



Master STEP, IPGP, Paris. Frontiers in geosciences class, 21/03/2008.

# The economics of CCS in 2008

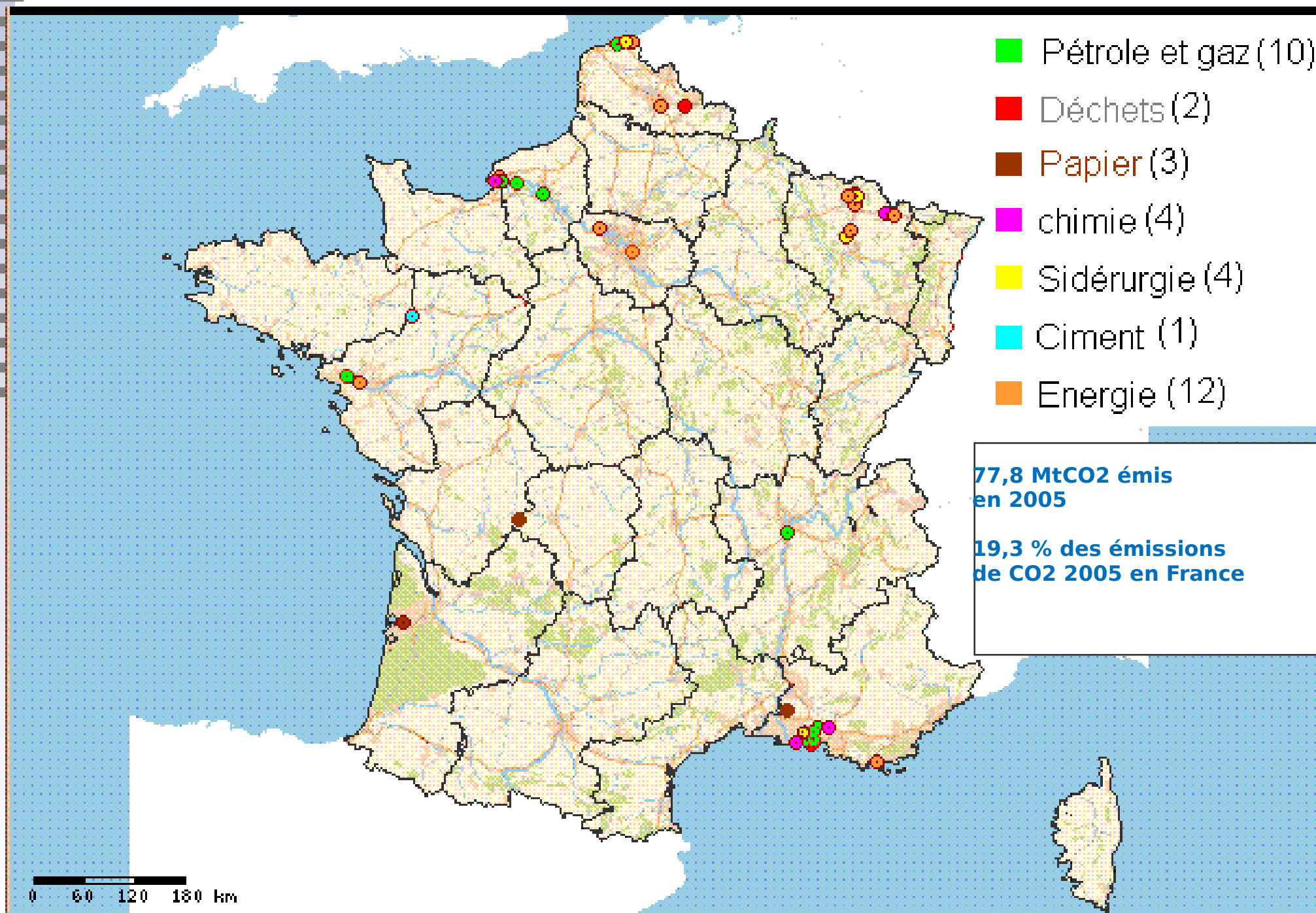
# Message

- Saving CO<sub>2</sub> is worth ~20 €/t (market price)
- CCS costs ~50 €/tCO<sub>2</sub> (capture expensive)
- Therefore something must be done

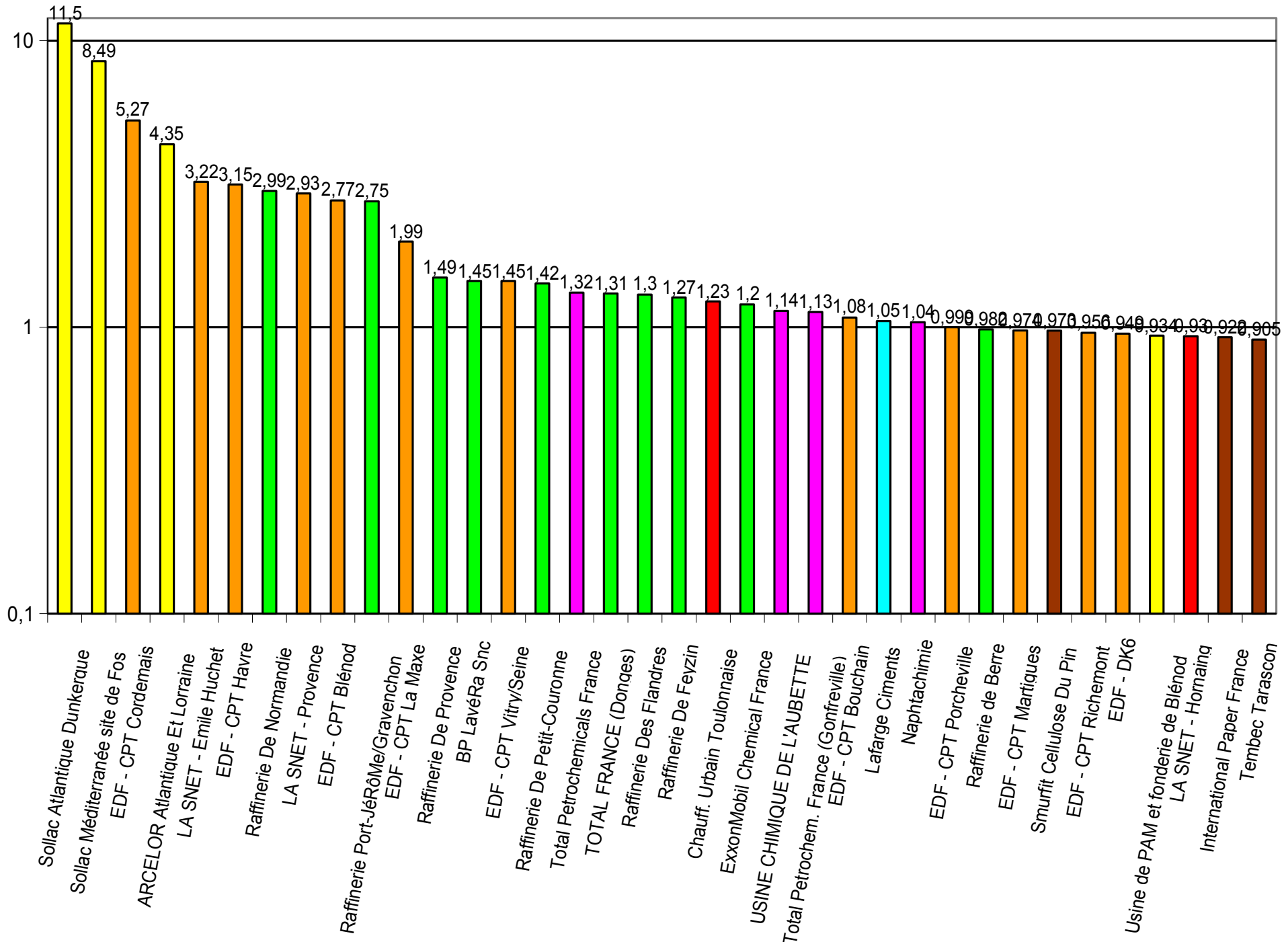
# CO<sub>2</sub> emission permits market

- There is a wide variety of industries
- One market to rule them all is efficient

# 36 largest CO<sub>2</sub> emitters industry & energy



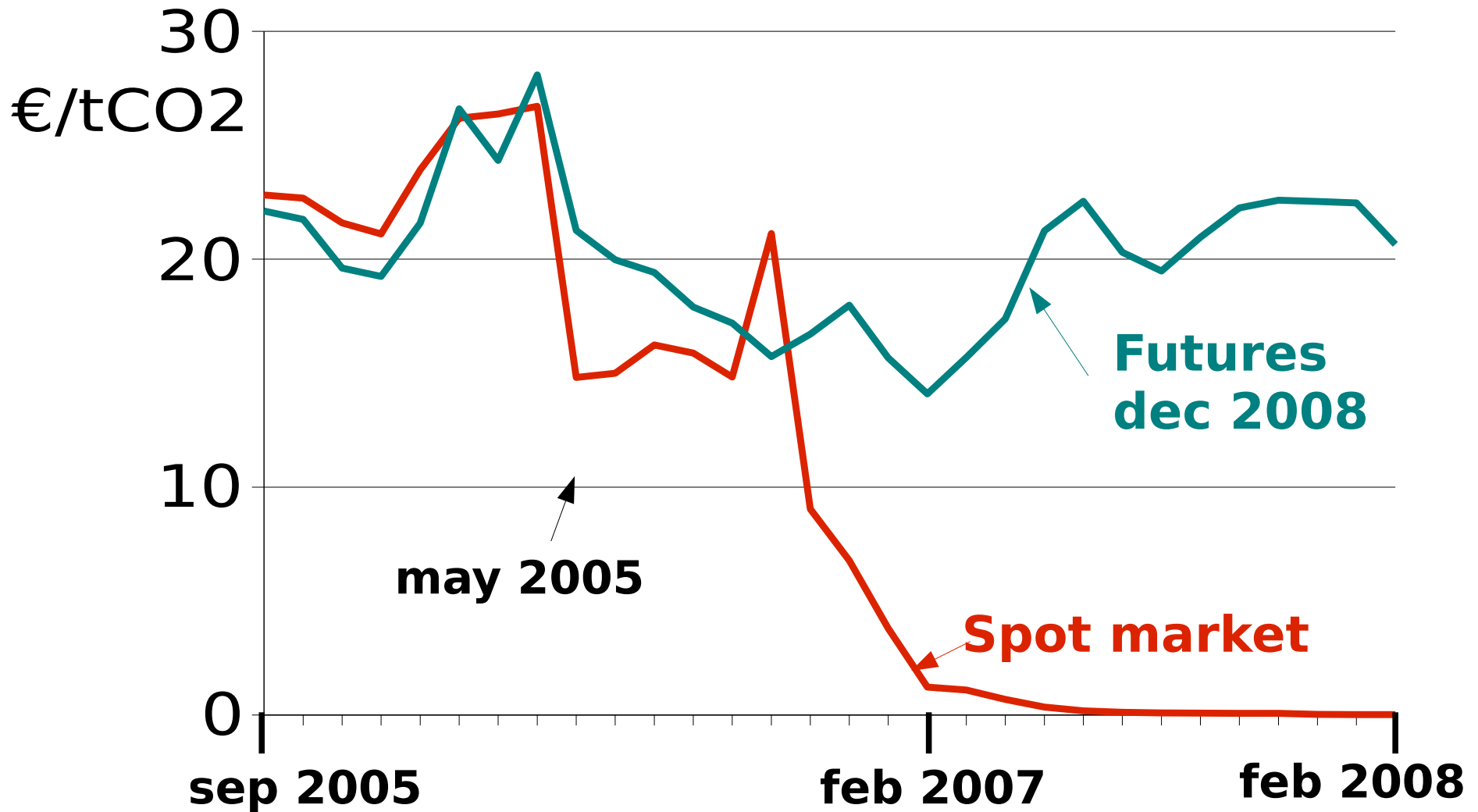
# 36 largest (MtCO<sub>2</sub>, 2005)



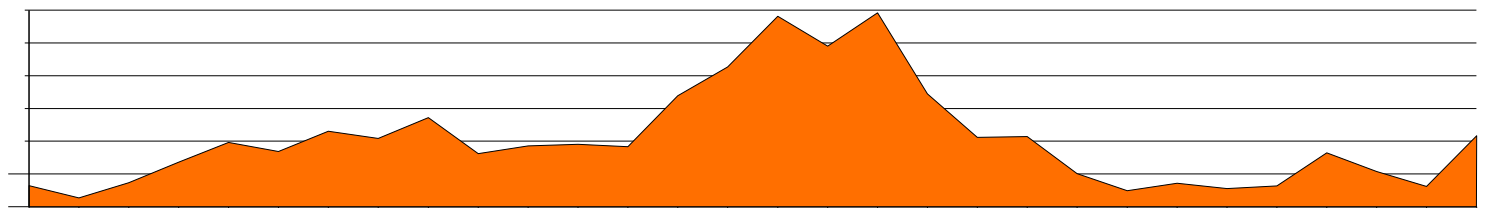
# ETS: Emission Trading System

- To emit CO<sub>2</sub> european firms must have *allowances*
- Allowances can be sold or bought
- Initial quantity given free in 2005,  
Auctions to be used in later periods

# ETS CO<sub>2</sub> allowances: Price history



**Volume  
(Mt/month)**





ETS allowance is 15-25 €/tCO<sub>2</sub>

Is that enough to justify CCS ?



## 2. Costs along the CCS chain

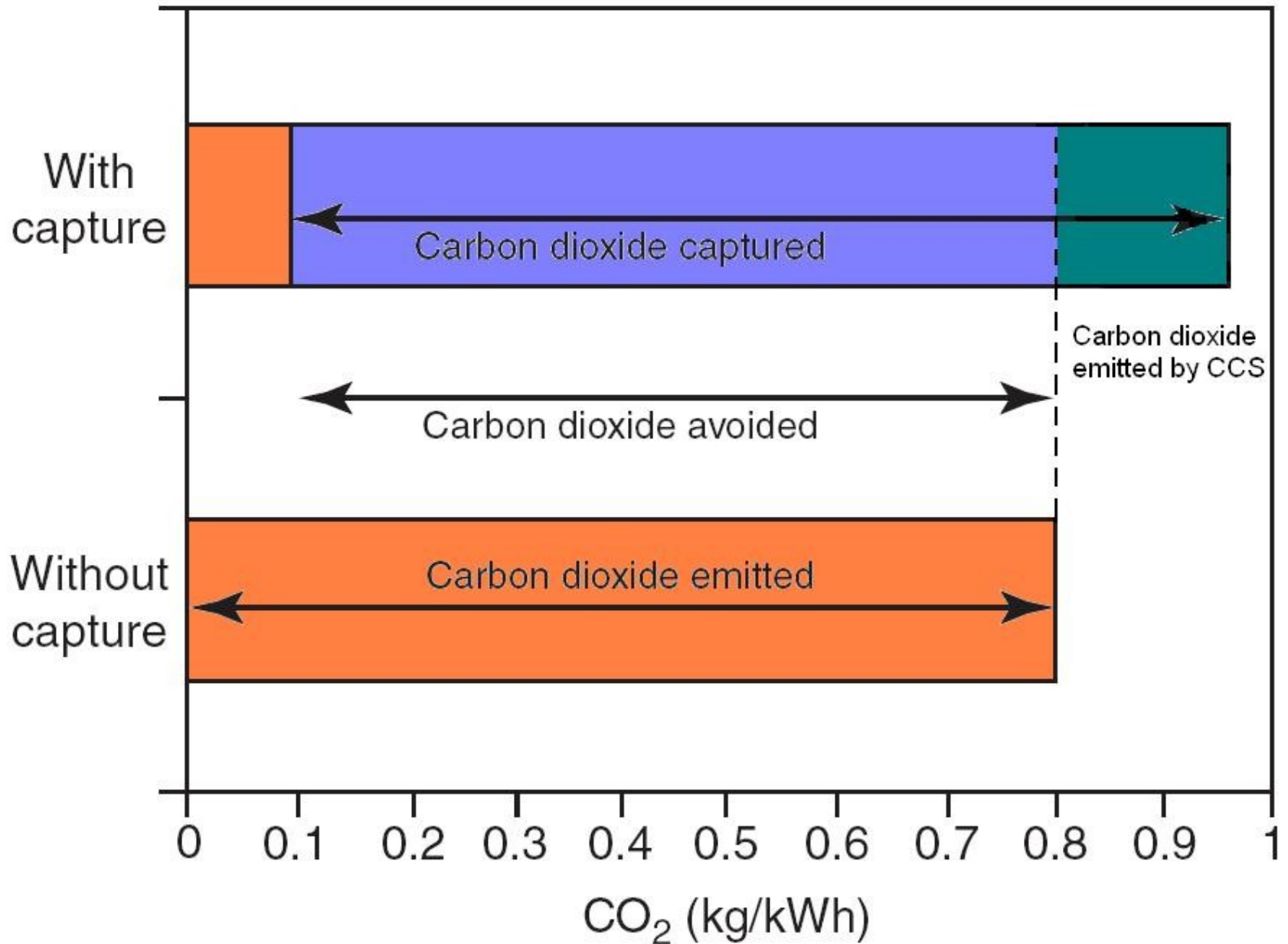
Adding up the costs of:

- Capture + compression,
- Transport: pipeline or ship
- Storage; siting, injection, monitoring

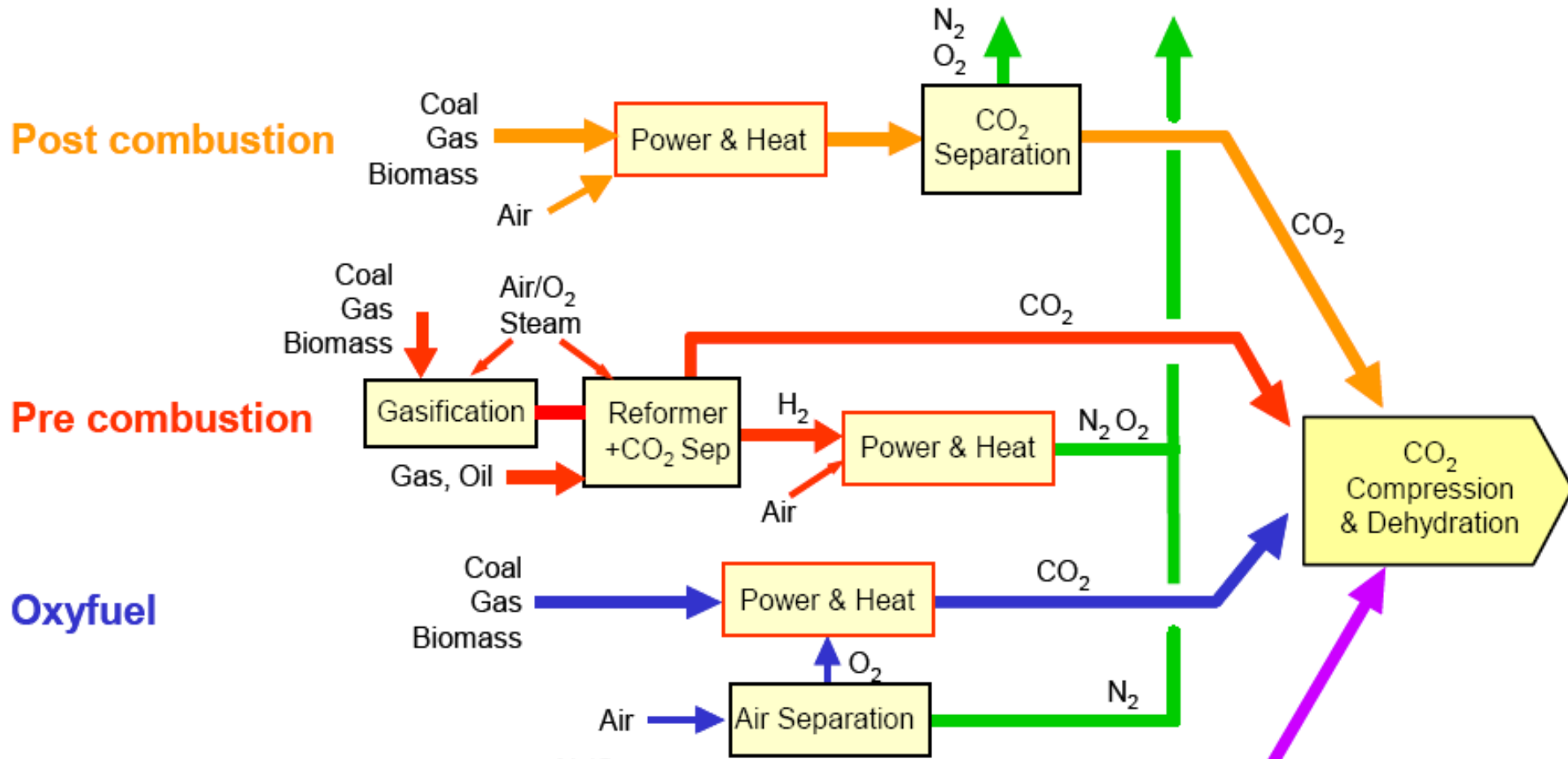
Technologies known, but

We need large scale, integrated pilots

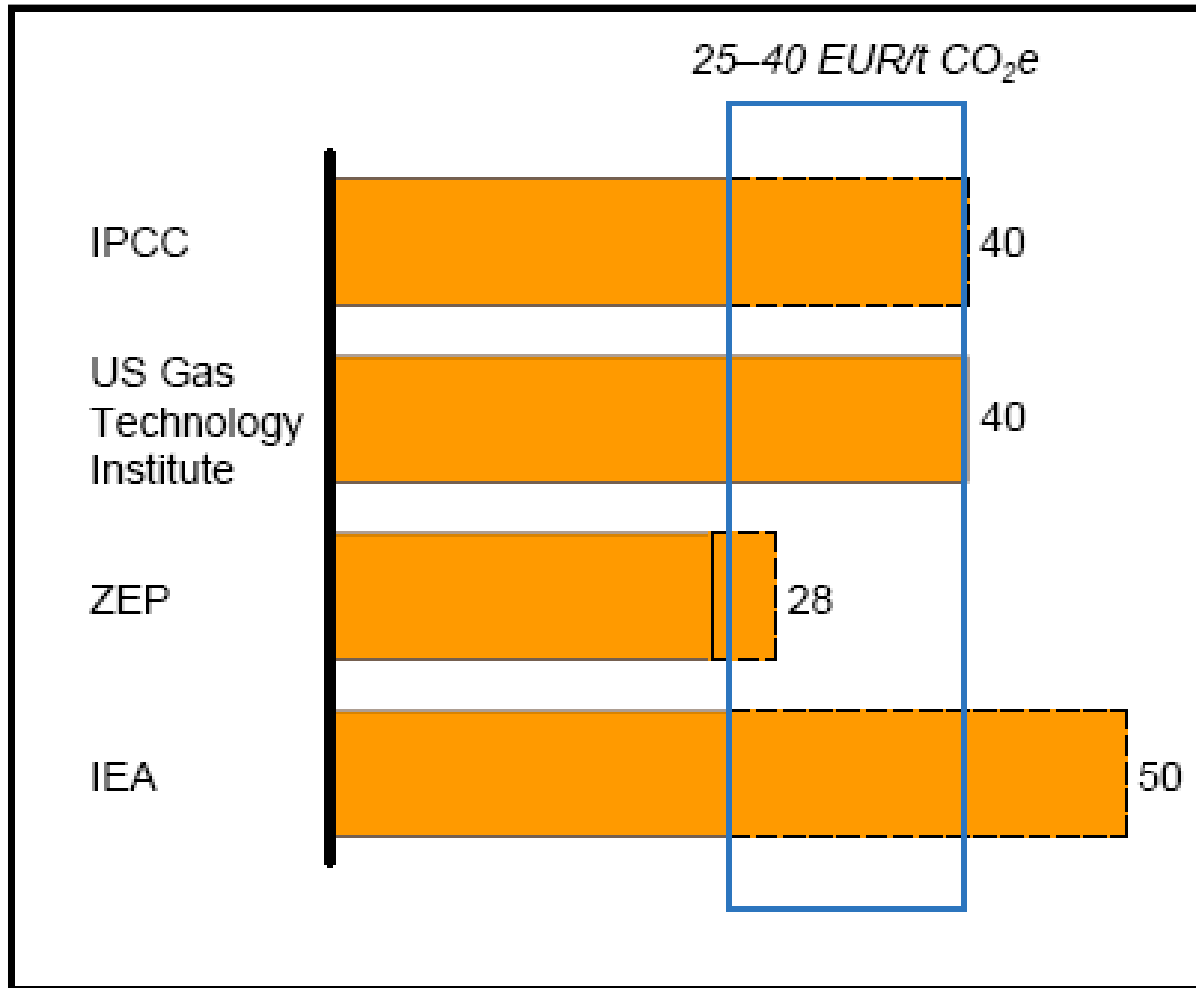
$\text{CO}_2$  avoided =  
 $\text{CO}_2$  captured - emissions of CCS



# 3 ways to capture



# Capture costs estimates (€/tCO<sub>2</sub>)



Source : Vattenfall

Existing studies suggest 25-40 €/tCO<sub>2</sub> in 2020, but no technology is mature.

Between post- and oxy-combustion, it's unclear which is cheapest.

Post-combustion as retrofit on coal plant: + 10-20 €/tCO<sub>2</sub>, but it's the only choice

# Moving CO<sub>2</sub> around

Pipeline

(supercritical dense phase)



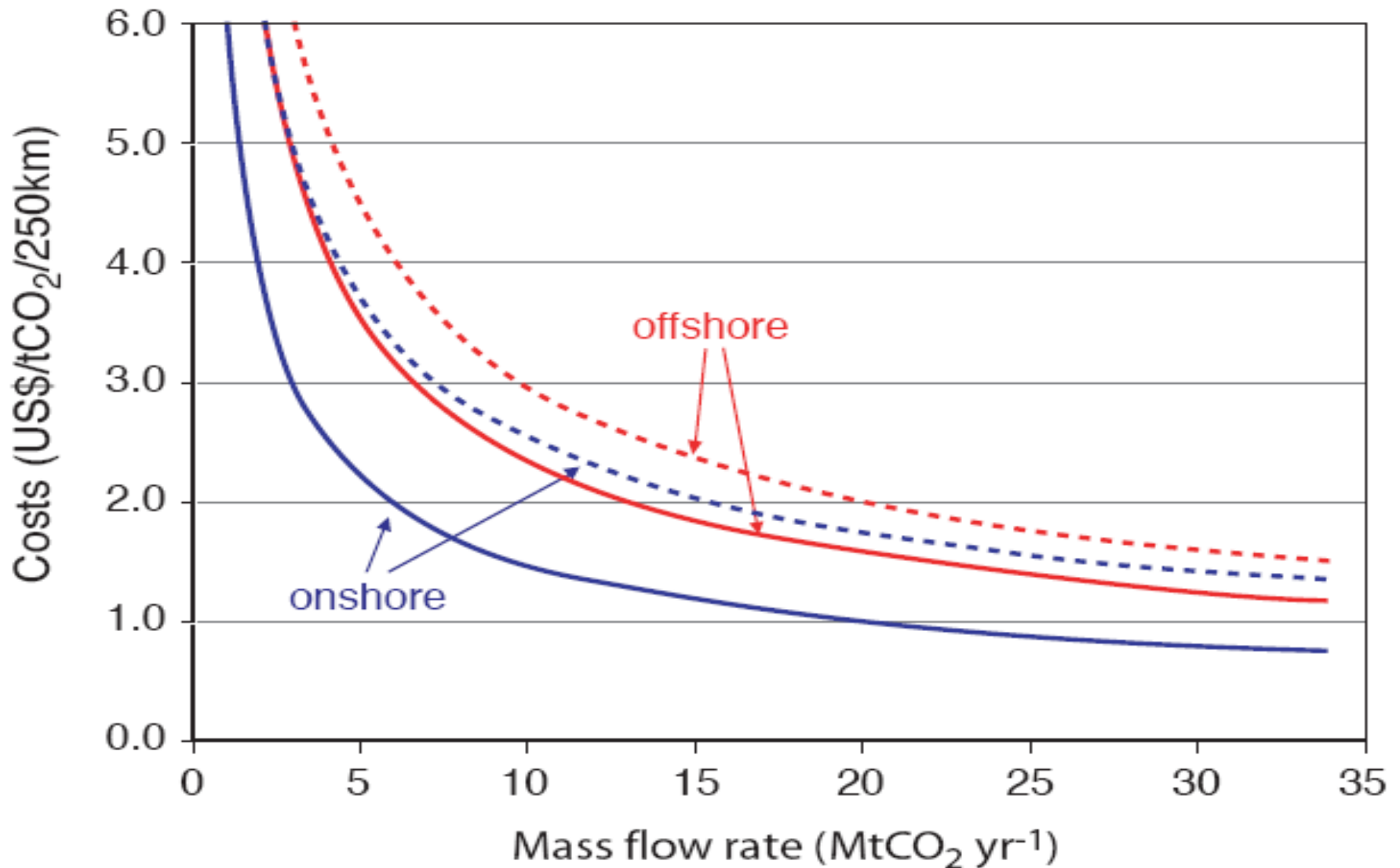
Ship

(oversea/offshore storage)

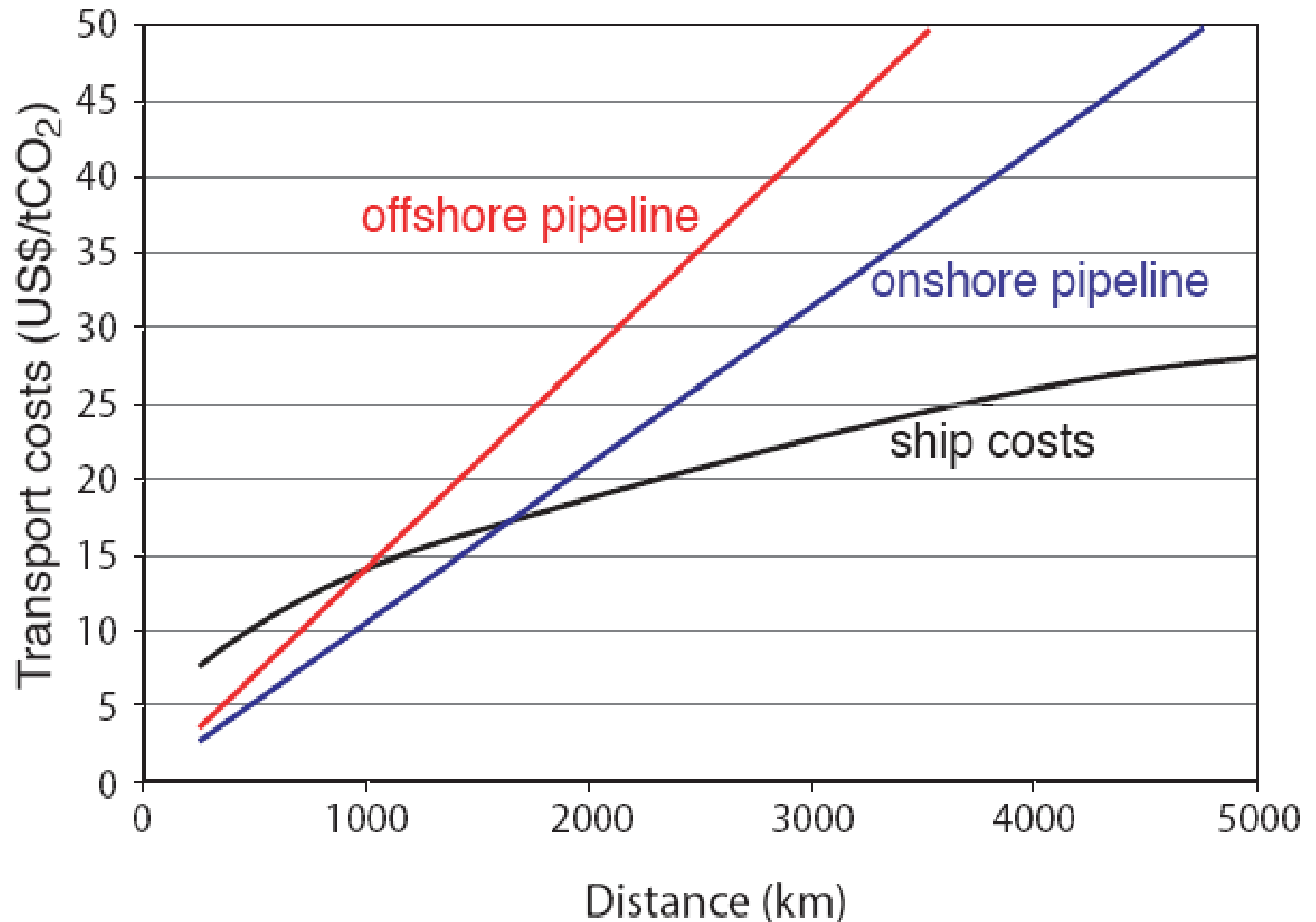


- Commercially available technologies
- Low technical progress
- Economies of scale

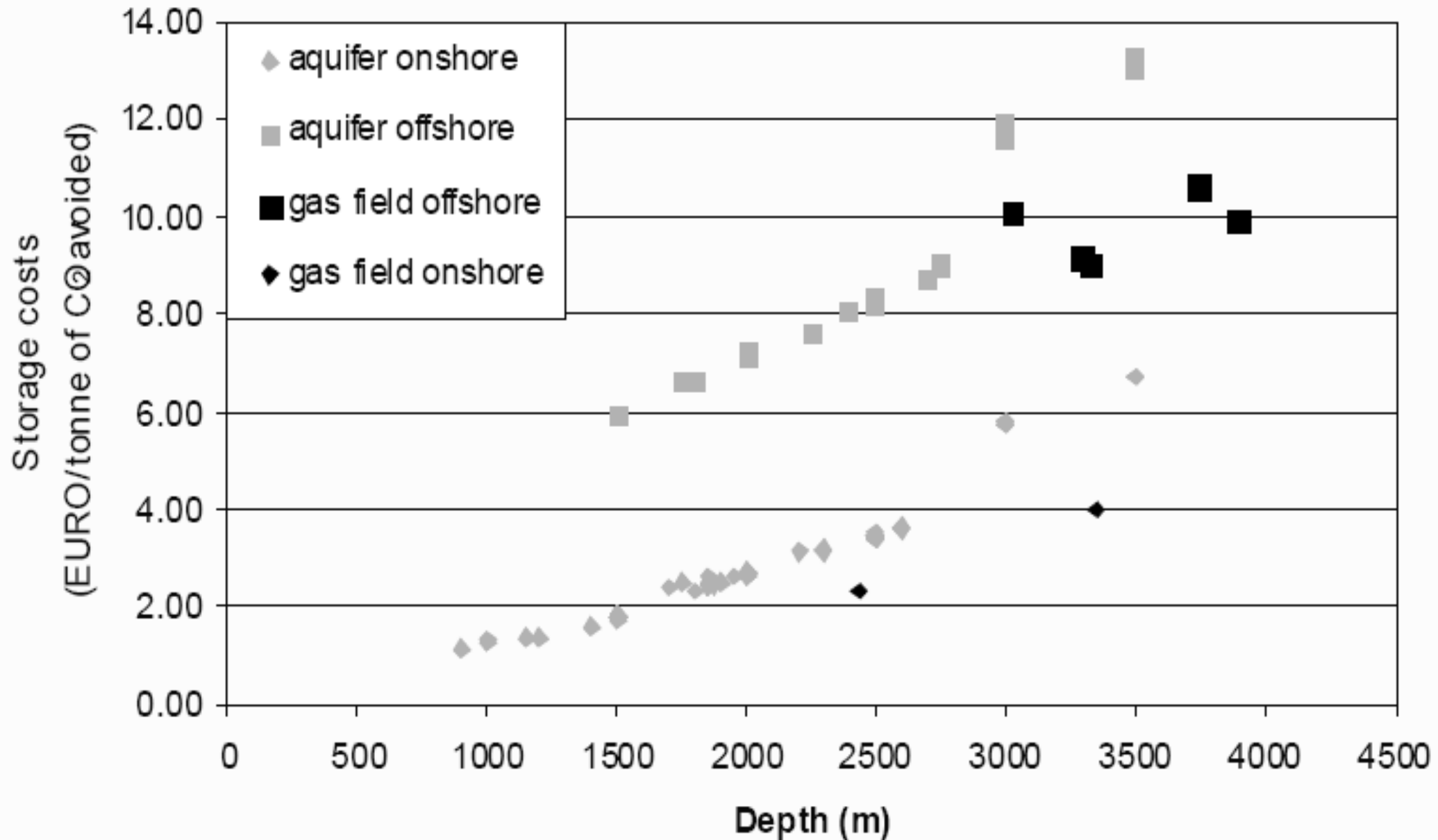
# Costs with pipelines (US\$/tCO<sub>2</sub>/250km)



# Shipping cheaper over 2000km



# Storage costs - €/tCO<sub>2</sub> avoided (TNS-Ecofys 1999)





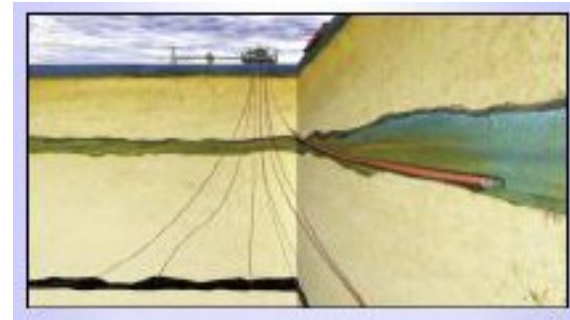
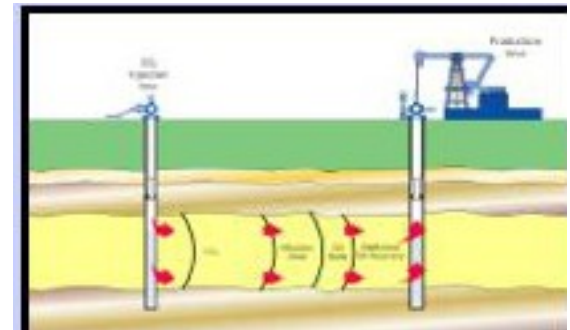
# But there are uncertainties

Risks of leakage:

Imply long term monitoring

Economic framework is uncertain  
(post Kyoto regulation, ETS...)

No public opinion exists yet



# Estimated total cost, today

**43 - 52 € / tCO<sub>2</sub> avoided for 10 M t/yr**



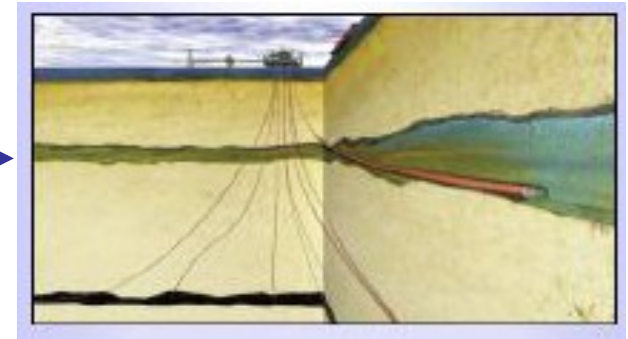
**Capture  
compressed to 110 bar**

**37-44 €/tCO<sub>2</sub>**



**Transport  
100km**

**1-3 €/tCO<sub>2</sub>**

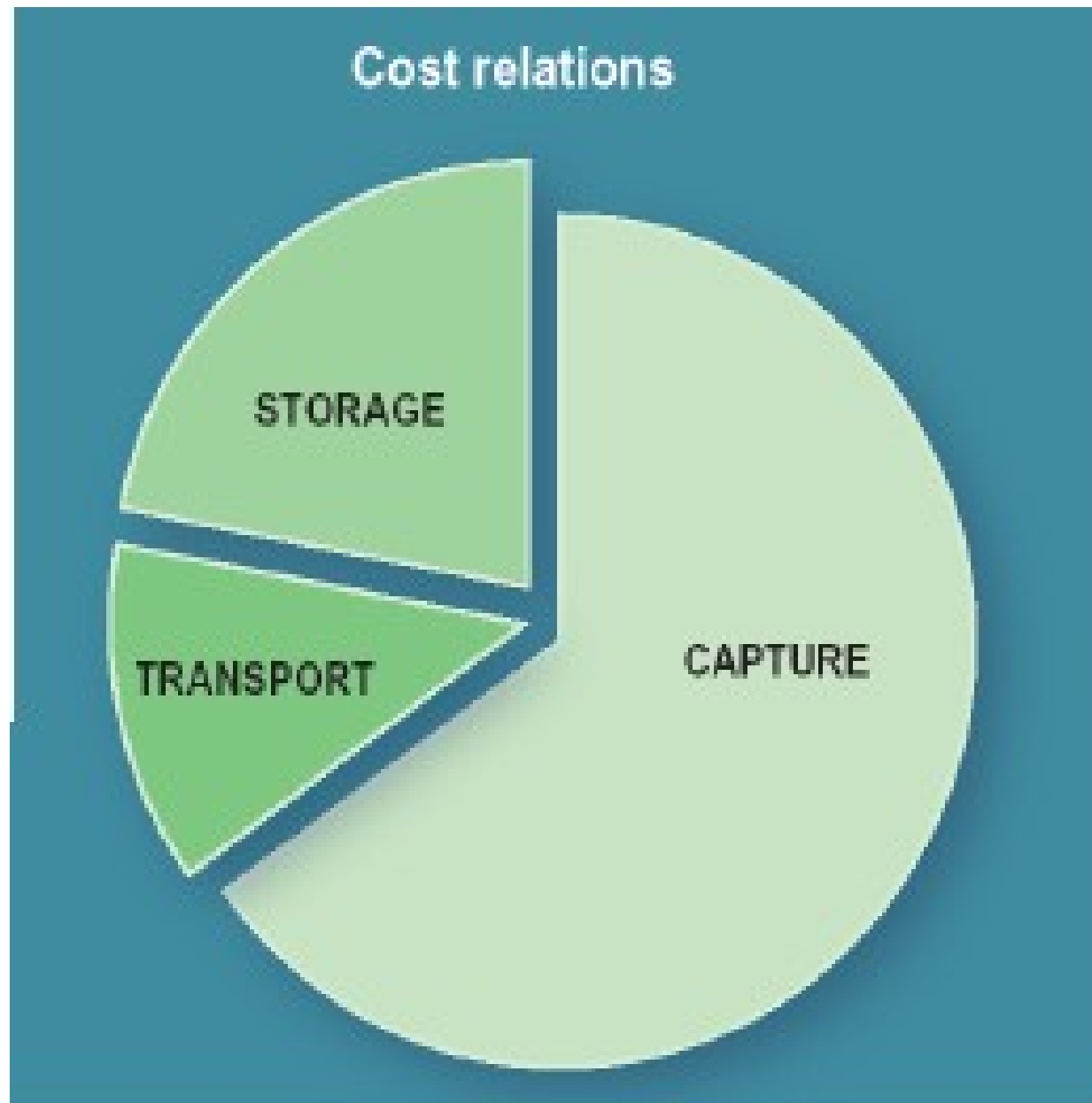


**Storage  
1Mt/yr      10Mt/yr**

**15 €/tCO<sub>2</sub>**

**5€/tCO<sub>2</sub>**

# Capture is the expensive step



# CCS is way over CO2 market price

Incitations are needed

$$50 \text{ €/tCO}_2 \text{ (CCS)} > 20 \text{ €/tCO}_2 \text{ (ETS)}$$

There are public benefits to R, D & D

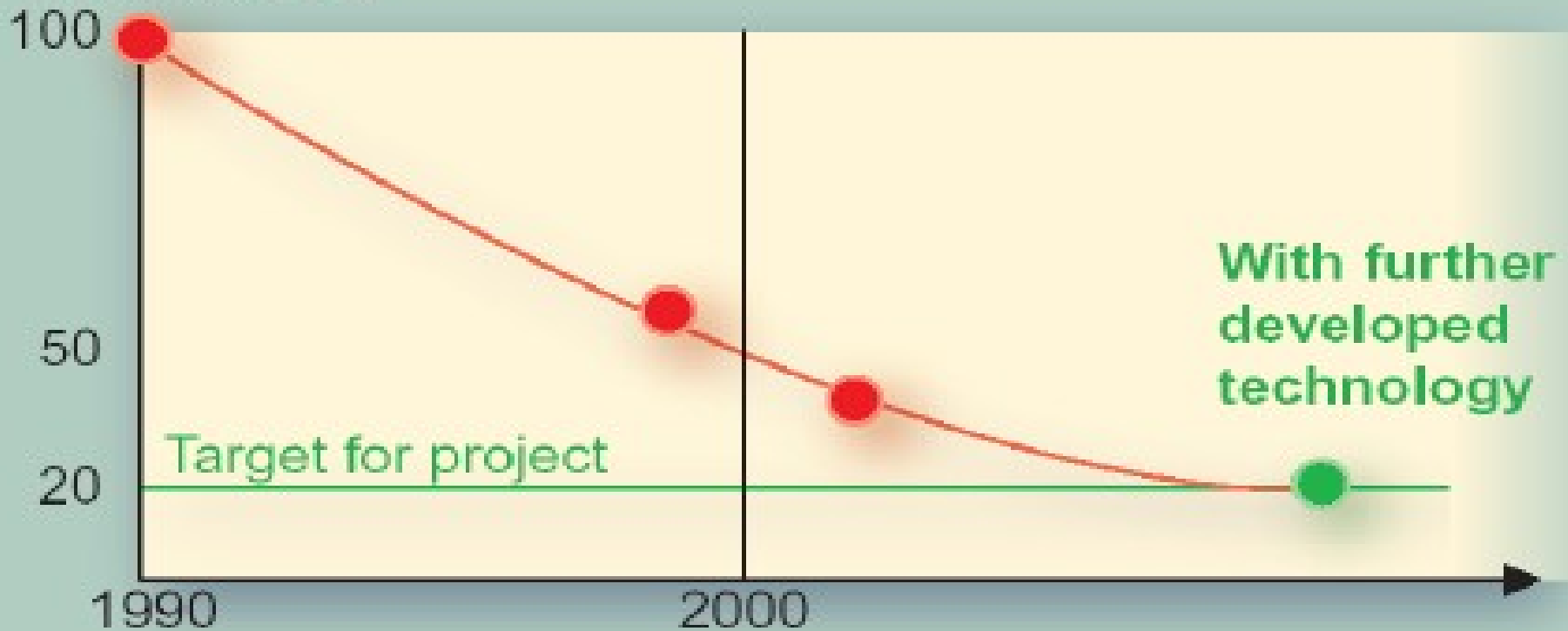
# Electricity production cost increases by >30%

- Coal plant:  
from 4.3-5.2 c/kWh without  
to 6.3-9.9 c/kWh with CCS  
400M\$ additional investment
- Natural gas combined cycle:  
3.1 - 5.0 c/kWh without  
4.3 - 7.7 c/kWh with

# Cost reduction target: 20€/tCO<sub>2</sub>

Development of total estimated cost  
(capture, transport and storage)

EUR/ton CO<sub>2</sub>



# Conclusion

- European market (ETS)  $\sim 20_{\pm 5}$  €/tCO<sub>2</sub>
- CCS costs  $\sim 50$  €/tCO<sub>2</sub> today
- Capture is expensive