CARBON CAPTURE AND STORAGE

International Energy Agency

Carbon Capture and Storage:
Opportunities and Challenges

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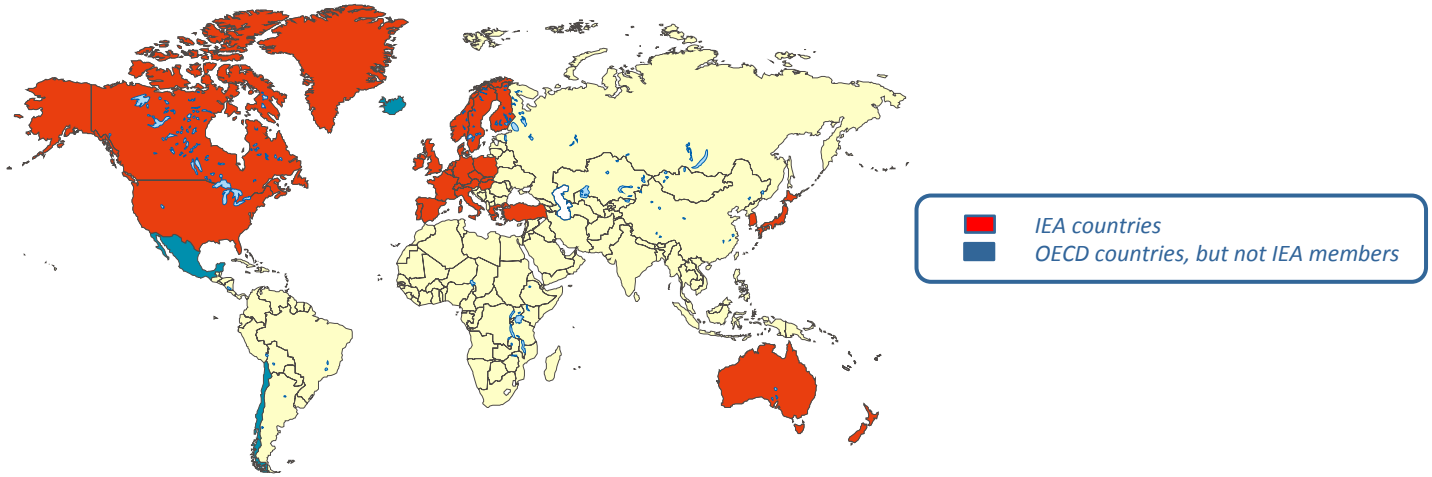
INTERNATIONAL ENERGY AGENCY (2/18)



- Inter-governmental body founded in 1973, currently 28 Member Countries
- Policy advice and energy security coordination
- Whole energy policy spectrum and all energy technologies
- Flagship publications include WEO and ETP
- Host to more than 40 technology-specific networks ("Implementing Agreements" or "IAs")
  - Operated independently with their own membership and financing
  - Includes GHG IA (often called IEA GHG)
- Active in CCS since 2000; dedicated CCS unit created in 2010
  - Provides policy advice
  - Supports broader IEA cross-technology analysis

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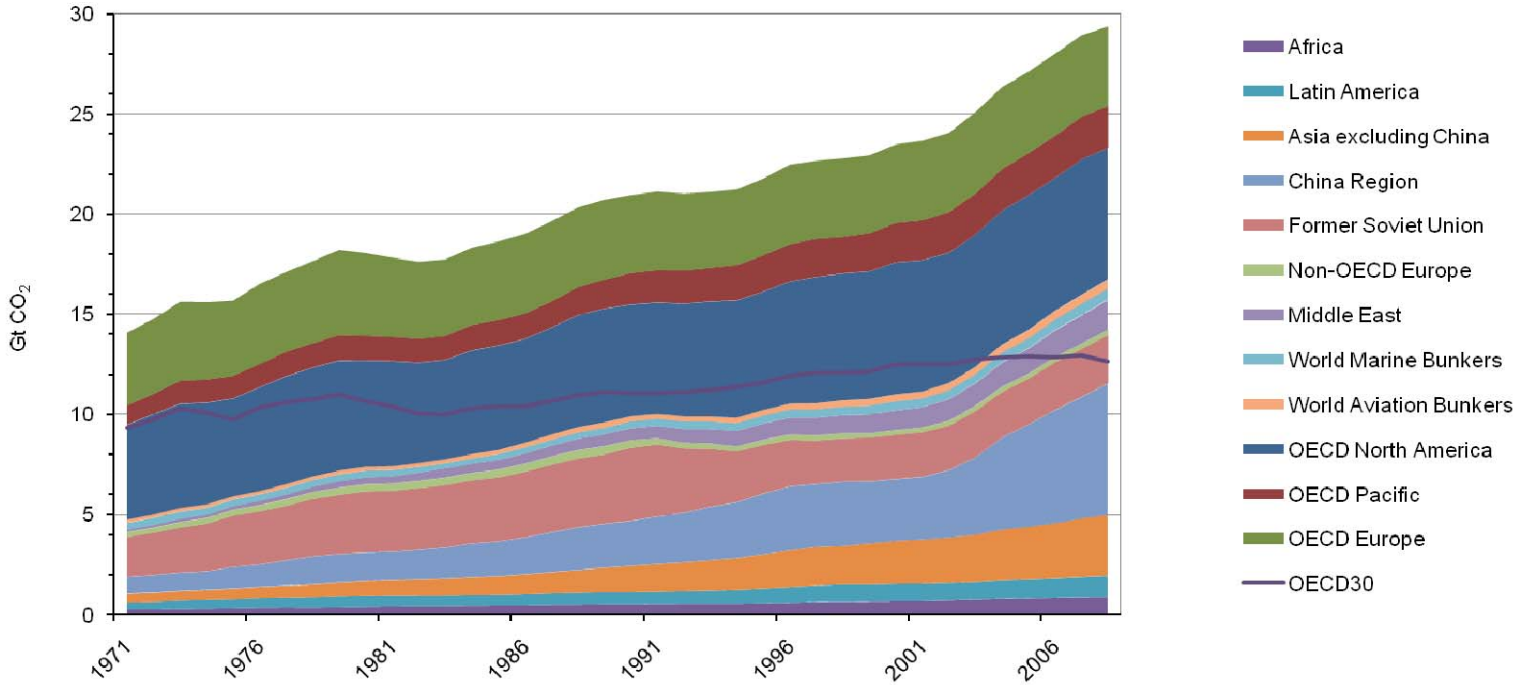
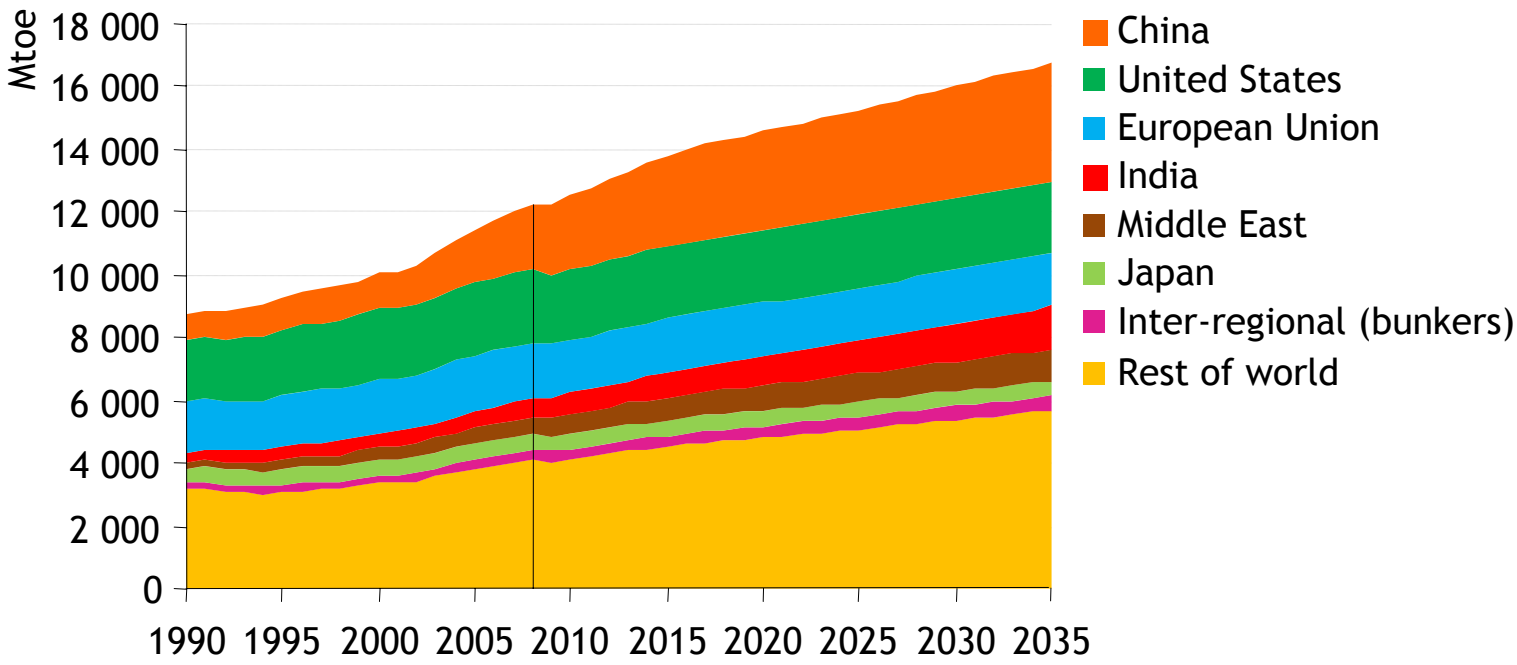
GLOBAL CO_2 EMISSIONS DOUBLED (3/18)

- Global energy-related CO_2 emissions have more than doubled in past 40 years, from 14Gt to 30Gt
- Until very recently, emissions are driven by OECD countries
- Since 2005, non-OECD countries emit more than OECD
- Current CO_2 concentration in atmosphere roughly 390ppm



ENERGY DEMAND CONTINUES TO GROW (4/18)

- Energy demand +35% by 2035
- OECD demand stagnates



* "New Policies Scenario", IEA World Energy Outlook 2010

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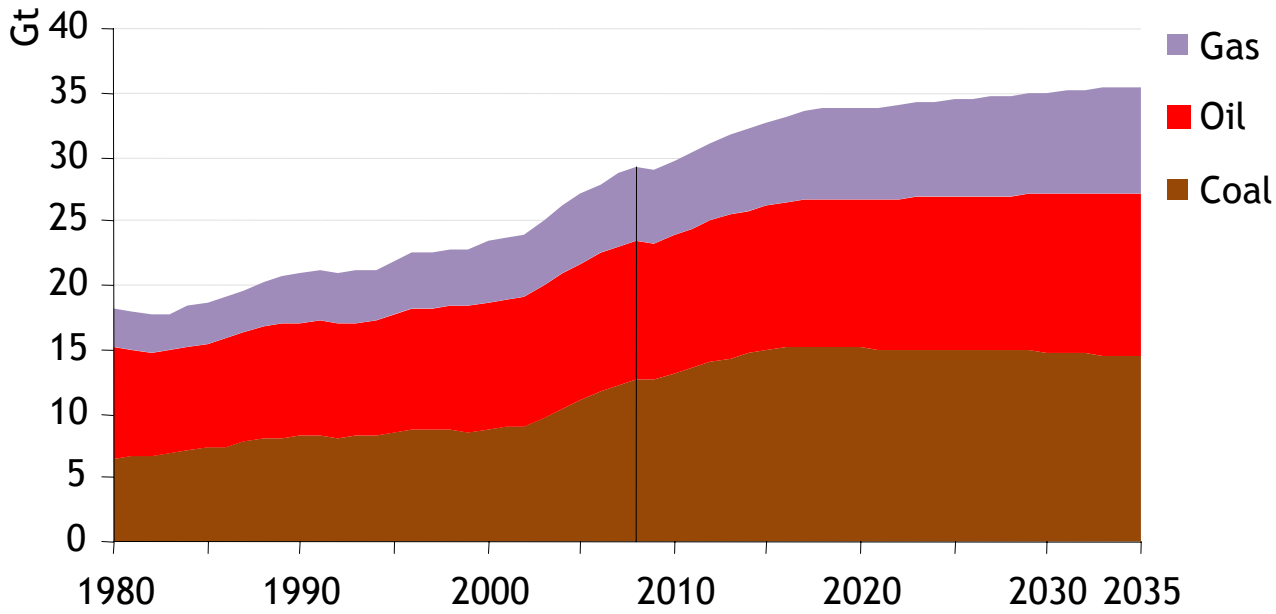
CO_2 EMISSIONS CONTINUE TO GROW (5/18)

- Energy-related CO_2 emissions 35 Gt by 2035
- Gas-related CO_2 emissions grow fastest (1,3%pa), followed by coal (0,5%pa)
- 650ppm CO_2-eq pathway



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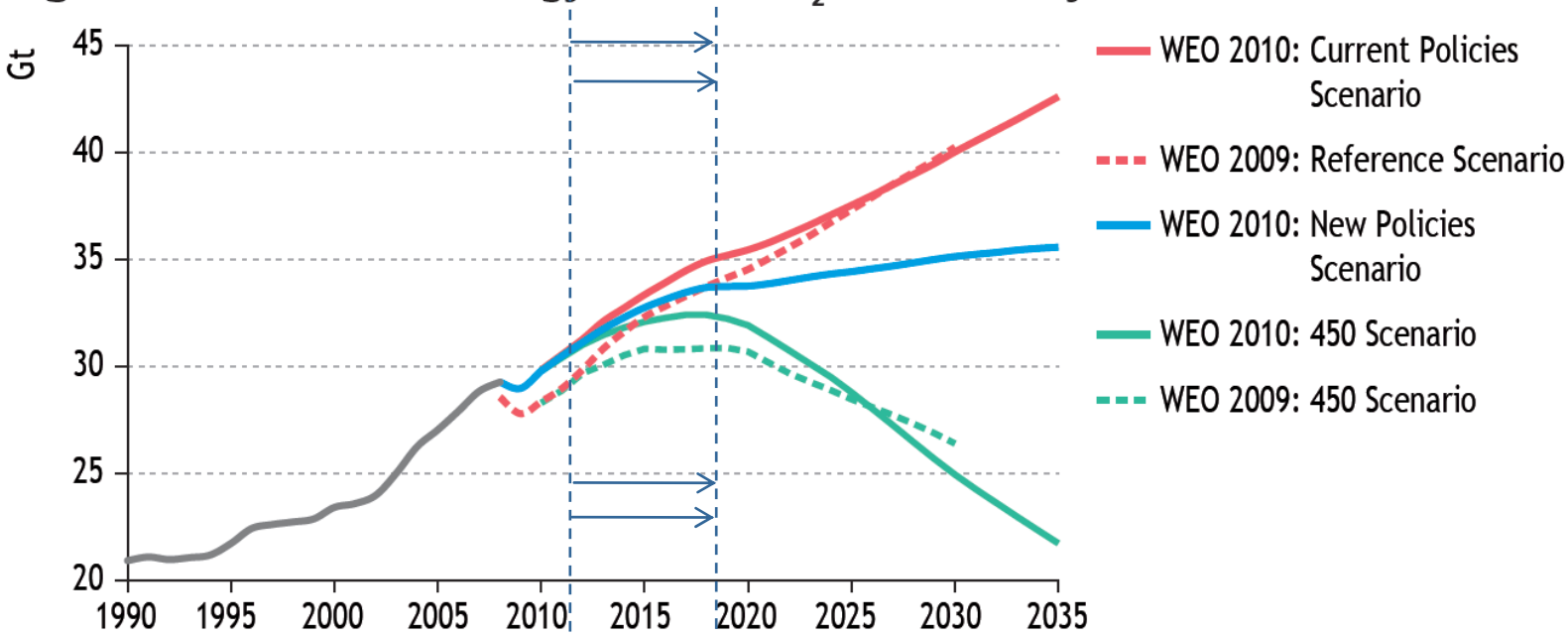
TOWARDS SUSTAINABLE FUTURE (6/18)

- Current policies or "reference scenarios" unsustainable
- Scientific evidence and policy ambitions now often target "450ppm scenarios" (50-50 chance to keep temperature increase at ≤2°C)
- Critical period NOW to establish policy and develop technology

Figure 13.2 • World energy-related CO_2 emissions by scenario



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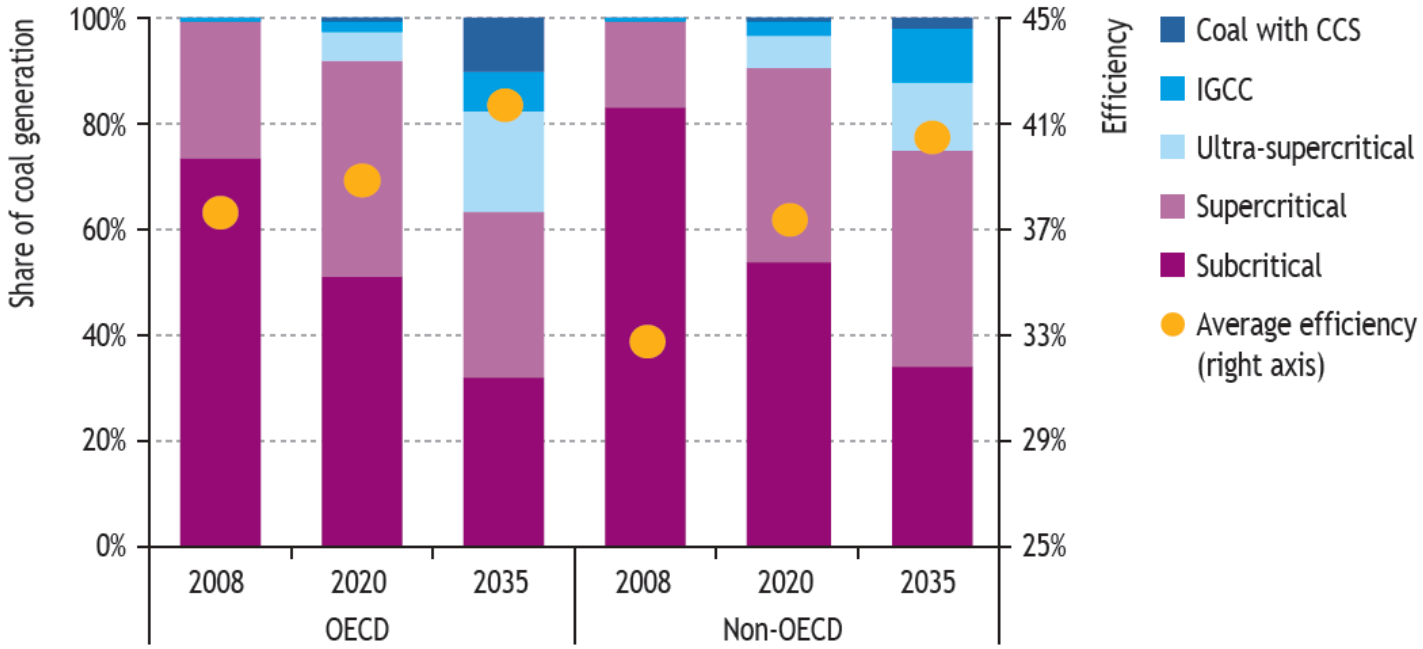
CARBON CAPTURE & STORAGE: LIMITED ROLE WITH KNOWN POLICIES... (7/18)



- Steady improvement of average coal plant efficiency
- Share of CCS in coal-fired power remains below 10% in 2035 (and only 3% of total power generation)
- No gas-CCS
- Very limited industry-CCS

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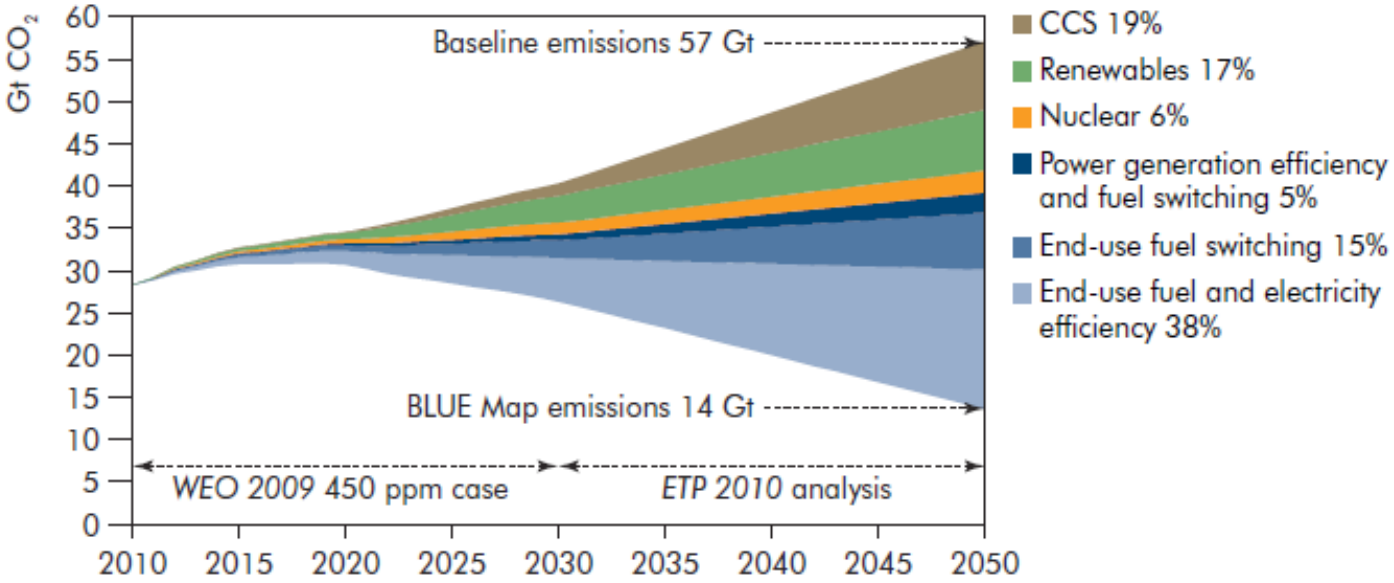
… BUT CRITICAL IN "450" SCENARIOS (8/18)



- IEA analysis assigns critical role for CCS in a least-cost pathway to reaching 450ppm scenario
- Role of CCS increases after 2030 → contributes 1/5 of total needed reductions against baseline 2010-2050
- 450ppm achievable without CCS, but at higher cost
- Stronger reliance globally on gas replacing coal is alone not enough to stabilise emissions

ENERGY TECHNOLOGY PERSPECTIVES 2010

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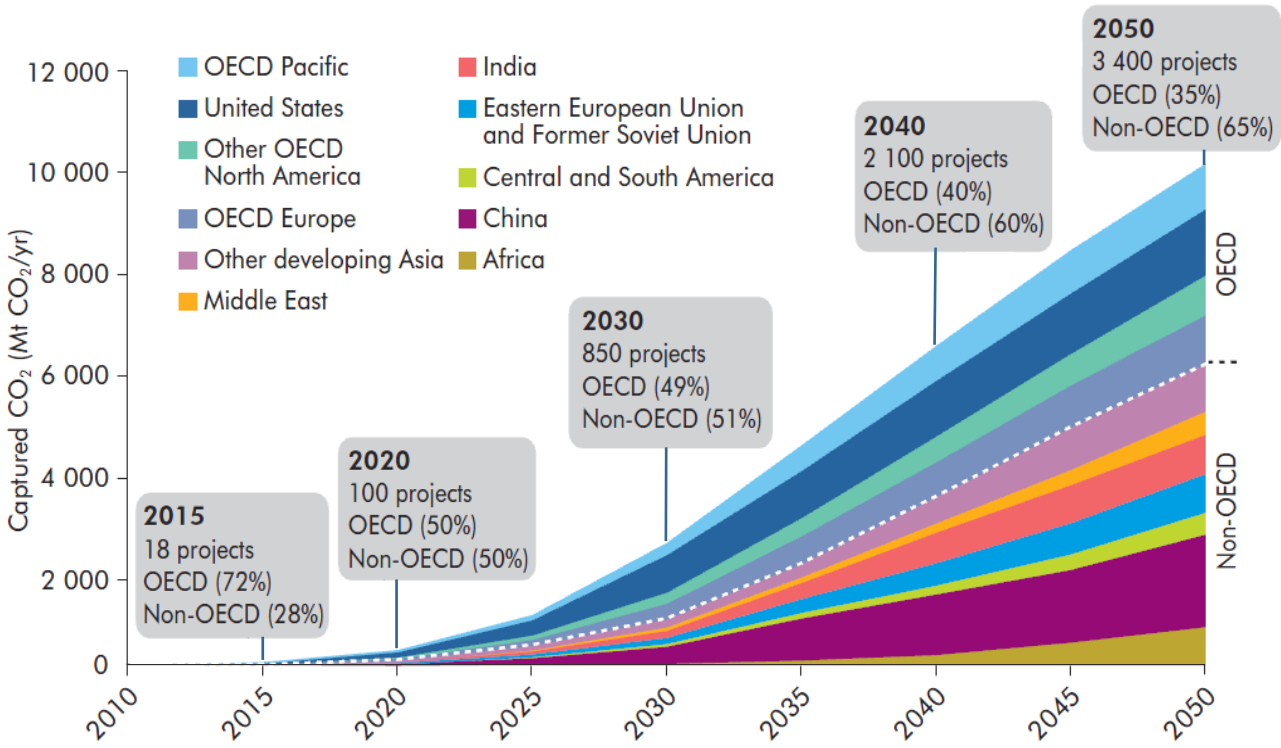
THE ROLE OF CCS IN MITIGATING CLIMATE CHANGE (9/18)

1. CCS is only one of a portfolio of energy technologies that can be applied to reduce emissions;
2. CCS should not be opposed to other low-carbon technologies;
3. CCS offers governments and industry flexibility in the way climate targets are met and contributes to their acceptance of stronger targets;
4. CCS is a relatively new undertaking in all parts of the world and could provide a basis for cooperation and partnership between developing and developed countries
5. CCS is a technology that allows the oil and gas industry to play direct role in reducing emissions by applying industry specific knowledge and tools

CAN THE POTENTIAL OF CCS BE EXPLOITED? (10/18)

- 3000+ projects across the globe
- and across industries: CCS not only about coal-fired power
- 150Gt CO_2 captured and stored



Technology Roadmap
Carbon capture and storage

ENERGY TECHNOLOGY PERSPECTIVES 2010

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EMISSIONS REDUCTION POTENTIAL FOR CCS (11/18)

- **Industry:** Potential to reduce CO_2 emissions by up to **4.0 Gt annually by 2050**
- Needed: Up to **1800 projects globally** by 2050 with an investment of some **$880 Bln (USD) 2010-2050**
- Applying CCS in high-purity sectors represents early opportunity
- **Power sector:** Potential to reduce emissions by **5.5 Gt CO2 annually by 2050**
- Needed: **22 GW** of power generation with CCS installed in **2020**;
- Around 60 GW of power plant will need to be retrofitted with CCS by 2050

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PROJECTS ARE NEEDED IN NON-OECD COUNTRIES (12/18)

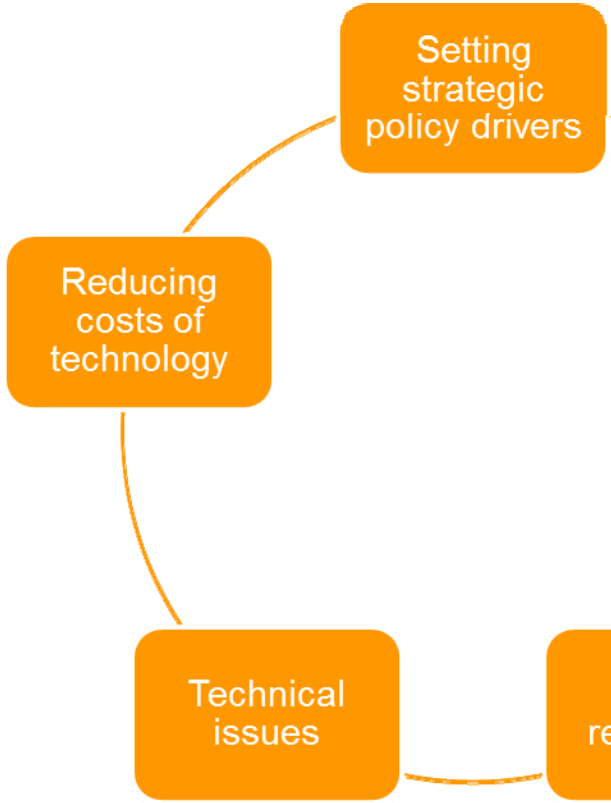
2020 Roadmap goal is **100 projects—50** in OECD countries, **50** in non-OECD countries

Region	Operating Projects	Projects in Advanced Planning or Construction[1]	Projects in Early-Planning Stages[2]
OECD	7 (88%)	28 (90%)	27 (71%)
Non-OECD	1 (13%)	3 (10%)	6 (29%)
Total	8	31	38

[1]Defined as those projects in the "Define" or "Execute" stages (GCCSI, 2010)
[2]Defined as those projects in the "Evaluate" or "Identify" stages (GCCSI, 2010)

CHALLENGES REMAIN FOR CCS (13/18)

- Firm decisions to address climate change
- Understanding of CCS and recognition of its role



- High cost
- Market dynamics, incl. impact of cheap gas
- Infrastructure planning and coordination

- Existing public support 25-35bn USD globally
- Need to mobilise 5 trillion USD 2010-2050
- Incentive policy pathways

- Knowledge on storage capacity
- Site selection, site monitoring
- Long-term liability
- Public acceptance

- OECD vs. non-OECD countries
- UNFCCC rules for CDM
- International legal issues e.g. London Protocol and OSPAR

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STATUS OF CCS COSTS (14/18)

CO_2 Capture from power generation (IEA, 2011)

Fuel *(capture route)*	Coal *(similar for all capture routes; relative to a pulverized coal baseline)*	Natural gas *(post-combustion)*
Capital costs	3 800 USD/kW (74% increase)	1 700 USD/kW (82% increase)
Cost of CO_2 avoided	55 USD/tCO_2	80 USD/tCO_2

Notes: Averages figures for OECD countries shown (costs in China estimated to be about half for most cases), capital costs are overnight costs

CO_2 Capture from industrial application (UNIDO, 2010)

Refining sector 28-96 €/tCO_2
Cement plant 36-107 €/tCO_2
Pulp and paper 30-40 €/tCO_2
Iron & Steel 30-40 €/tCO_2 (Kuramochi, 2011)

Engineering-Economic Analysis and Historical Experience Curves suggest significant cost reduction potential over time.

CO_2 transport & storage

Very site-specific; likely additional costs of about 20 USD/tCO_2

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ROLE OF UNFCCC IN ADDRESSING CCS CHALLENGES (15/18)

- Strategy, policy and financing challenges
  - Acceptance in CDM is a positive policy signal on its own
  - CCS projects could be incentivized by availability of CDM funding
  - Acceptance could encourage adoption of CCS as NAMAs
- Technical and legal challenges
  - Build consensus on how key issues should be addressed both in CDM and non-CDM projects, such as: CCS site selection criteria; Monitoring, reporting, and verification (MRV); Project boundaries; Risk, safety, and socio-economic impact assessment; Short-, medium- and long-term liability; Financial assurance, etc.
  - Encourage development of appropriate and consistent national regulations for CCS projects
- Broader deployment
  - Improved understanding and acceptance

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CCS in the CDM: positive implications (16/18)

- If CCS is included in the CDM, there would be several positive implications for the future of CCS technologies:
  - The process would legitimise CCS technologies in developing countries;
  - Create incentives for CCS demonstration and deployment for those developing countries that rely heavily on fossil fuels and plan to use CCS as one of their climate mitigation options;
  - Create a set of international rules and principles for CCS projects and provide international oversight for carbon offset-generating CCS projects.

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Thank you!

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(17/18)

AN EXAMPLE: MANAGING LONG-TERM LIABILITY (18/18)

- Establishing the way in which "global liability" arising from leakage—is monetized:
  - Crediting period: CO_2 seepage is treated as project emissions and can be deducted from the CER
  - Beyond crediting period: new accounting methods will be required
- Establishing who is "on the hook" for these liabilities:
  - PDD needs to provide clarity on entities responsibility across CCS project phases, including whether liability is or can be transferred
- Establishing how these financial liabilities are to be managed:
  - Provisions will be needed to guarantee availability of funds over a period of time longer than that which can be managed by private operators
  - Many jurisdictions have approached the problem by collecting fees from the operator during the project phase through a variety of mechanisms: e.g., a per ton levy on CO_2 injected, or a lump sum payment for the project
  - For CDM projects, an international insurance pool or risk sharing mechanism could be considered; *however, the creation of such a mechanism should not be a prerequisite for implementing CCS in CDM.*
- Establishing mechanisms for developing country governments to build the necessary capacity to regulate geologic storage
- Establishing a CO_2 storage site database—to ensure transparency of long-term accounting for CO_2 storage sites under the CDM

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