CCS – Renewing the vision

25 February 2015

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Carbon capture and storage

What I plan to say

- The case for CCS continues to grow
- What CCS could be, and why it is not
- Where is CCS succeeding, and why?
- A new narrative for CCS in the EU?

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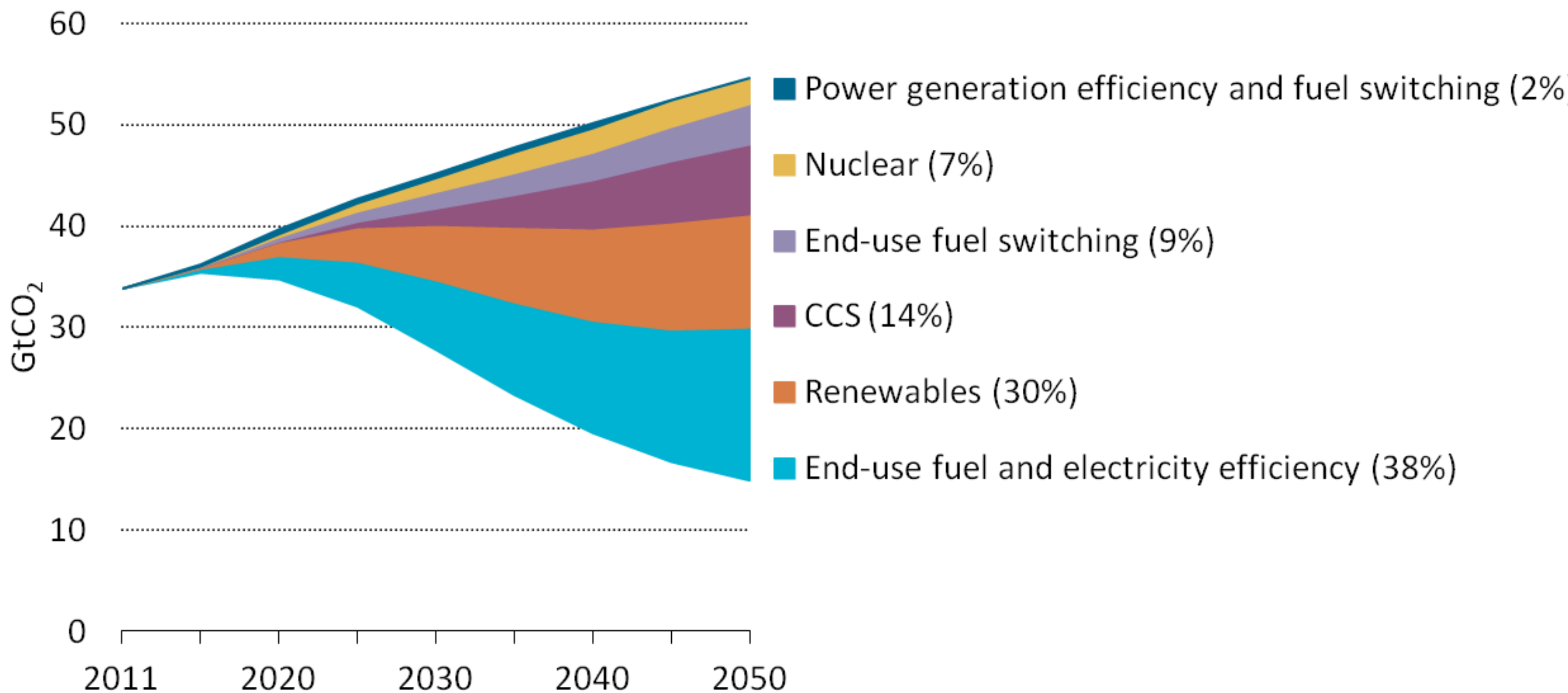
The case for CCS continues to grow



14% of total emissions reductions through 2050 relative to the 6DS (IEA, 2014)

If CCS is unavailable to the electricity sector, total CAPEX requirements rise by 40% (IEA, 2012)

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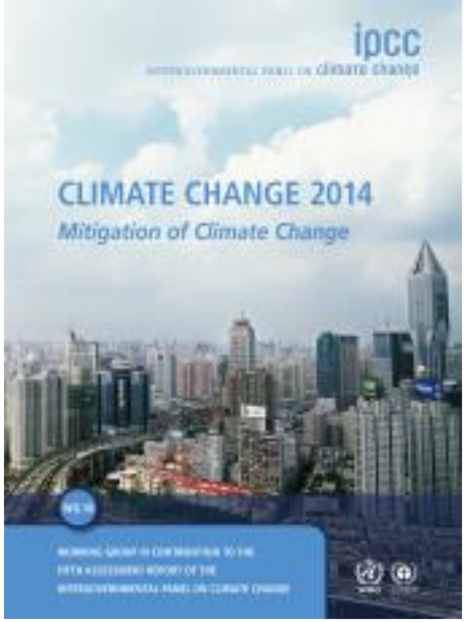
The case for CCS continues to grow

the lack of availability of CCS is most frequently associated with the most significant cost increase

Many models could not achieve atmospheric concentration levels of about 450 ppm CO_2eq by 2100 if additional mitigation is considerably delayed or under limited availability of key technologies, such as bioenergy, CCS, and their combination (BECCS).

	Increase in total discounted mitigation costs in scenarios with limited availability of technologies [% increase in total discounted mitigation costs (2015–2100) relative to default technology assumptions]			
2100 Concentration [ppm CO_2eq]	No CCS	Nuclear phase out	Limited Solar/Wind	Limited Bioenergy
450 (430–480)	138 (29–297) [N: 4]	7 (4–18) [N: 8]	6 (2–29) [N: 8]	64 (44–78) [N: 8]



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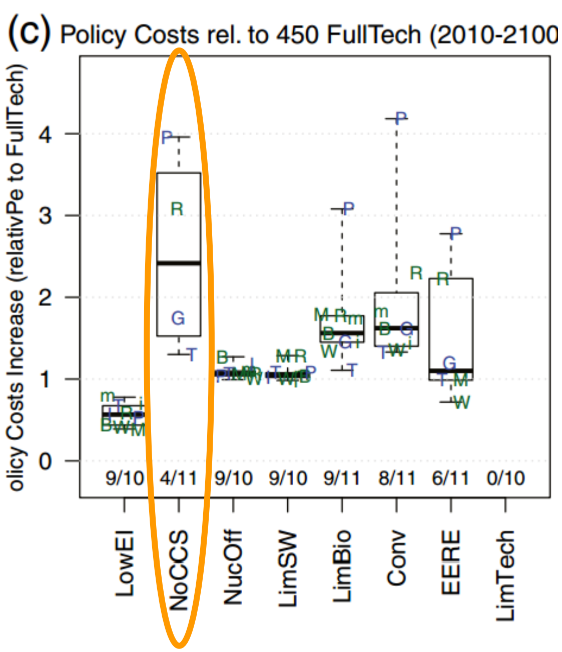
The case for CCS continues to grow

the vast majority of situations
in which models could not produce scenarios were those in which CCS was assumed to be unavailable.

the unavailability of CCS leads to the
strongest increase in mitigation costs for any single technology variation



CCS serves several different
purposes, the most relevant of which is the capability of sequestering carbon from the atmosphere

it is a very versatile technology that has the potential to contribute to decarbonization via different processes, such as electricity generation and synthetic fuel production from different feedstock and in industry.

Krey *et al.*, 2014

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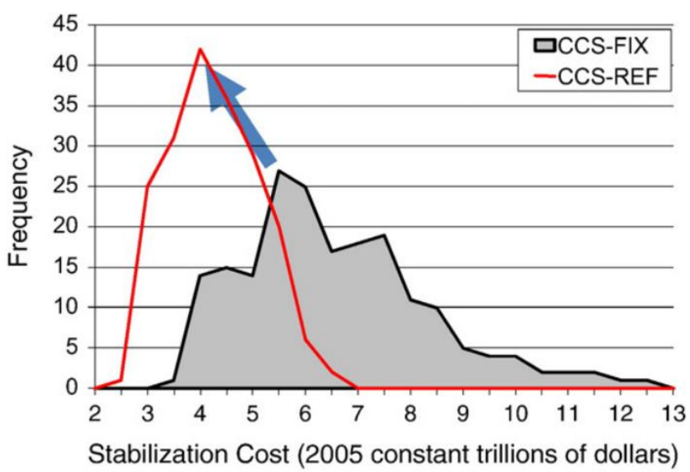
The case for CCS continues to grow

if CCS technology were fully available in the market (CCS-REF), then even if all others failed to advance, the stabilization cost would not exceed \$6.5 trillion for 450 ppmv and \$1.6 trillion for 550 ppmv. If CCS were not available, however (CCS-FIX), the costs could be more than \$12 trillion and \$2.8 trillion, respectively.

the presence of CCS serves as a hedging strategy



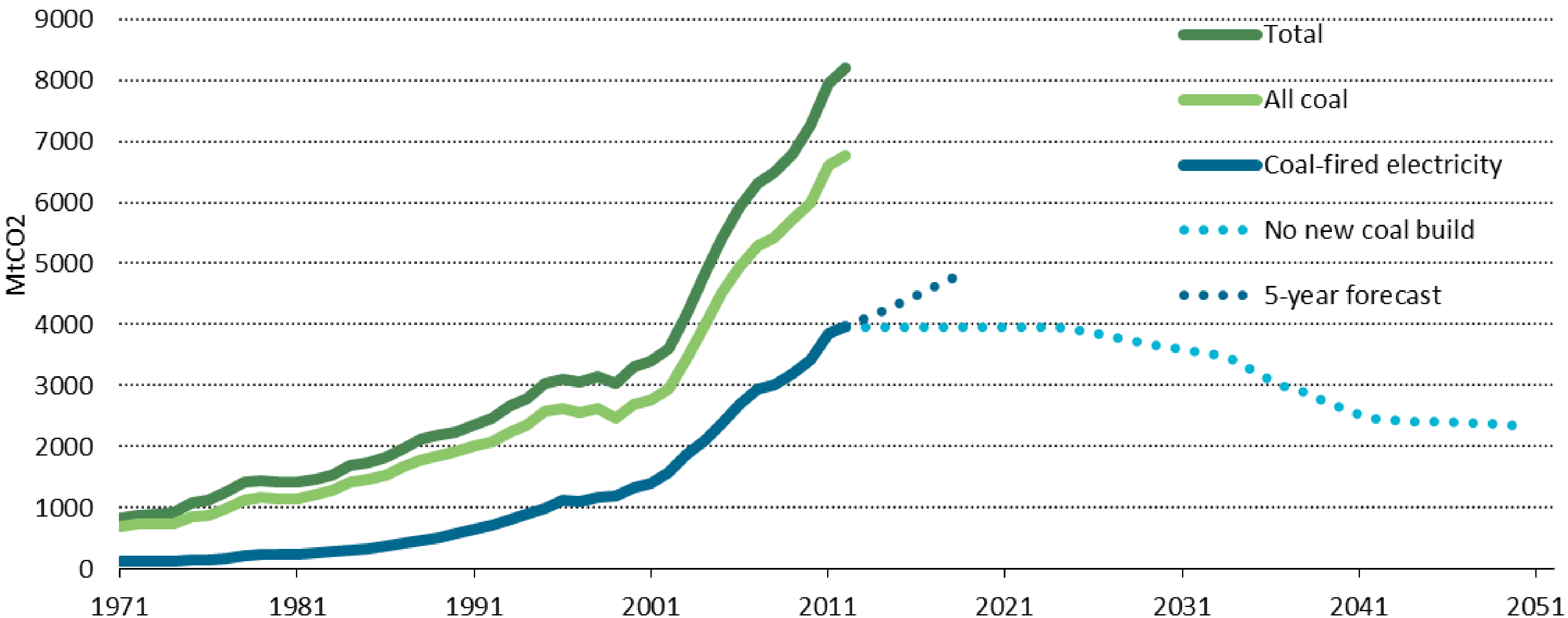
The presence of CCS is most valuable when substitutes such as nuclear power are not available.

energy efficiency technologies in the transportation and buildings sectors, in conjunction with CCS, were critical in determining high-cost outcomes.

Advances that further reduce the costs of CCS would not have nearly as much value as the advances that allow the technology to be used in the market

McJeon *et al.*, 2011

China…



Illustrative numbers

What I plan to say

- What CCS could be, and why it is not
- Where is CCS succeeding, and why?
- A new narrative for CCS in the EU?

CCS could be the workhorse of mitigation

- Unobtrusive
- Versatile
- Can do critical tasks in sectors where other technologies cannot
- Can do the really heavy lifting
- Not flashy, but dependable
- Compared to end-use and small-scale technologies, a relatively small number are needed

But the workhorse is unloved

Shared visions of a sustainable future do not include CCS

Horizon2020

DG Environment

In the real world, CCS raises conflicting emotions

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Conflicting emotions make decisions difficult and create vicious circles

I should support CCS because…	…but…
it is vital for long-term climate stabilisation	money/attention for CCS will reduce that available for my favourite technology in the near-term
the fossil fuel industry needs to take responsibility for its emissions	it is promoted by the fossil fuel industry so they can continue the status quo
fossil fuel owners/suppliers/users wield power and could block change	none of them are prioritising CCS among their political requests
it needs to be available in the 2030-2070 window	it is not needed to meet emissions targets in the 2015-2030 or 2070-perpetuity windows
there may be no other acceptable options for industrial applications	my stakeholders are only interested in electricity and transport
it can avoid stranding valuable fossil fuel assets in the long term	CCS assets will be stranded in the near term if there is a gap from demonstration to deployment
it is large-scale and potentially limits market disruption and costs	my vision of the future is decentralised, deindustrialised and non-corporate
it desperately needs financial support	what about the polluter pays principle?

What I plan to say

- Where is CCS succeeding, and why?
- A new narrative for CCS in the EU?

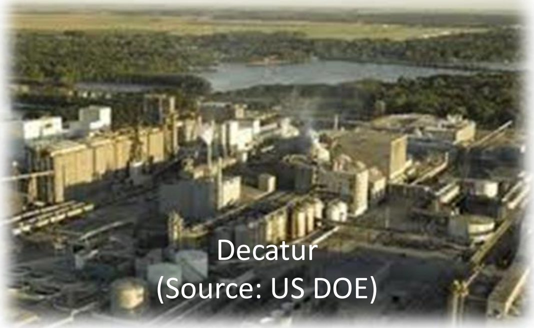
Where is CCS succeeding, and why?

Sleipner
(Source: Statoil)

Great Plains Synfuels
(Source: Dakota Gasification)

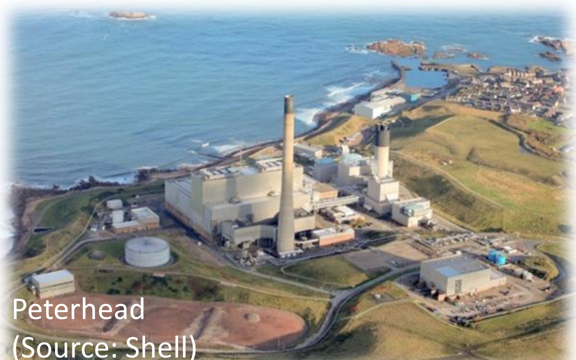
Boundary Dam
(Source: SaskPower)

Kemper
(Source: IEA)



Decatur
(Source: US DOE)

Port Arthur
(Source: Air Products)



Peterhead
(Source: Shell)

Gorgon (Source: Chevron)

Scotford Upgrader
(Source: Shell)

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Where is CCS succeeding, and why?

Key criteria for existing plants using CCS technologies:

1. Clear opportunity for continued use or export of local fossil fuel resources
2. Understood local geology, attractive for CO_2 storage and available storage expertise
3. Low expectation of near-term competition in the supply of the primary product (e.g. due to the stability of regulated electricity utilities)
4. Low-risk political and social environment for CO2 injection into deep geological formations, along with a predictable regulatory framework.

Plus one or more of the following:

- Dependable revenue stream for CO_2 sales, for example for EOR
- Manageable impact on profit margins (e.g. low-cost producer, or can pass on costs)
- Large volumes of CO_2 are being vented from existing facilities
- Explicit national emissions reduction policy that includes reductions via CCS
- Strong government support for the development of CCS
- Strategic benefits (e.g. a boost to reputation or an advantage from being first)

What I'm going to say

- A new narrative for CCS in the EU?

A new narrative for CCS in the EU?

1. CCS is not one-size-fits-all
   - It won't make sense for every sector in every EU country
2. No CCS without CO_2 storage services available for purchase
   - Government engagement is vital & a barometer for commitment
3. CCS can be cost-competitive
   - Costs will come down if R&D & early markets are supported in parallel, but it will not come for free. How will it thrive in future markets?
4. Strong climate policy delivers CCS, not vice versa
   - CCS is not needed in the EU for a 4°C target
5. Without EOR in the EU, a sustainable pathway for scale-up is needed
   - How can CO_2 demand be fostered? Does utilisation enable CO2 capture or vice versa? Can demand be created for CO_2 to be stored?

"People don't want more information. They are up to their eyeballs in information. They want faith – faith in you, your goals, your success, in the story you tell." -Annette Simmons

"No, no! The adventures first, explanations take such a dreadful time." -Lewis Carroll

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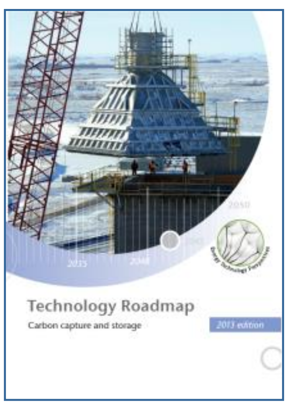
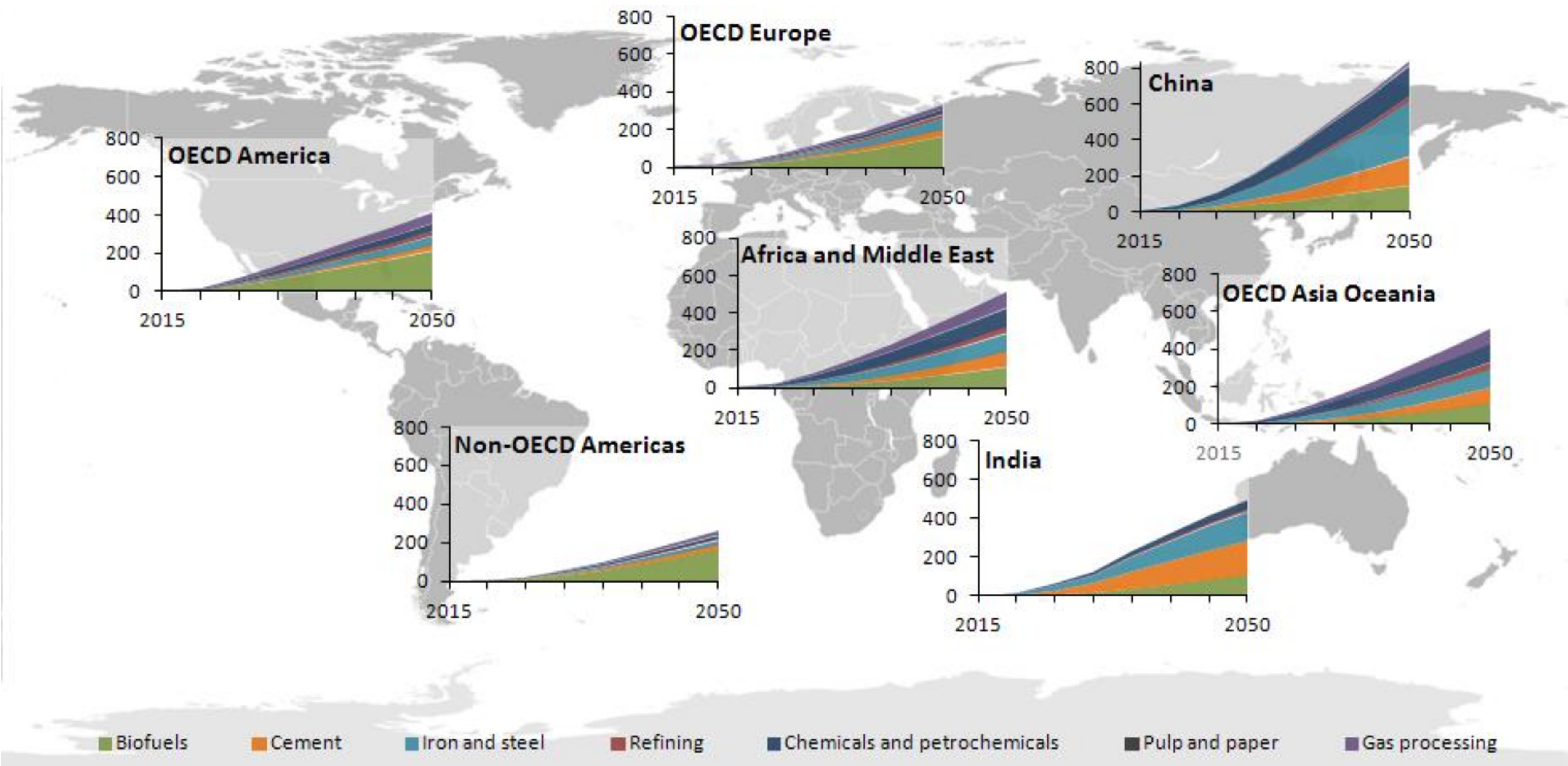
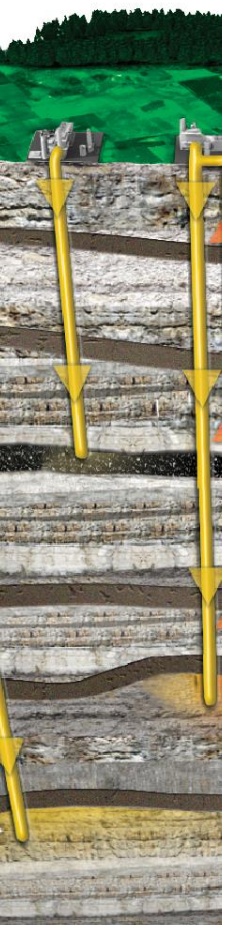


http://www.iea.org/topics/ccs/ccsroadmap2013

http://www.iea.org/publications/insights/insightpublications/ccs-2014---what-lies-in-store-for-ccs.html


OECD Europe
China
OECD America
Africa and Middle East
OECD Asia Oceania
Non-OECD Americas
India
800
600
400
200
0
2015
2050
Biofuels
Cement
Iron and steel
Refining
Chemicals and petrochemicals
Pulp and paper
Gas processing

To fulfil its role, CCS needs further improvement



- Increased cost driven by need of additional **capital investment**
  - +80% on power investment / kW ("nth plant"; first ones even more)
  - Varying degree in other industrial applications
- Increased cost also driven by **energy penalty**
  - 10-12 %-point loss in power plant efficiency…
  - …leads to 25-30% increase in fuel demand per unit of output
- Penalty linked to energy requirements of **capture**
  - Separation work 2,5 to 3,5 GJ / t CO_2 today
  - Compression 0,5 GJ / t CO_2 today
- Hence critical to **accelerate technical learning** and **economies of scale** to reduce energy penalty and capital costs
- Examples of **improvement targets**: CSLF, US DOE:
  - "2020": gradual improvements, -30% energy penalty
  - "2030 and beyond": novel technologies, -50% energy penalty

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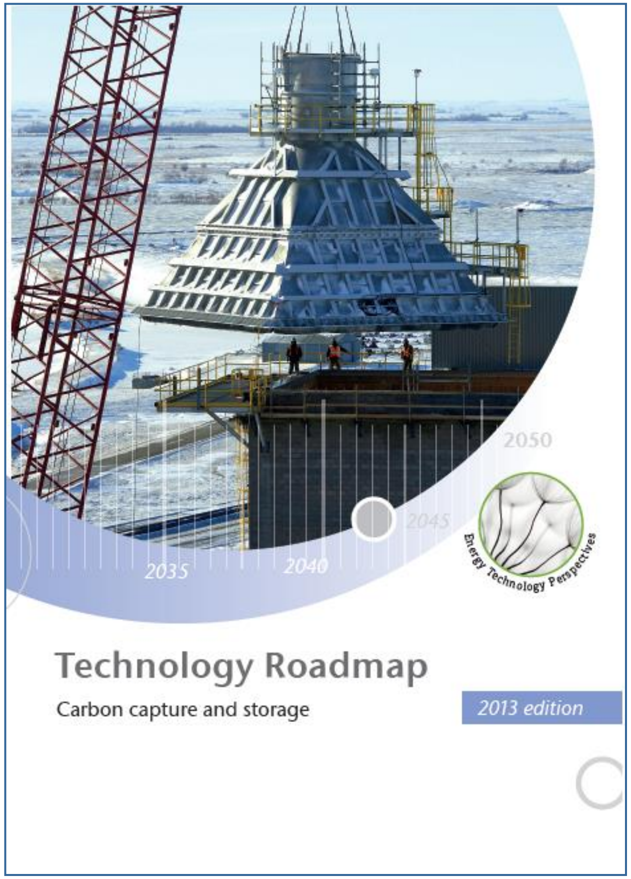
2013 CCS Roadmap: Key findings



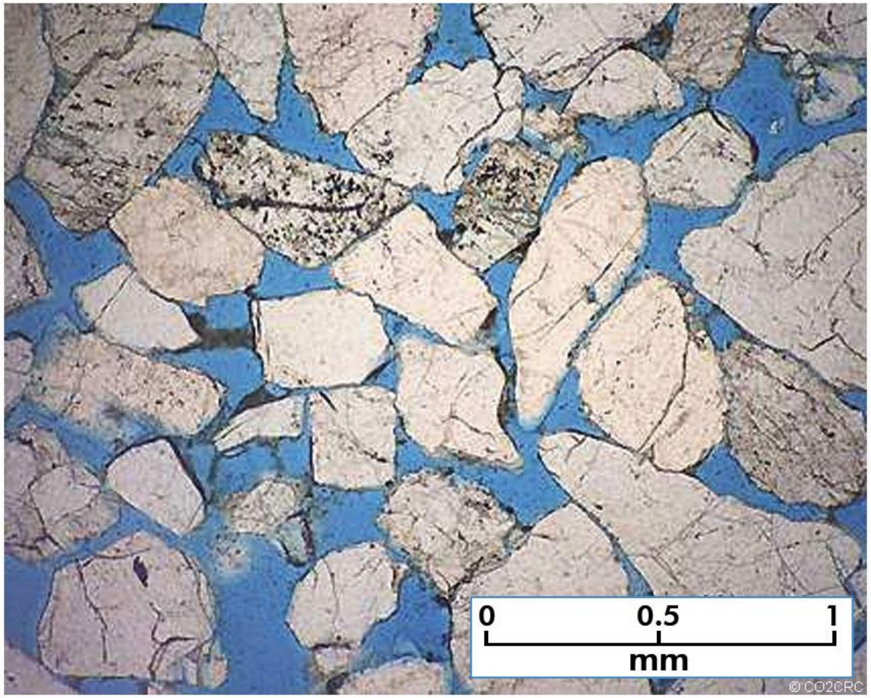
- CCS is a **critical component** in a portfolio of low-carbon energy technologies, contributing 14% of the cumulative emissions reductions between 2015 and 2050 compared with business as usual.
- The individual component technologies are generally well understood. **The largest challenge is the integration** of component technologies into large-scale demonstration projects.
- Incentive frameworks are urgently needed to deliver upwards of **30 operating CCS projects by 2020**.
- CCS is not only about electricity generation: 45% of captured CO_2 comes from **industrial applications** between 2015 and 2050.
- The largest deployment of CCS will need to occur in **non-OECD countries, 70% by 2050**. China alone accounts for 1/3 of the global total of captured CO_2 between 2015 and 2050.
- The urgency of CCS deployment is only increasing. **This decade is critical** in developing favourable conditions for long-term CCS deployment.

Four families of CO_2 capture routes

- **Post-process capture**
  - *CO_2 is separated from a mixture of gases at the end of the production process*
  - Can be used in most sectors, especially power generation
- **Syngas/hydrogen capture**
  - *Syngas, a mixture of hydrogen, carbon monoxide and CO_2, can be generated from fossil fuels or biomass. The CO_2 can be removed, leaving a combustible fuel, reducing agent or feedstock.*
  - Can be used for IGCC power plants or in DRI steel production
- **Oxyfuel combustion**
  - *Pure (or nearly pure) oxygen is used in place of air in the combustion process to yield a flue gas of high-concentration CO_2. There is an initial separation step for the extraction of oxygen from air, which largely determines the energy penalty.*
  - Can be used in oxyfuel power generation or in oxyfuel cement production
- **Inherent separation**
  - *Generation of concentrated CO_2 is an intrinsic part of the production process (e.g. gas processing and fermentation-based biofuels). Without CO_2 capture, the generated CO_2 is ordinarily vented to the atmosphere.*
  - CO_2 is captured every day in the gas processing, refining and chemicals sectors

Pore space – what is it?

- In porous rock, pore space exists in the rock matrix which can be occupied by CO_2 when injected into the subsurface.
- The term reservoir is not used literally. CO_2 does not sit in the subsurface in a "pool" but rather in small connected pores in the rock.
- Understanding and managing pressure increases in the reservoir is important.



Pore space is blue and grains of quartz are white in this photograph of a microscopic cross-section of rock (courtesy of CO2CRC)

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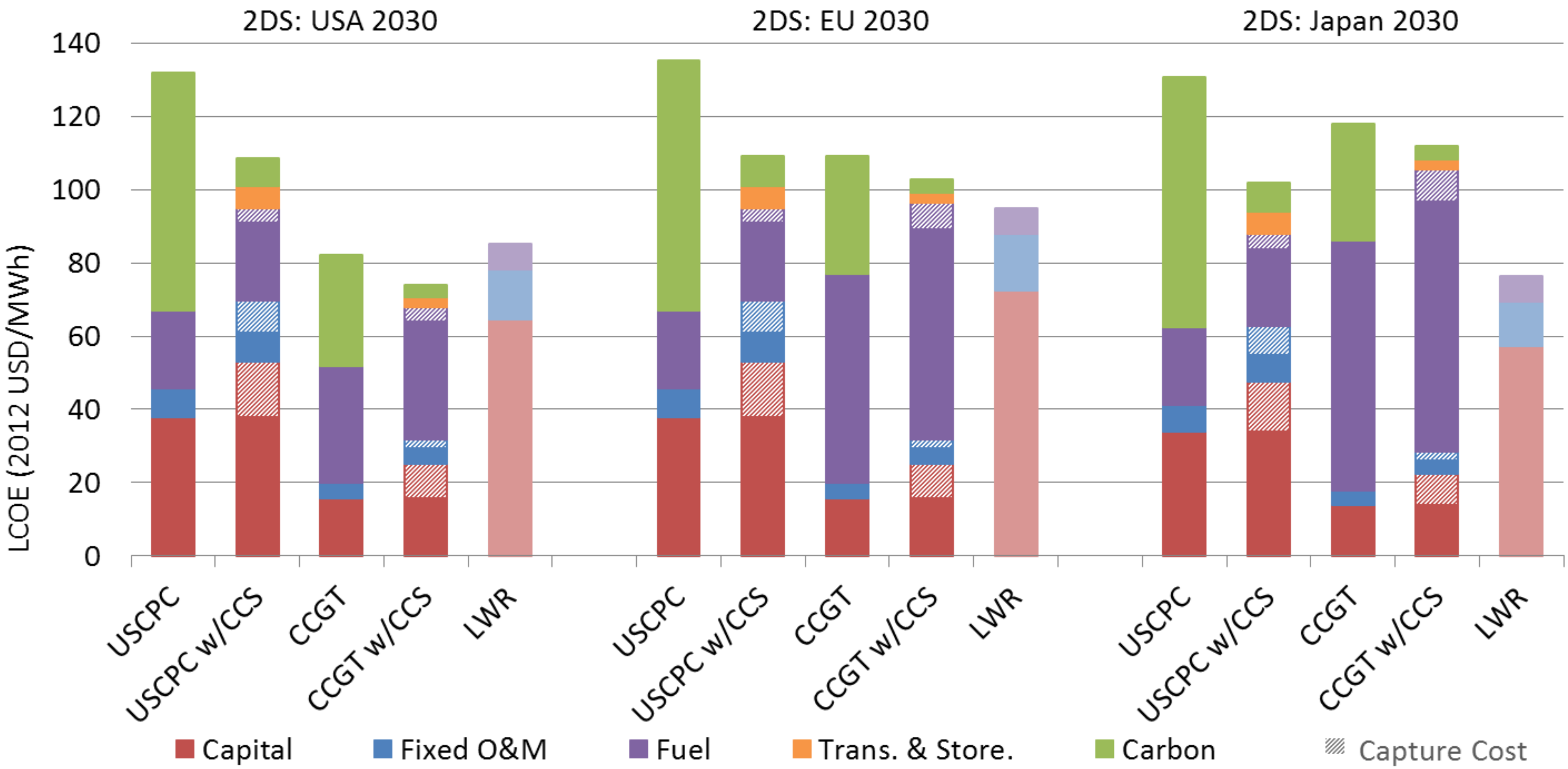
The CO_2 storage resource is large

- The storage resource is distributed unevenly, with some regions having little or none, and some having an abundance
- Current estimates are high level resource estimates; data and methods are lacking to perform more detailed capacity (i.e., reserve) estimates

Technical Resource ($GtCO_2$)		Global		USA	EU	South Africa
		IPCC, 2005	IEAGHG, 2009a,b	NETL, 2012	Vangkilde-Pederson, 2009	CSG, 2008
Storage type	DSF	1,000 – 10^4		2,102 – 20,043	96	150
	Depleted Gas	680 – 900	650	226	20	
	CO_2-EOR		140			
	ECBM	3 – 200		56 – 114	0.7	

The choice between coal and gas with CCS varies by region



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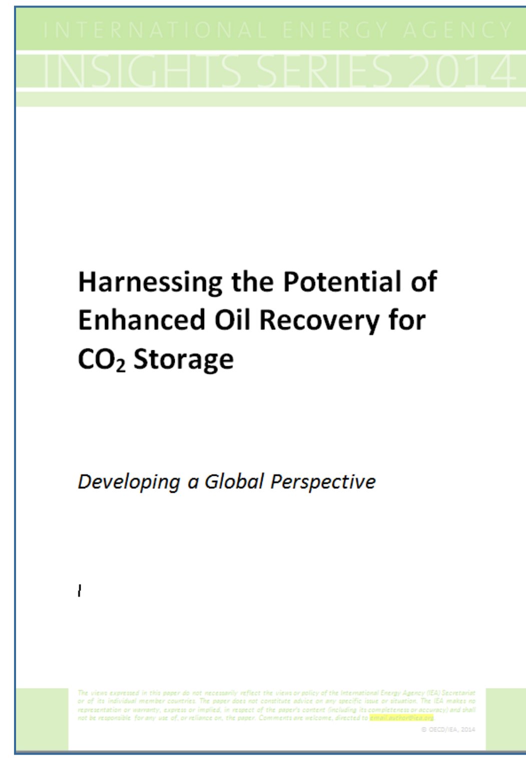
Context

- CO_2 - EOR as an early CCS option
  - Oil revenue could offsets storage cost
  - Storage reservoir
- IEA study details role of CO2-EOR to contribute to CO2 abatement
  - Co-optimisation oil recovery & CO2 use
  - Global technical potential
  - Project economics and cost
  - Impact on oil demand and global emissions
  - Required policies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INSIGHTS SERIES 2014

Harnessing the Potential of Enhanced Oil Recovery for CO_2 Storage

Developing a Global Perspective