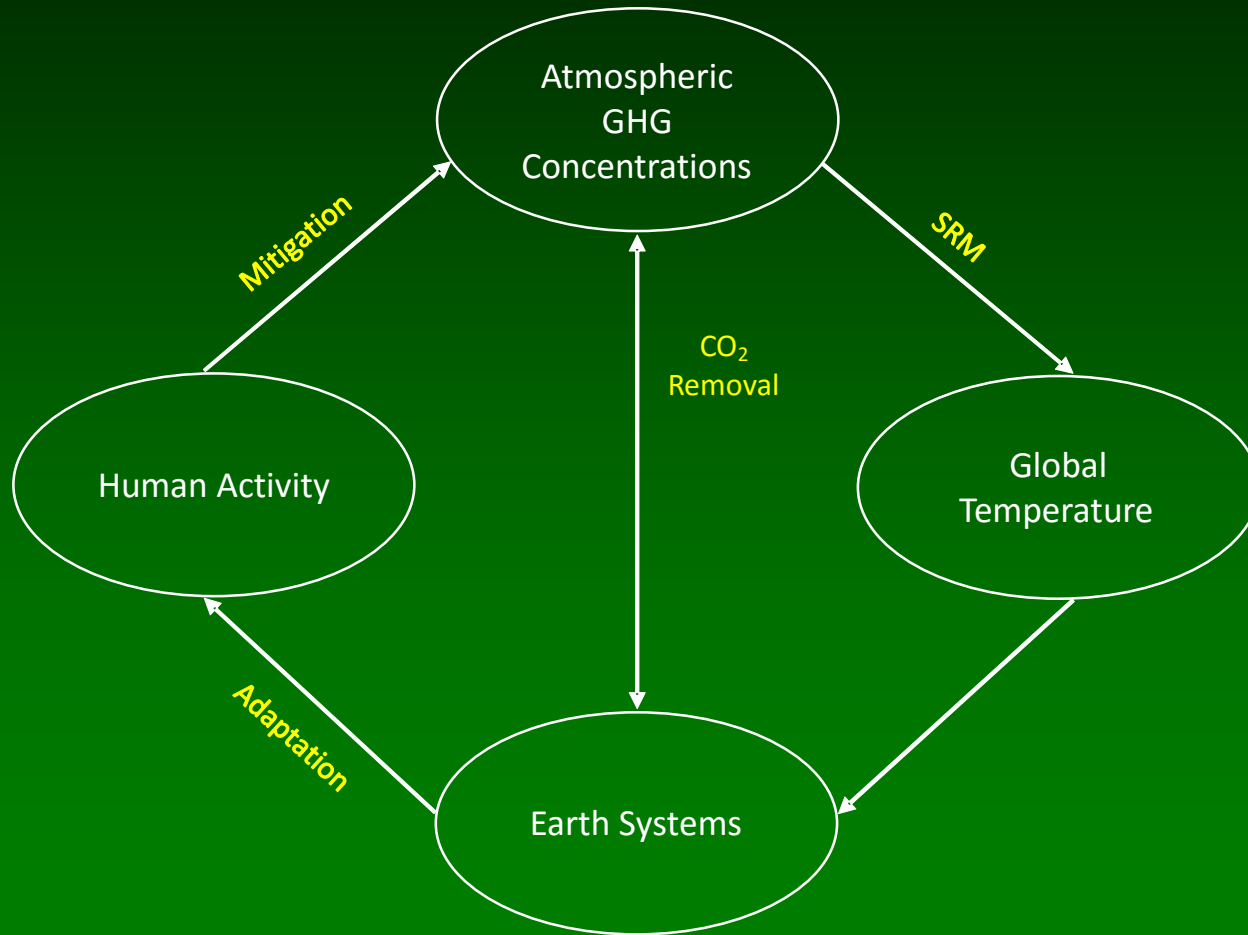
Working Group 3 - Summary for Policy Makers

- April, 2014
- CCS mentioned 35 times
- Key points:
 - CCS reduces costs of meeting key stabilization targets (i.e., 450 and 550 ppm)
 - Strong call by IPCC for negative emissions by BECCS (bio-CCS)
 - Without CCS, certain targets cannot be met (due in part to CCS role in negative emissions)

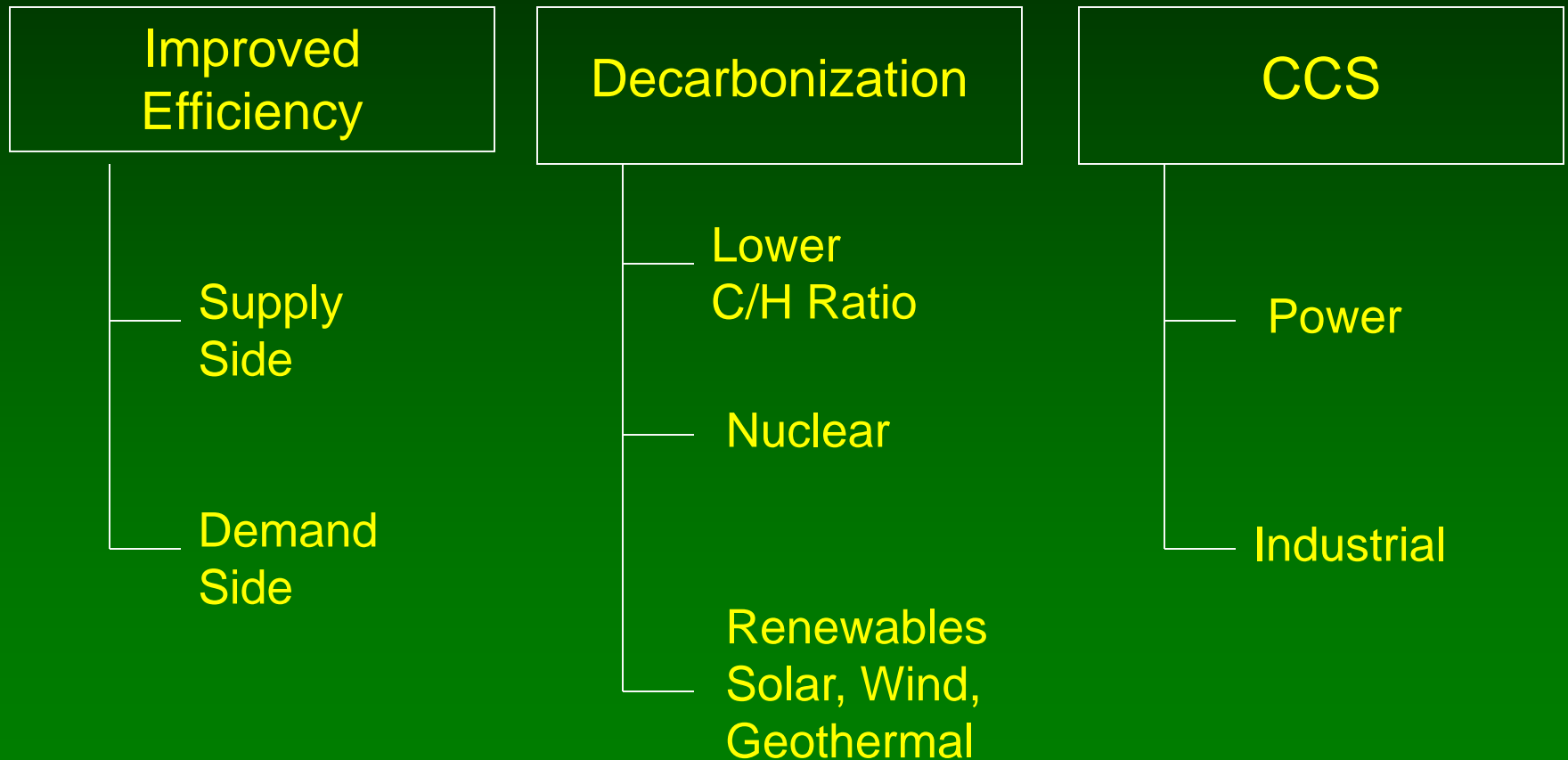
Options to Address Climate Change

Intervention Strategies

Intervention Strategies

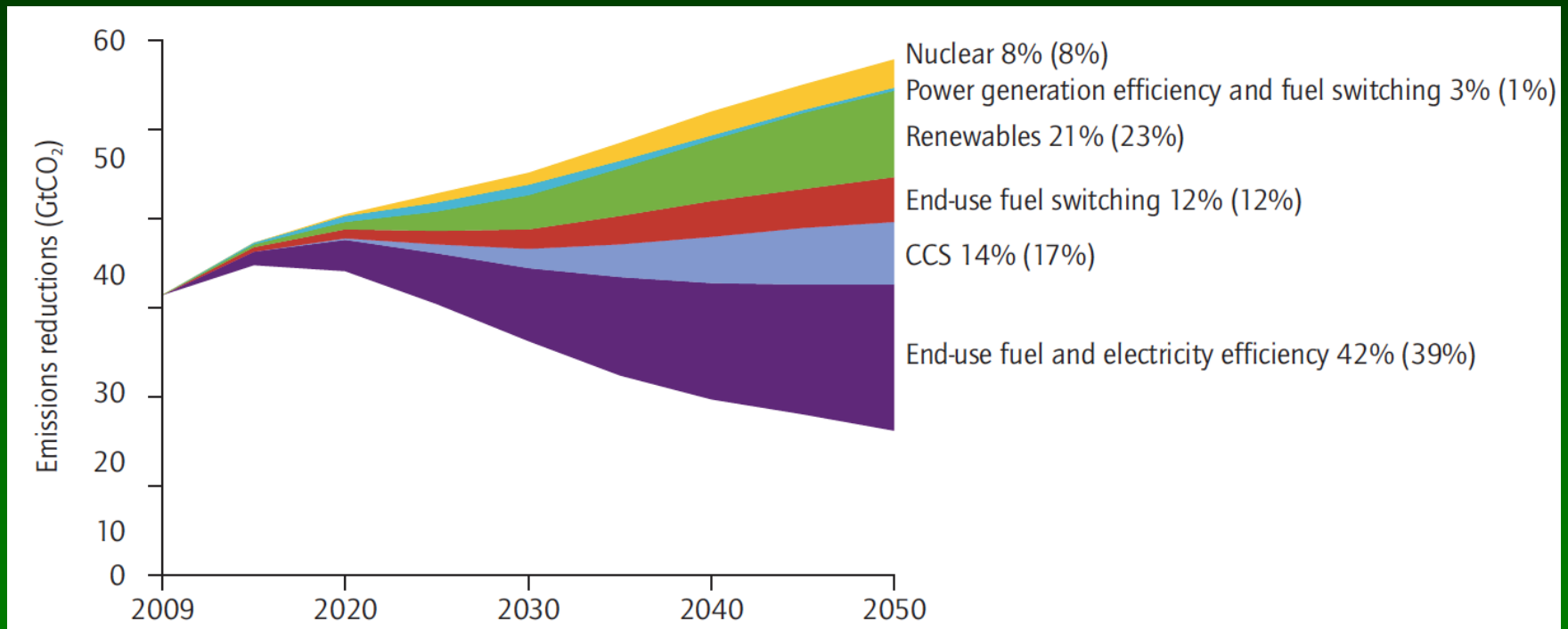


CO₂ Mitigation Options



Role of CCS in a Mitigation Portfolio

Portfolio of CO₂ Emissions Reductions for 2DS through 2050



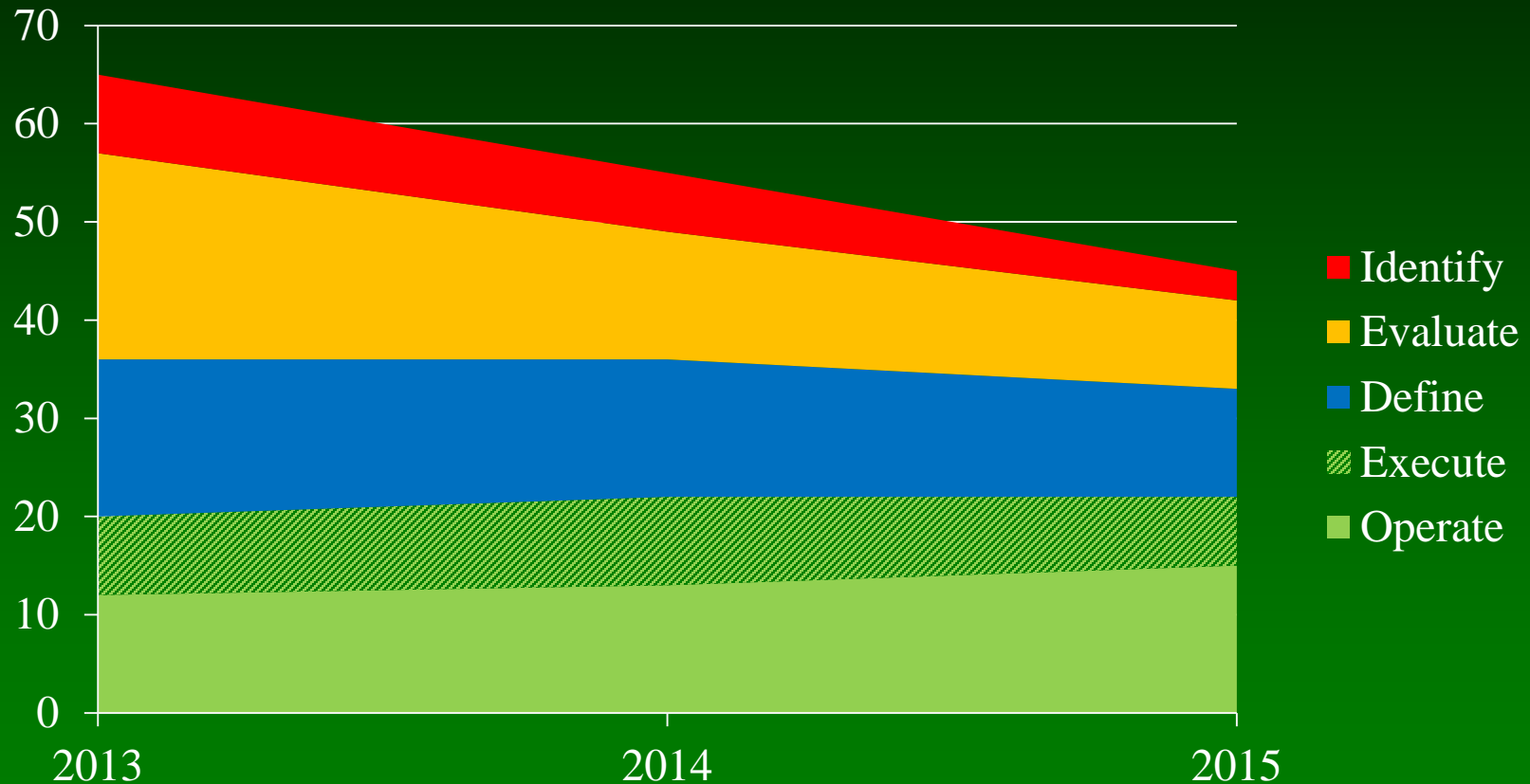
IEA CCS Roadmap, 2013; consistent with World Energy Outlook 450 Scenario through 2035

CCS at a Crossroads

The Crossroads

- CCS Technology Development has made great strides in the past 25 years
- The technology is ready for commercial scale demonstration and deployment
- However, the necessary markets have not developed due to lack of strong climate policy

CCS Project Pipeline

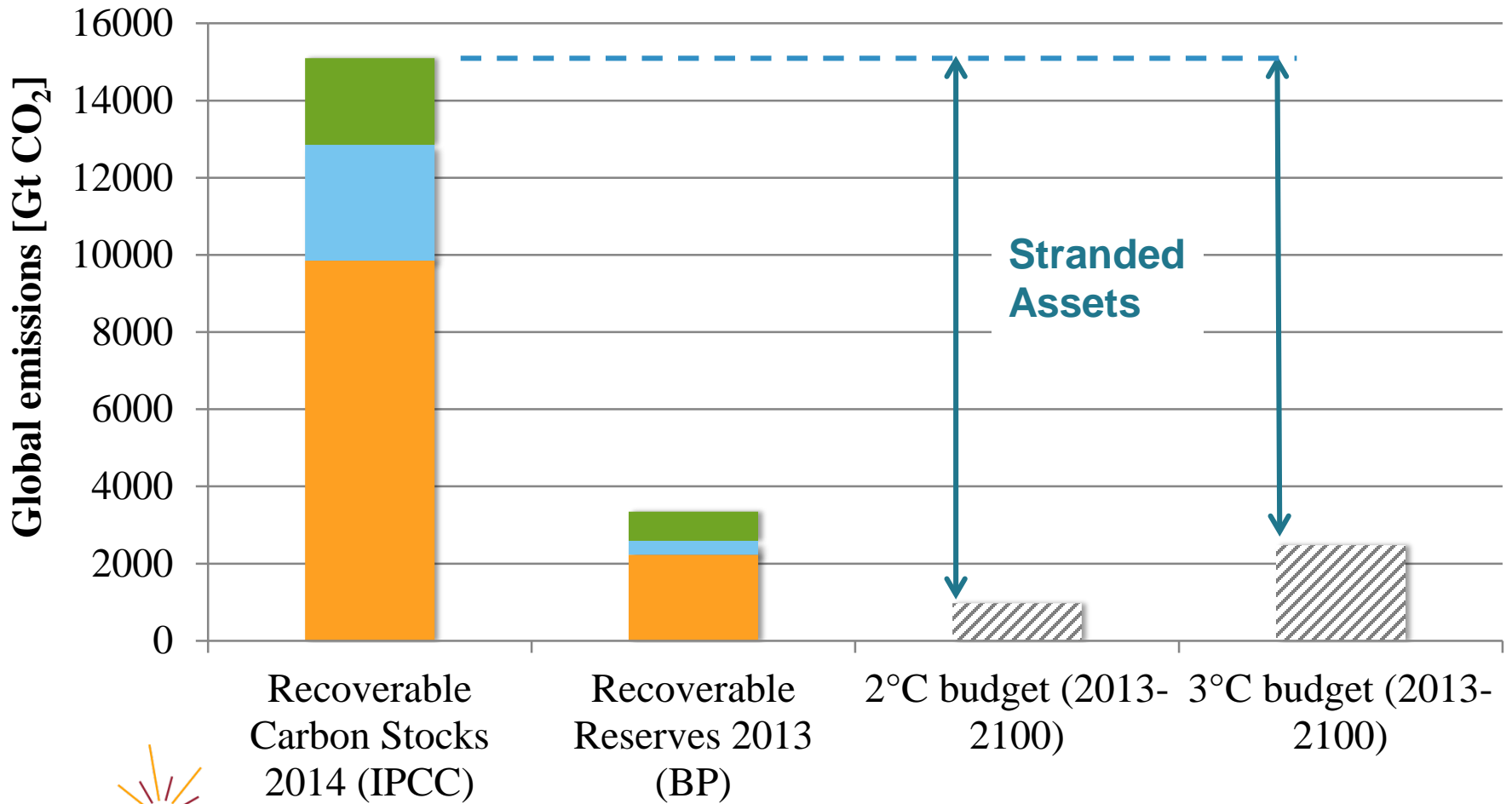
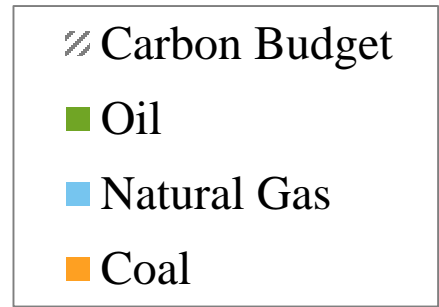


Data from the GCCSI

Inherent Strengths of CCS

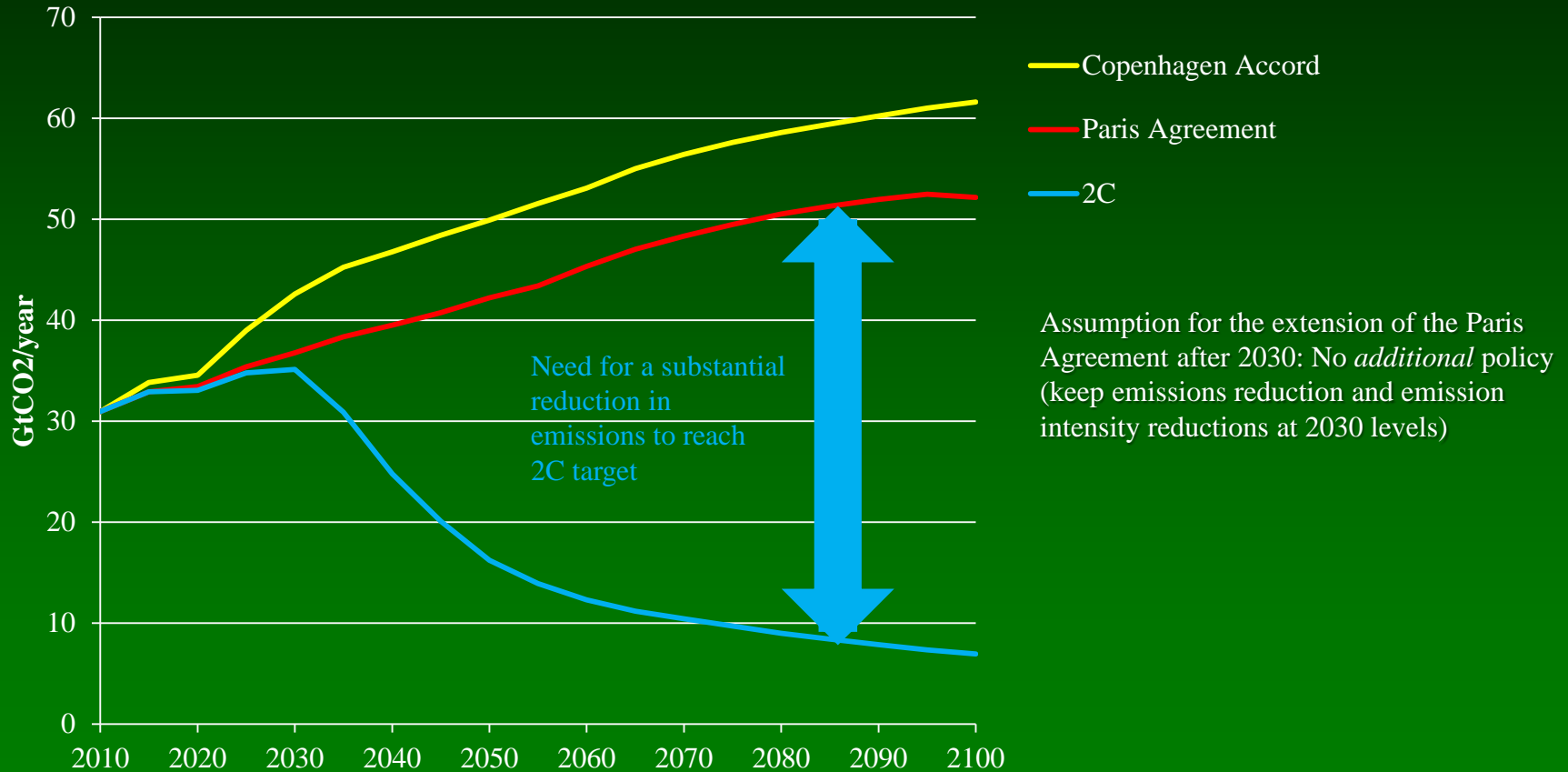
- It produces dispatchable power, as opposed to intermittent power from wind and solar.
- It is the primary option for energy intensive industries like cement, refineries, petrochemicals, and iron & steel
- It is the only mitigation technology that can rescue potentially hundreds of trillions of dollars of stranded fossil assets.
- It provides the major pathway to negative emissions when combined with biomass-fired power plants.

FOSSIL FUEL ASSETS AND CLIMATE CHANGE



Policy

Mitigation Status Report



Source: MIT Joint Program Outlook (2013); MIT Joint Program Report 291 (2016)

Climate Policy or Renewable Policy?

- I would argue that most countries have a renewable/efficiency policy, not a climate policy
 - Renewables have strong political constituencies, which translates into political clout
- Example Germany
 - Achieved over 30% electricity generation with renewables, but
 - » Increased CO₂ emissions
 - » Highest electricity cost in Europe
 - » Electric utilities are under financial duress
 - » Upset neighbors being randomly flooded with excess electricity
- Cost effective mitigation requires a mix of technologies
 - Carbon pricing is most effective solution

Current US Policies

- Support Renewables and Efficiency
 - Portfolio Standards for Renewables
 - Efficiency Standards (including CAFE)
 - Solar Investment Tax Credits plus Net Metering
 - Wind Production Tax Credits
- CO₂ Storage Tax Credits and Loan Guarantees
- Clean Power Plan
- Fight Fossil (grass roots policy)
 - Keystone pipeline
 - Coal export terminals on US West Coast
 - Hydraulic Fracturing
 - LNG export terminals
 - Arctic drilling
 - Divestiture

Financing CCS Projects

- Market Pull
 - Carbon markets
 - Electricity markets
 - Enhanced Oil Recovery (EOR)
 - Others (e.g., polygeneration)
- Technology Push
 - Direct Subsidies
 - Tax credits (e.g., investment, production)
 - Loan guarantees
 - Mandates (e.g., portfolio standards)
 - Others (e.g., Feed-in tariffs, contracts-for-differences)
- Other Drivers
 - Regulatory
 - Business

Closing Thoughts

Paris Agreement

- Nationally Determined Commitments
 - Commits to perhaps 20% of mitigation efforts ultimately needed for stabilization
 - These will be the “easiest” 20%
 - Not even sure countries will follow through on their commitments
 - CCS not needed
- Stabilization Goals
 - Can we get their without CCS?

Contact Information



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CO₂ Removal Options

- **BECCS:** Bioenergy with carbon capture and storage
- **DAC:** Direct air capture of CO₂ from ambient air by engineered chemical reactions
- **EW:** Enhanced weathering of minerals, where natural weathering to remove CO₂ from the atmosphere is accelerated and the products stored in soils, or buried in land or deep ocean
- **AR:** Afforestation and reforestation to fix atmospheric carbon in biomass and soils
- **Ocean:** Manipulation of carbon uptake by the ocean, either biologically (that is, by fertilizing nutrient-limited areas) or chemically (that is, by enhancing alkalinity)
- **Agriculture:** Altered agricultural practices, such as increased carbon storage in soils
- **Biochar:** Converting biomass to recalcitrant biochar, for use as a soil amendment.

From Smith, et al., “Biophysical and economic limits to negative CO₂ emissions”, *Nature Climate Change*, **6**, January (2016).

Where is Best Opportunity for CCS?

Application	Pro	Con
Coal-fired Power	Largest Source	Lots of Competition
Gas-Fired Power	Growing Energy Source	Capacity Factors
Industrial CCS	Only Option	Counties do not want to put their industries at a competitive disadvantage
Negative Emissions	Silver Bullet	Very Expensive