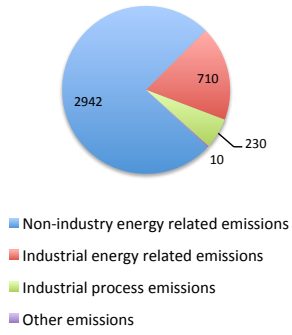
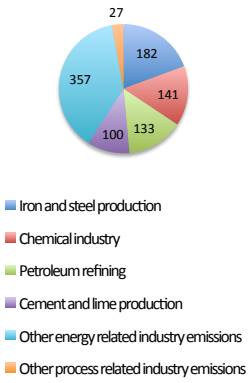
CCS for Industrial Sources of CO_2 in Europe

- Industry direct CO_2 emissions are one quarter of total EU emissions
- 60% of this is from four sectors:
  - Iron and steel
  - Chemical industry
  - Petroleum refining
  - Cement and lime
- 25% of industrial emissions are inherent to process chemistry of some key materials
  - Steel – blast furnace, reduction of iron ore
  - Cement – calcination, lime from limestone
  - Hydrogen – steam reforming, for fuel upgrading, methanol and ammonia/fertiliser production
- IPPC targets for industry emission reductions in EU
  - 34-40% by 2030
  - 83-87% by 2050
- CCS necessary to make deep cuts in industry emissions
- CCS for high-emission processes could achieve 200-300 Mt/yr CO_2 reduction
  - Processes listed above plus:
  - Fluid catalytic cracking – catalyst regeneration
  - Steam cracking for olefin production

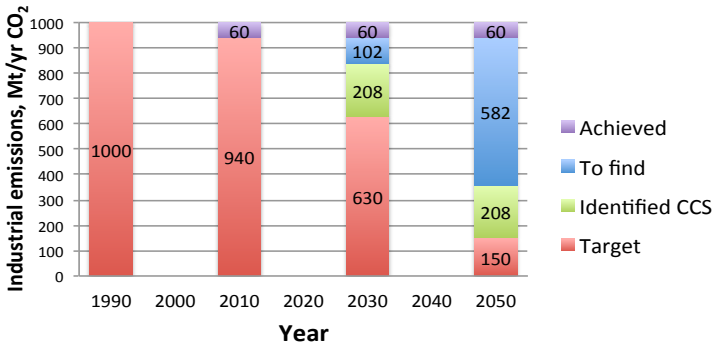
Total European CO_2 emissions Mt/yr
EU27 2011, excluding LULUCF Ref: ZEP, 2013



Industrial CO_2 emissions Mt/yr



Identified CCS Options - Contribution to CO_2 emission reduction targets
Indicative figures



- Energy intensive industries in Europe contribute significantly to GDP, employment and innovation
  - Iron and steel, cement, refineries, chemicals combined have turnover of € 900 billion, c.7% of EU GDP, 25% of EU industry
  - These sectors employ directly 1.75 million, 0.7% of EU labour force, 2.9% of EU industry employment
  - Materials and innovations skills from these industries needed to grow green economy

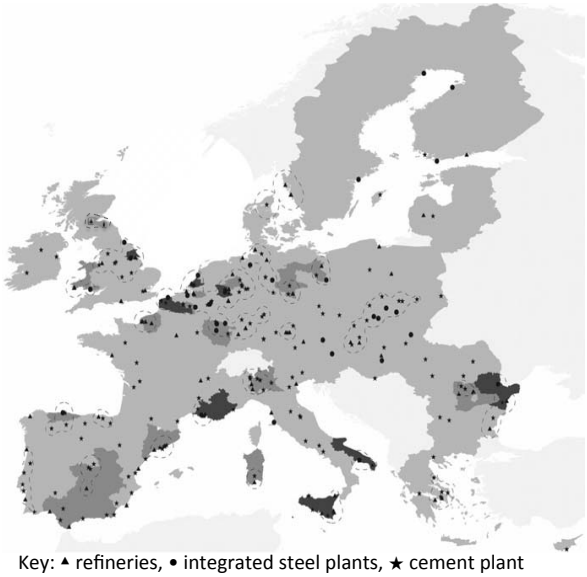
- Identified options for CCS from large industrial sources could contribute most of reductions required by 2030
- Needs concerted action now to achieve this
- But CCS from these large sources alone not sufficient for 2050 target, even at high-end estimates

Sector	Assumption for estimate (SCCS, 2013)	CO_2 emission reduction, Mt/yr
Iron and Steel	50% of emissions from blast furnaces captured	89
Cement	50% of emissions from cement plant captured	50
Refineries	Most emissions from hydrogen production captured, some emissions from combustion plant captured, totalling 25%	33
Chemicals	Available (W Europe) ammonia plant emissions captured, 80% cracker emissions captured, 10% combustion emissions captured	36
Total		208

- CCS is a key technology to achieve deep cuts in emissions from industry
- Fundamental industrial processes have inherent CO_2 formation where capture is only option for avoiding emissions

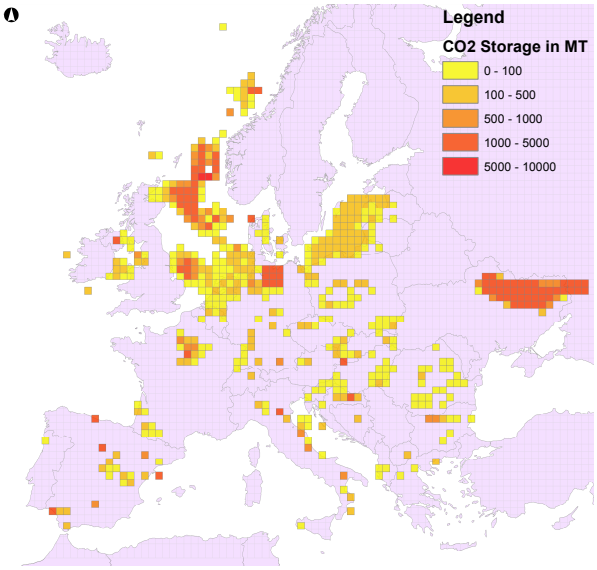
- Industry with high emissions clustered in several areas in Europe
- Storage sites identified in feasibility studies
- NW Europe clusters match well with storage availability in North Sea

Distribution in Europe of refineries, integrated steel plants, cement plants emitting >0.5 Mt/yr CO_2



Key: ▲ refineries, • integrated steel plants, ★ cement plant
Mid grey: regions with large industry sources totalling >5 Mt/yr,
Dark grey: regions totalling >10 Mt/yr,
Pecked lines: potential capture clusters.
Adapted from: Rootzén, et al, Management of Environmental Quality, **22,** (1), 2011

CO_2 storage sites and volumes around Europe



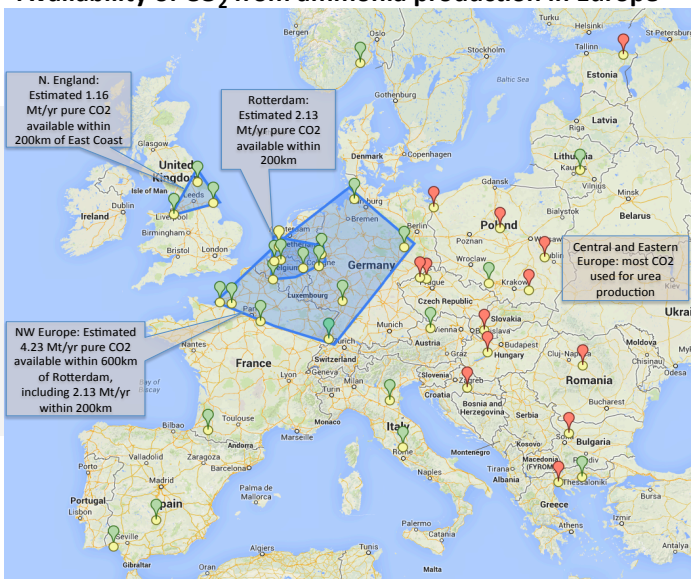
Source: Feasibility Study for Europe-Wide CO2 Infrastructures, Haszeldine et al, 2010. ARUP, Leeds, UK.

CO_2 from ammonia production

- 6-7 Mt/yr CO_2 already separated at ammonia plants and available for use
  - Figures adjusted for estimated bulk CO_2 sales and consumption in urea
- Most close to North Sea coasts

➢ Could be used to prove CO_2 transport and storage infrastructure

Availability of CO_2 from ammonia production in Europe



Key: yellow circle - ammonia plant;
green flag - excess CO_2 available;
red flag - CO_2 unlikely to be available.
Source: SCCS analysis, 2013

- CCS from large industrial sources can play major role in achieving 2030 emission reduction targets
- Appropriate policies and support mechanisms needed to achieve rate of deployment required
- Need wider measures to achieve 2050 targets
  - Efficiency improvements, fuel switching, CCS in wider and smaller applications