International Energy Agency

Carbon Capture and Storage: **Where do we stand?**

Technical Experts' Meeting on CCS
Bonn, 21 October 2014

Juho Lipponen, IEA

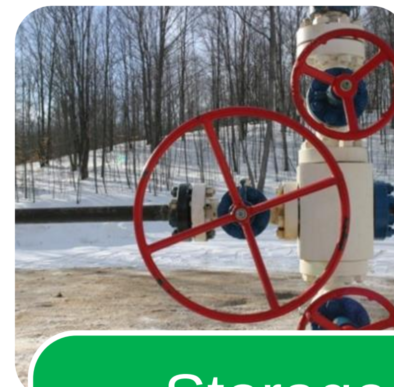
Carbon capture and storage

Three points on carbon capture and storage:

1. Carbon Capture and Storage technologies exist and are in use
2. To fulfil its role, CCS needs further improvement
3. Drivers and supportive policies are essential

International Energy Agency

Carbon capture and storage defined



Capture

Separation of CO_2 produced during production of power or other products, followed by clean-up and compression of the CO_2

Transport

Movement of CO_2 by pipeline, truck, rail, ship, or barge to a storage facility

Storage

Injection of CO_2 into a suitable storage unit, selected to safely contain the injected CO_2 for long timescales

Source: From L-R, Vattenfall, http://startupblog.files.wordpress.com, US DOE/NETL

International Energy Agency

Why do we need to capture CO_2?

- CO_2 is rarely emitted in pure form
- It is usually in a mixture of gases
- Yet, storage (and especially EOR) require (very nearly) pure CO_2
    - Gas-fired power plant: 3-4% CO_2 (P_{CO2} 3-4 kPa)
    - Coal-fired power plant: 13-14% CO_2 (P_{CO2} 13-14 kPa)
    - Blast furnace gas: 60-75% CO_2 (P_{CO2} 60-75 kPa)
    - Coal gasification: 12-15% CO_2 (P_{CO2} 250-1000 kPa)
    - Acid gas: 2-60% (P_{CO2} 20-5000 kPa)

(↓ easier)

- Different % and partial pressures require different approaches
- The CO_2 capture step usually includes compression, if necessary

International Energy Agency

Four families of CO_2 capture routes

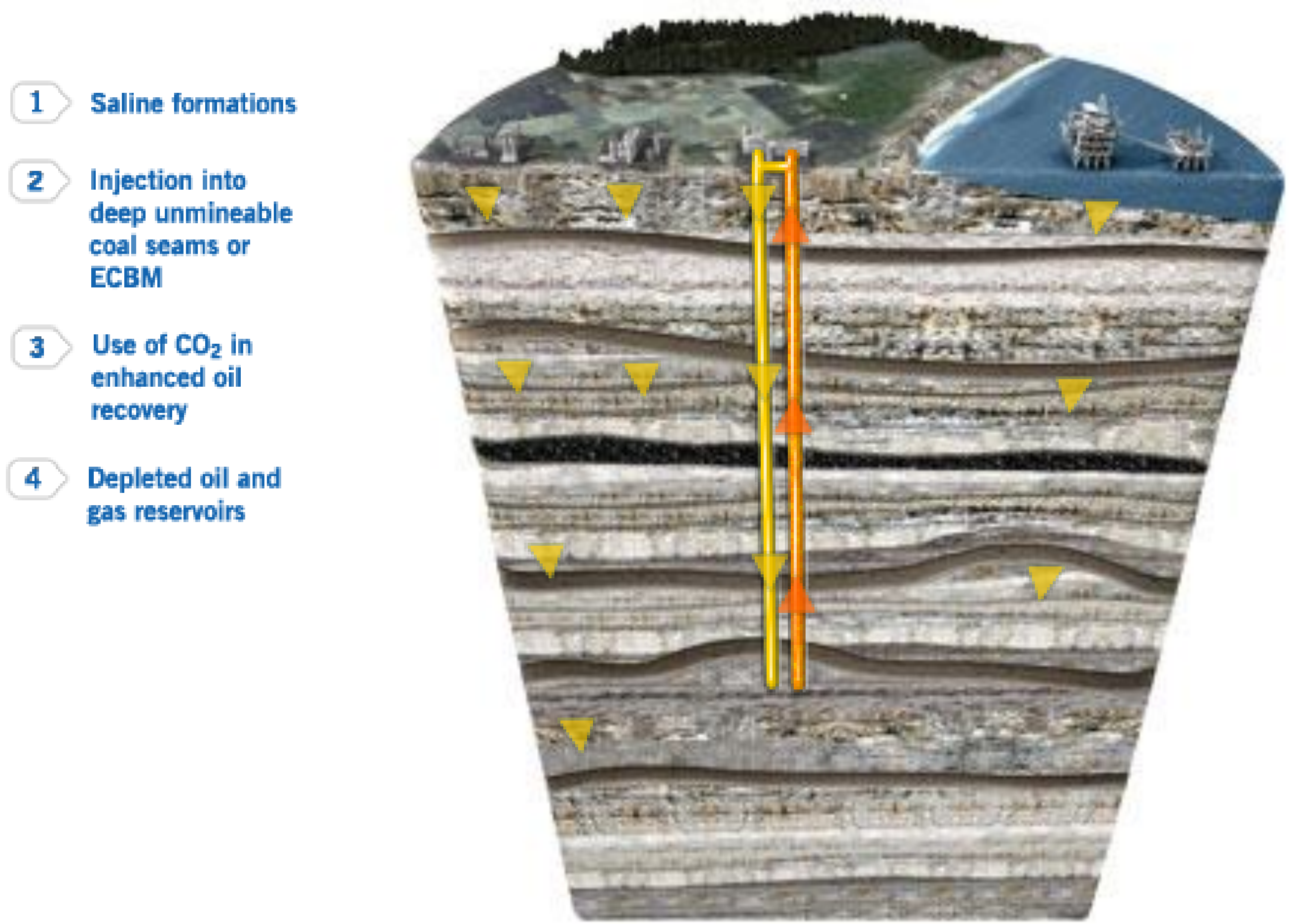
- **Post-process capture**
  - *CO_2 is separated from a mixture of gases at the end of the production process*
  - Can be used in most sectors, especially power generation

- **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

What are the options for CO_2 storage?

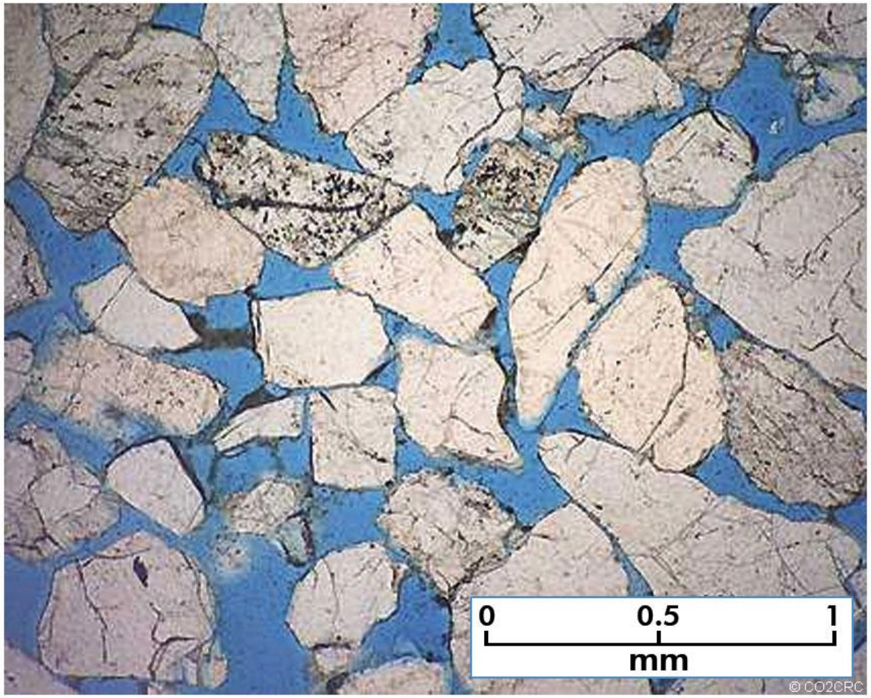


> 1 km

Image: Global CCS Institute

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)

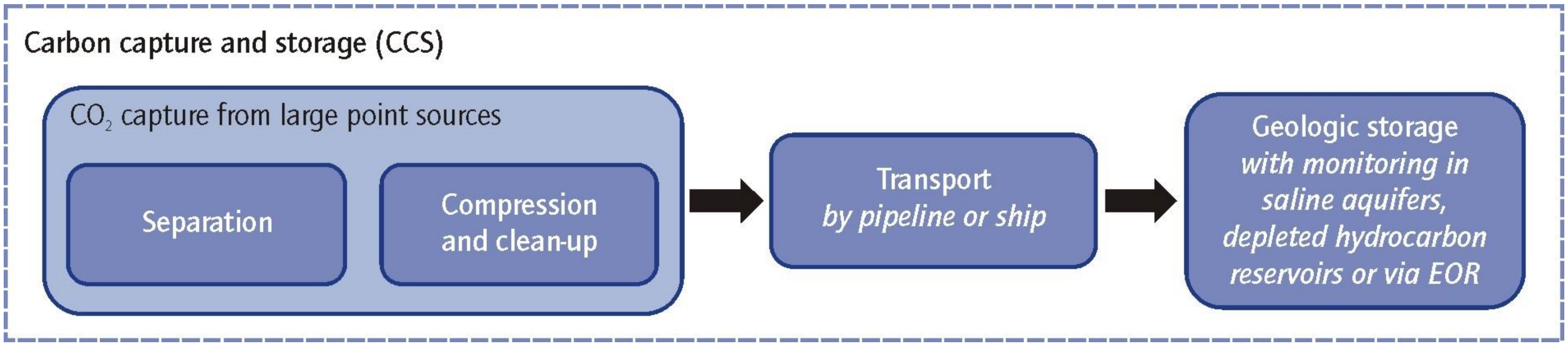
The CO_2 storage resource is large

- 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	

International Energy Agency

1. CCS technologies exist and are in use



- Technologies in use since 70s/80s
- Today: 1/2 of early energy requirement and 3-4 * scale!
- Power: pre-, oxy and post-combustion
- Gas processing, refining, cement, etc.

Capture technologies are well understood but remain expensive.

- 6000km existing pipelines
- Existing technical standards
- Transport by ship

Transport is the most technically mature step in CCS.

- 12 projects, 120+ EOR
- Capacities and CO_2 trapping mechanisms better understood
- Better storage engineering, modelling & monitoring

CO_2 storage has been demonstrated but further experience is needed at scale.

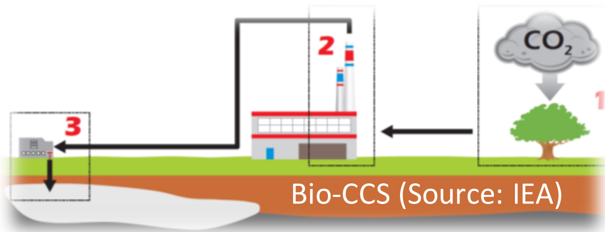
International Energy Agency


Sleipner (Source: Statoil)


Great Plains Synfuels (Source: Dakota Gasification)


Boundary Dam (Source: SaskPower)


Kemper (Source: IEA)



Bio-CCS (Source: IEA)

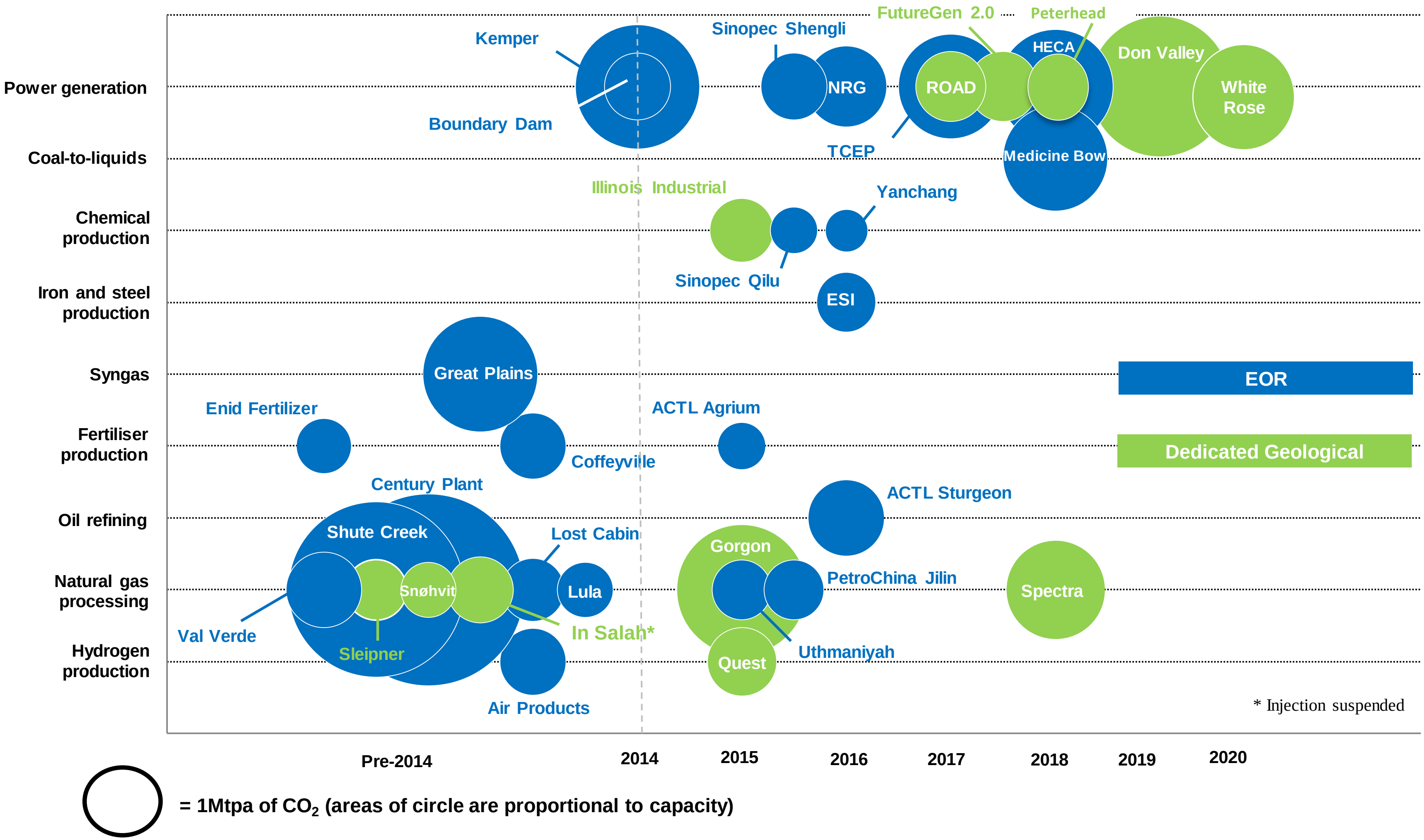

Taiwan Cement (Source: IEA)


Peterhead (Source: Shell)


Gorgon (Source: Chevron)


Scotford Upgrader (Source: Shell)

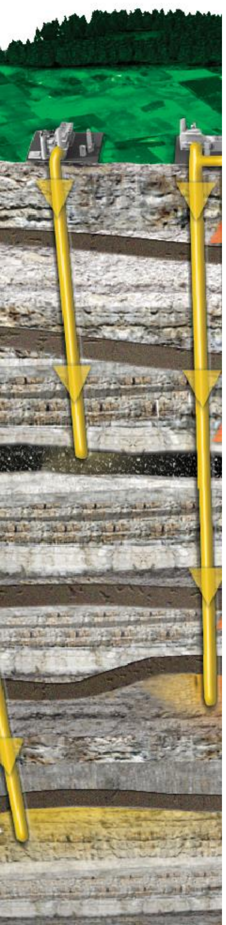
Actual and expected operation dates for CCS projects in ‘Operate’, ‘Execute’ and ‘Define’ stages



= 1Mtpa of CO_2 (areas of circle are proportional to capacity)

CCS projects in the power and industrial sectors and projects utilising dedicated geologic storage options

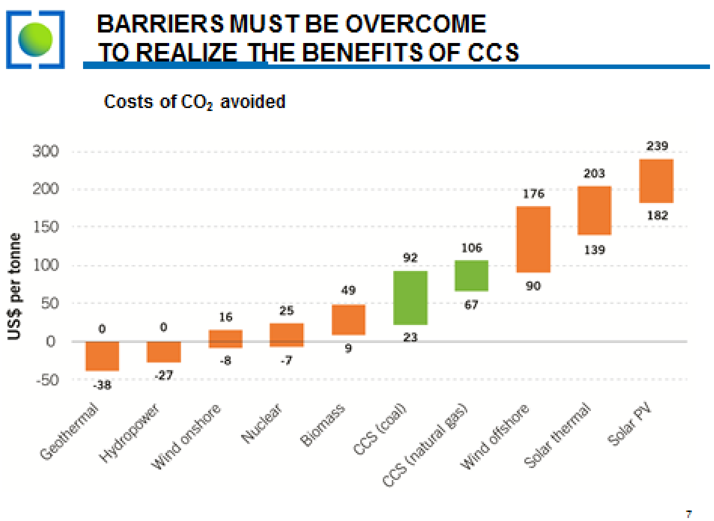
2. To fulfil its role, CCS needs further improvement



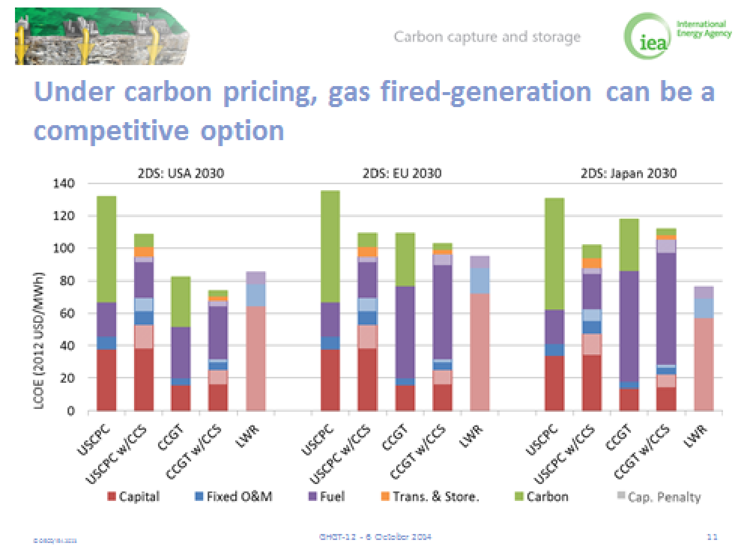
- Increased cost driven by need of additional **capital investment**
  - +80% on power investment / kW ("n^{th} plant"; first ones even more)
  - Varying degree in other industrial applications
- Increased cost also driven by **energy penalty**
  - 10-12 %-point loss in power plant efficiency…
  - …leads 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

CCS *can be* a competitive option

Cost of CO_2 avoided



Levelised cost of electricity



- Power sector 60-80 USD / t CO_2
- Industry 20-120 USD / t CO_2

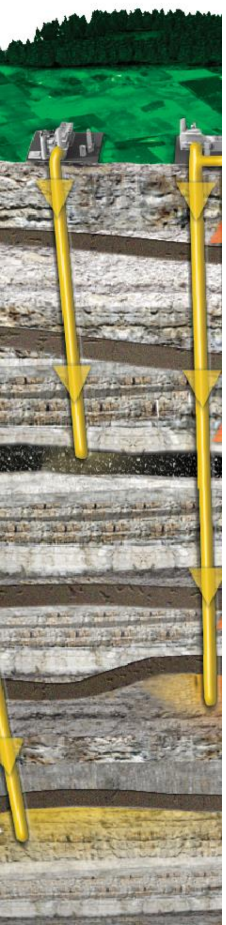
- Coal-CCS n^{th} plant: 100-120 USD / MWh
- Gas-CCS n^{th} plant: 80-120 USD / MWh

FOR REFERENCE:

- Wind onshore: 45 -160 USD / MWh
- Solar PV: 120-250-400 USD / MWh

Strong policy drives investment

Clean energy investment* between 2004-2013 (USD):



CCS:

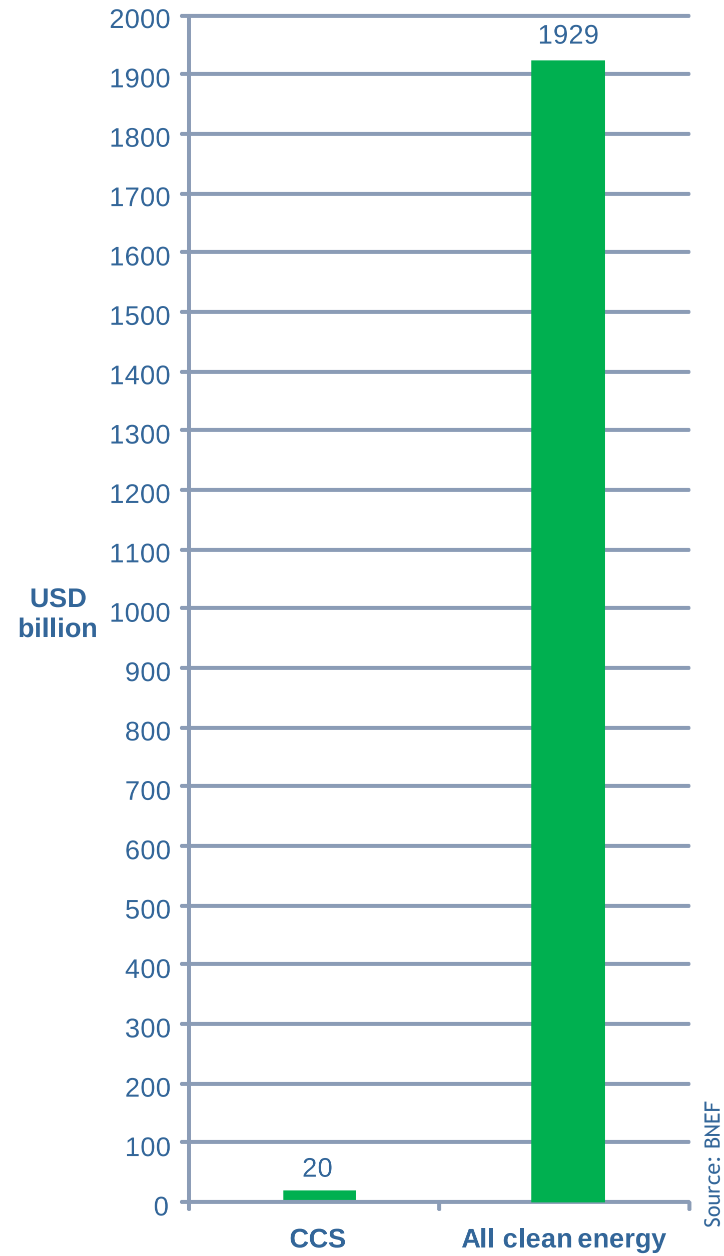
20

billion

All clean energy:

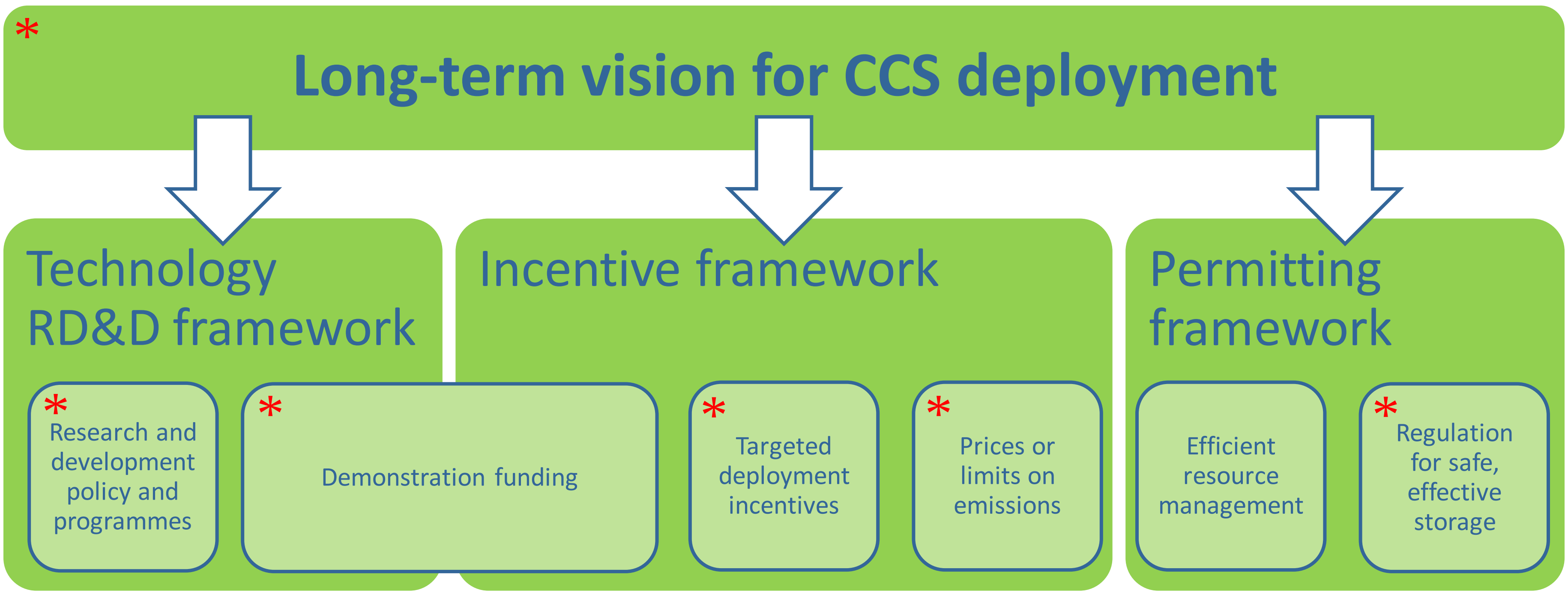
1929

billion



* Includes technology development, projects, M&A. Source: BNEF.

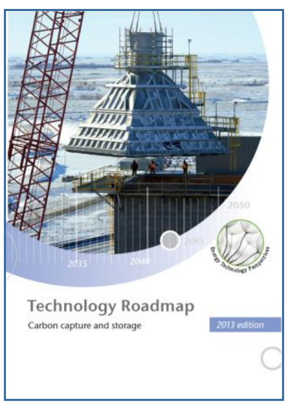
3. Drivers and supportive policies are essential



** UNFCCC process critical for shaping policy environment for clean energy including CCS: Ambitious climate targets, Technology Mechanism, Green Climate Fund, CDM, incl. modalities and procedures etc.*

THANK YOU!

juho.lipponen@iea.org



DOWNLOAD THE ROADMAP AT:
http://www.iea.org/topics/ccs/ccsroadmap2013