THE DEPLOYMENT OF CCS INFRASTRUCTURES

This time is different (?)

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PSL* SEMINAR – NOV. 29TH 2023

ROADMAP

Introduction

I: Insights from recent works on the economics of CCS

II: CCS in France: recent news from the French front

Some concluding remarks (& challenges ahead)

CCS deployment, a road paved with ~~roses?~~ No! BRAMBLES!

- CCS in the literature (so far)

Contents lists available at ScienceDirect

Energy Policy (2021)

journal homepage: www.elsevier.com/locate/enpol

What went wrong? Learning from three decades of carbon capture, utilization and sequestration (CCUS) pilot and demonstration projects

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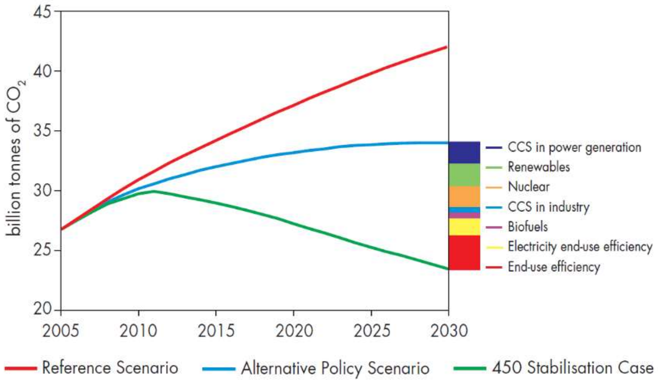
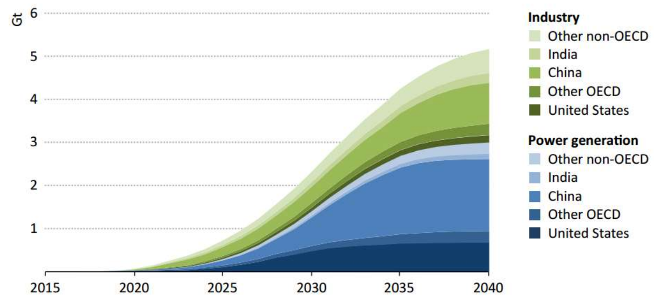
- A uninterrupted series of **delays & missed opportunities**

Figure 5.12: CO_2 Emissions in the 450 Stabilisation Case



Source: IEA (WEO 2007)

Figure 4.4 ▷ CO_2 captured in the 450 Scenario by sector and region



Note: Industry includes the following sectors: steel, cement (energy- and process-related), chemicals and paper production; oil refining; coal-to-liquids, gas-to-liquids and natural gas processing.

Source: IEA (WEO 2015, Special Report)

CCS deployment: this time is different?

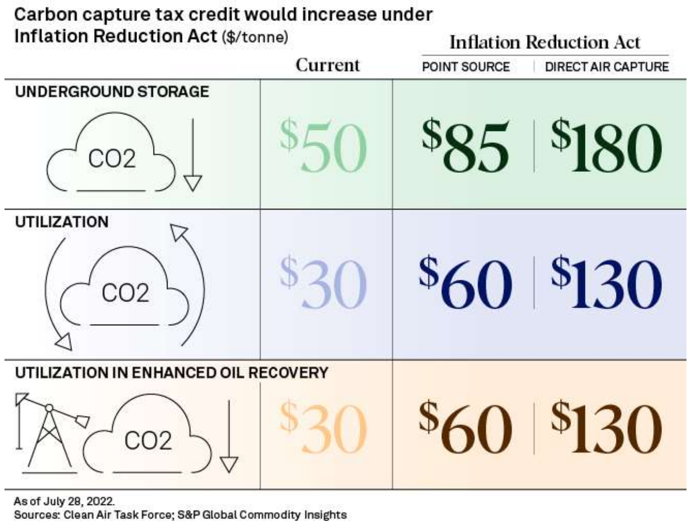
- **Demand-side**

  Changing focus
  - (from powergen to industrial emitters)

  & New policies for a **Technology Pull**
  - The U.S **Inflation Reduction Act** (2022)
  - In Europe
    - Higher CO_2 price levels
    - The EU's **Carbon Border Adjustment Mechanism** (**CBAM**)
    - The EU's **Net Zero Industry Act**

- **Storage**
  - A clarified regulatory framework

- **Infrastructures** ?

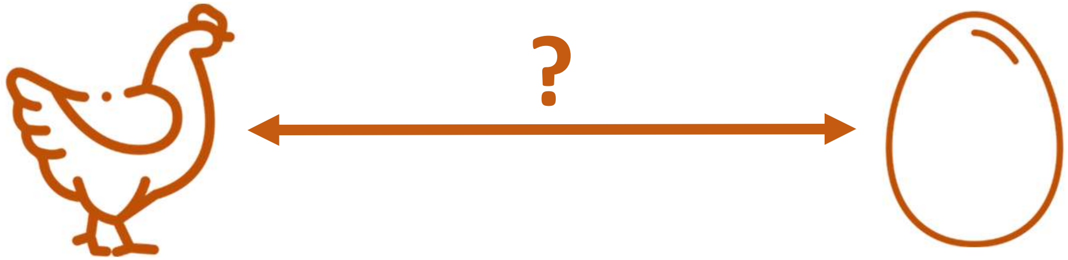


Carbon capture tax credit would increase under Inflation Reduction Act ($/tonne)

	Current	Inflation Reduction Act: Point source	Inflation Reduction Act: Direct air capture
UNDERGROUND STORAGE	$50	$85	$180
UTILIZATION	$30	$60	$130
UTILIZATION IN ENHANCED OIL RECOVERY	$30	$60	$130

As of July 28, 2022.
Sources: Clean Air Task Force; S&P Global Commodity Insights

Herzog (2011): a chicken and egg problem



I – Insights from recent works

Existing regulatory frameworks

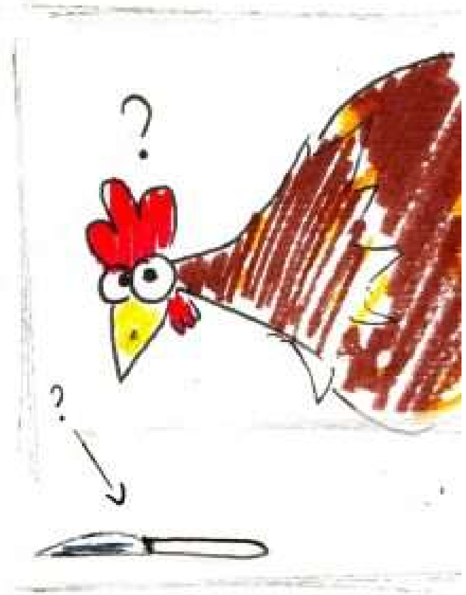
Table 1: Review of regulatory initiatives in early-adopter regions for CCS pipeline transportation infrastructures

	UK	U.S. Interstate	U.S. Intrastate	Norway	EU
Regulatory agency for rates and access	Ofgem likely to be appointed (BEIS 2022a)	Unclear regulatory mandate for pipelines crossing some federal lands and for pipelines not crossing federal lands	No agency, except for common carriers in Texas and Colorado	No agency, but the state intervenes as a project leader and as a stakeholder of the transportation infrastructure (Gassnova SF 2022)	Silent legislation
Non-discriminatory access prices	Yes	Mandatory for common carriers	Generally mandatory for common carriers	Yes (informational discussion)	Yes
Pricing scheme	Rate-of-return regulation combined with performance incentives (BEIS 2022a)	Project-dependent (STB intervenes in case of a dispute, see discussion in Appendix A)	Project-dependent	Two-tariff structure: (i) a user-specific maritime component based on distance, and (ii) a non-discriminatory access charge to the Norwegian onshore receiving terminal, the offshore pipeline, and the storage site	Silent regulation

Nicolle, A., Cebreros, D., Massol, O., & Jagu Schippers, E. (2023). Modeling CO2 Pipeline Systems: An Analytical Lens for CCS Regulation. *Economics of Energy & Environmental Policy*, *12*(2).

Three main types:

1. **The explicit approach (e.g., the UK)**
2. **State intervention (e.g., Norway)**
3. **The fuzzy approach (e.g., U.S., E.U.)**



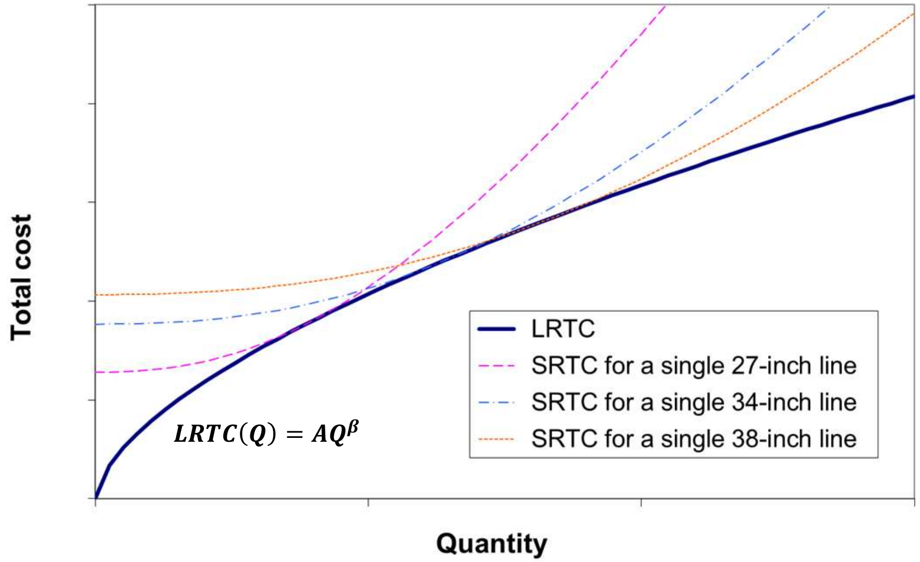
Back to basics: Technology 101

Nicolle, A., Cebreros, D., Massol, O., & Jagu Schippers, E. (2023). Modeling CO2 Pipeline Systems: An Analytical Lens for CCS Regulation. *Economics of Energy & Environmental Policy*, *12*(2).

- **Insights from the simplest pipeline system**
  - Point-to-point pipeline (length L) & a pumping station
  - 2 inputs (capital K, energy, E) & 1 output Q
  - CO_2 transported in a "dense phase" state
  - Engineering equations
- Production function

$$Q^{\beta} = K^{\alpha} E^{1-\alpha}$$

with $\beta = \frac{9}{11}$ and $\alpha = \frac{8}{11}$



- **Insight #1: costs are subadditive in the long-run**

  => a **natural monopoly**

- **Insight #2: K is irreversible + LR economies of scale**

  => **Building ahead of demand** can lower the intertemporal cost (Chenery, 1952; Manne, 1961)

Insight #1:
The case of an unregulated monopolist

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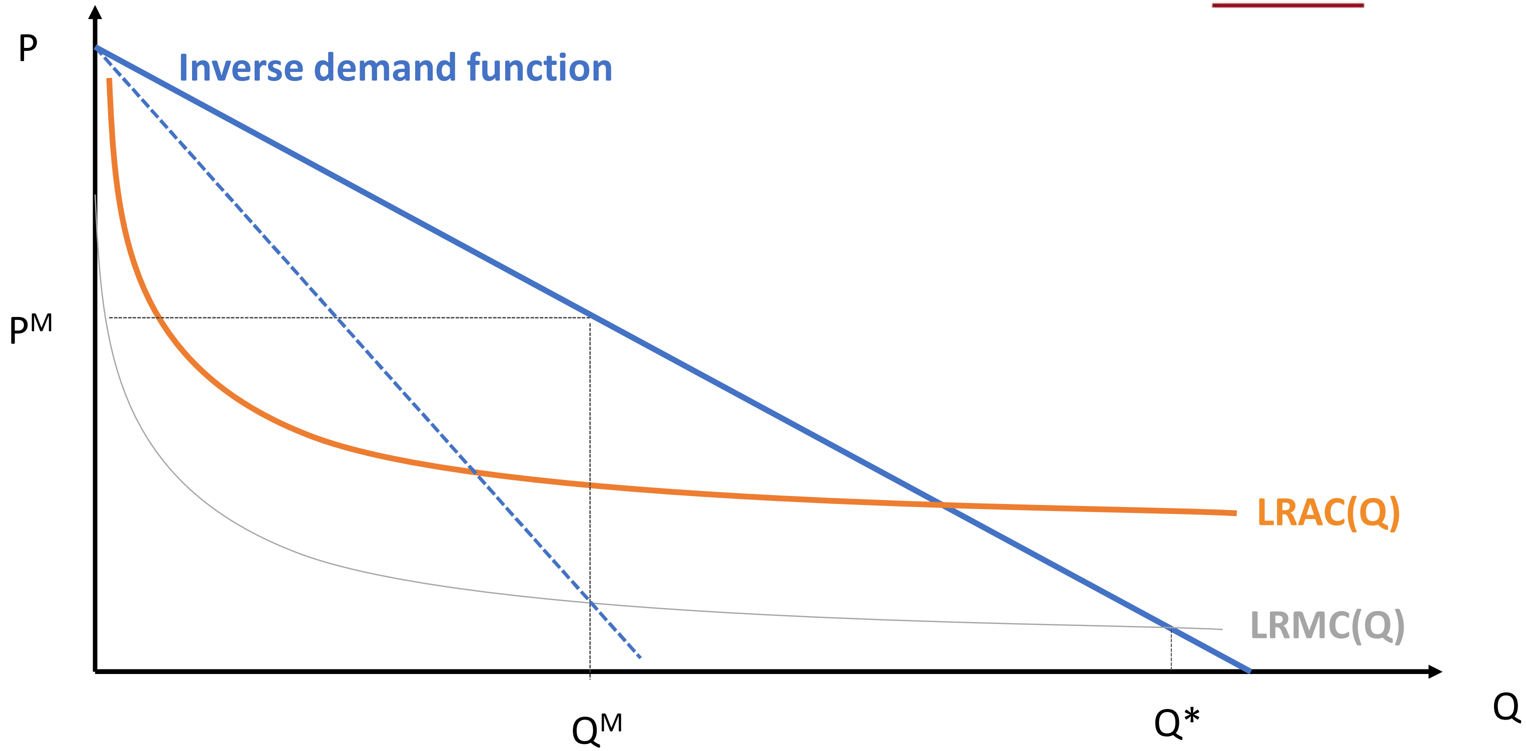

The case of a private monopolist operator

=> Absent any regulation, the amount of CO_2 captured will fall short of Q*

Insight #1: LRMC pricing cannot recoup the cost

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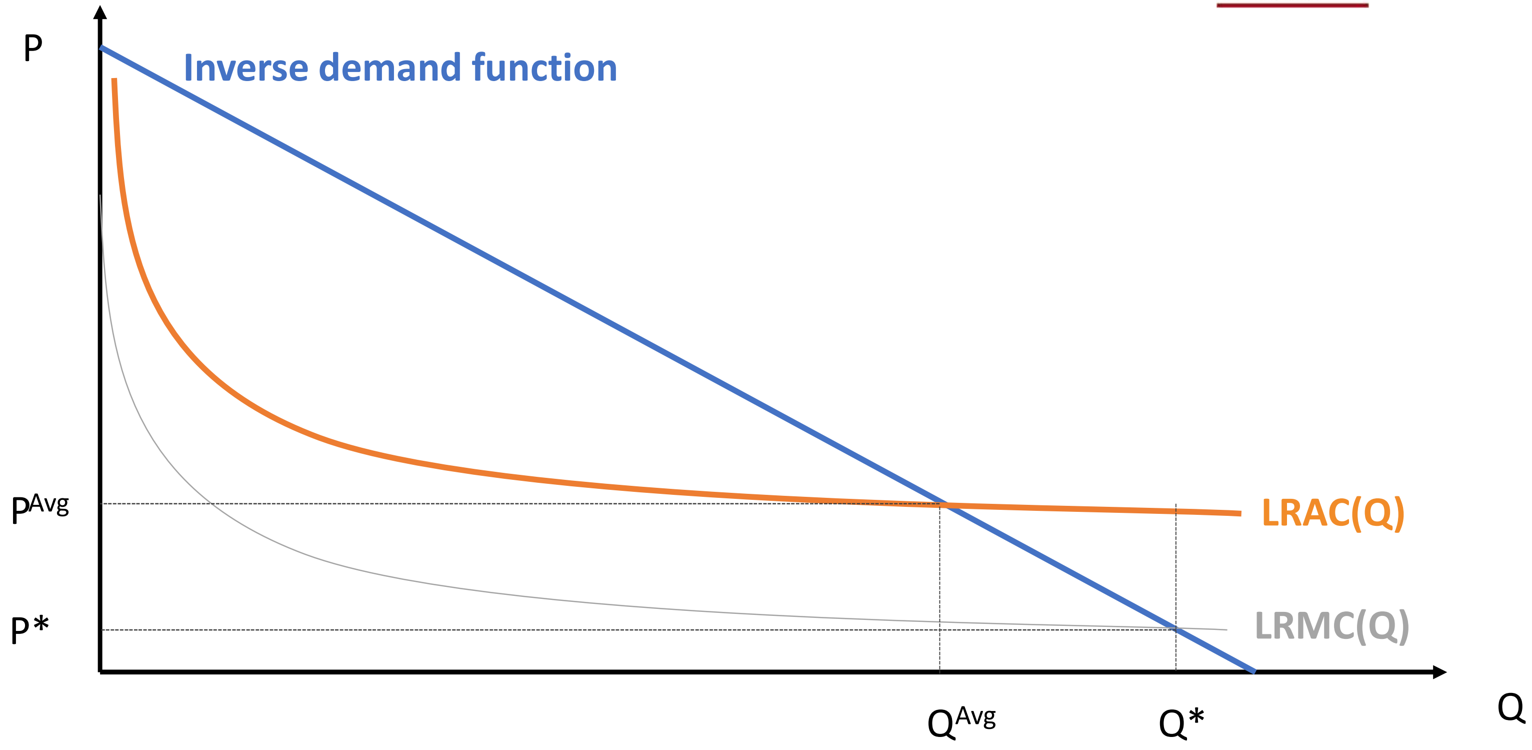
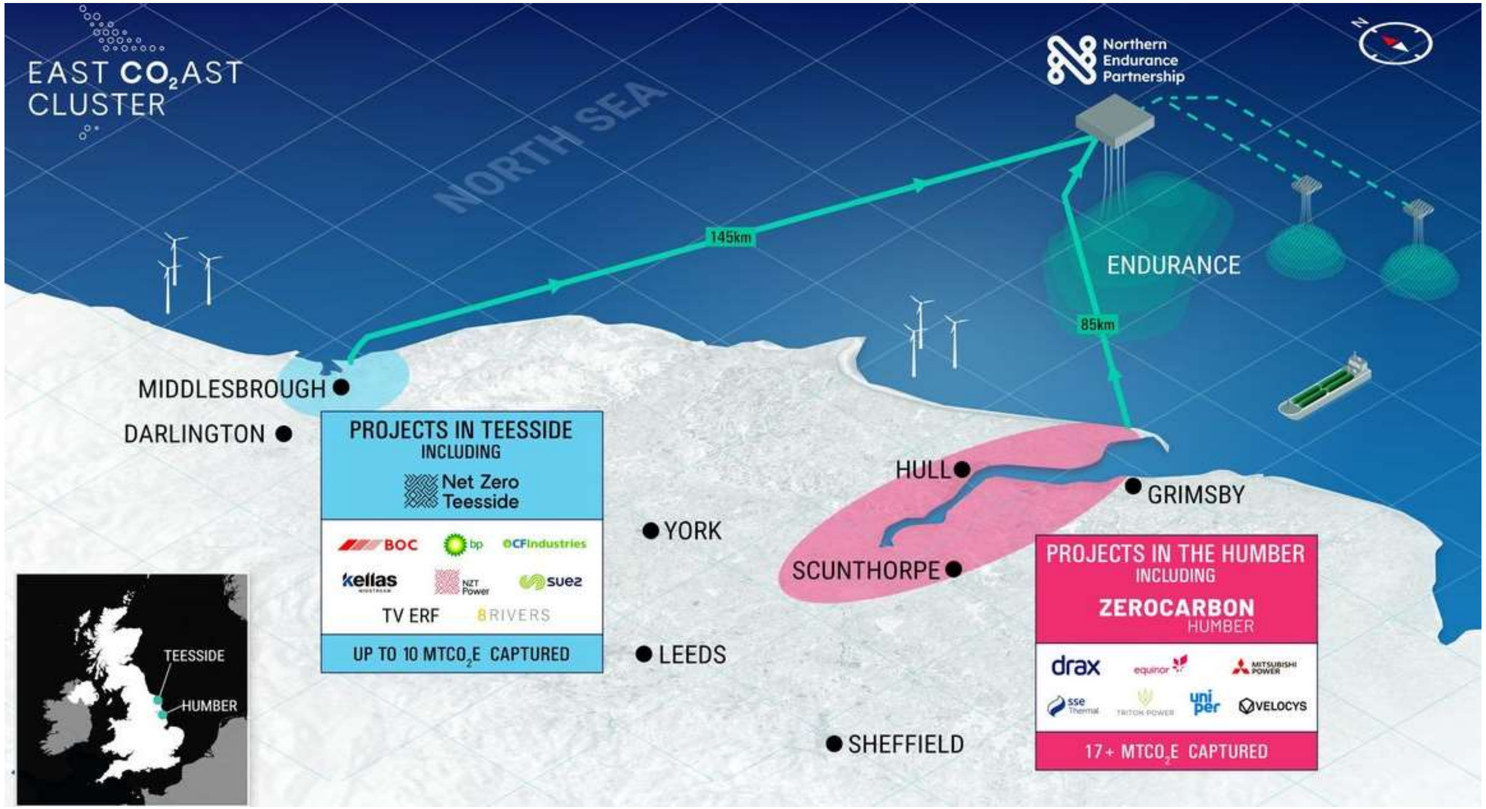


- Uniform (non-dicriminatory) prices => the use of a second-best solution (Q^{Avg}, P^{Avg})

But $Q^{Avg} \approx 0.7\, Q^*$ => **2 conflicting objectives**

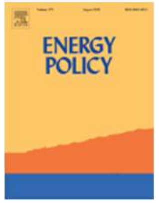
Max Q stored **vs.** **Preserve non-discriminatory prices**

Insight #2: The design problem



(Source: East Coast cluster's website)

Insight #2: The design problem



Nicolle, A., & Massol, O. (2023). Build more and regret less: Oversizing H2 and CCS pipeline systems under uncertainty. *Energy Policy*, *179*

<u>From a regulator's perspective</u>

- How can it distinguish between two types of project planner:

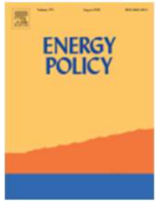
A project planner that **oversizes** its infrastructure to respond to future demand

(and that eventually misjudges its forecasts and ends up with an overcapitalized infrastructure)

A project planner that **voluntarily overcapitalizes** to exploit regulatory flaws

(A-J effect, fuzziness of regulation)

Insight #2: The design problem
Shall we build ahead of demand?



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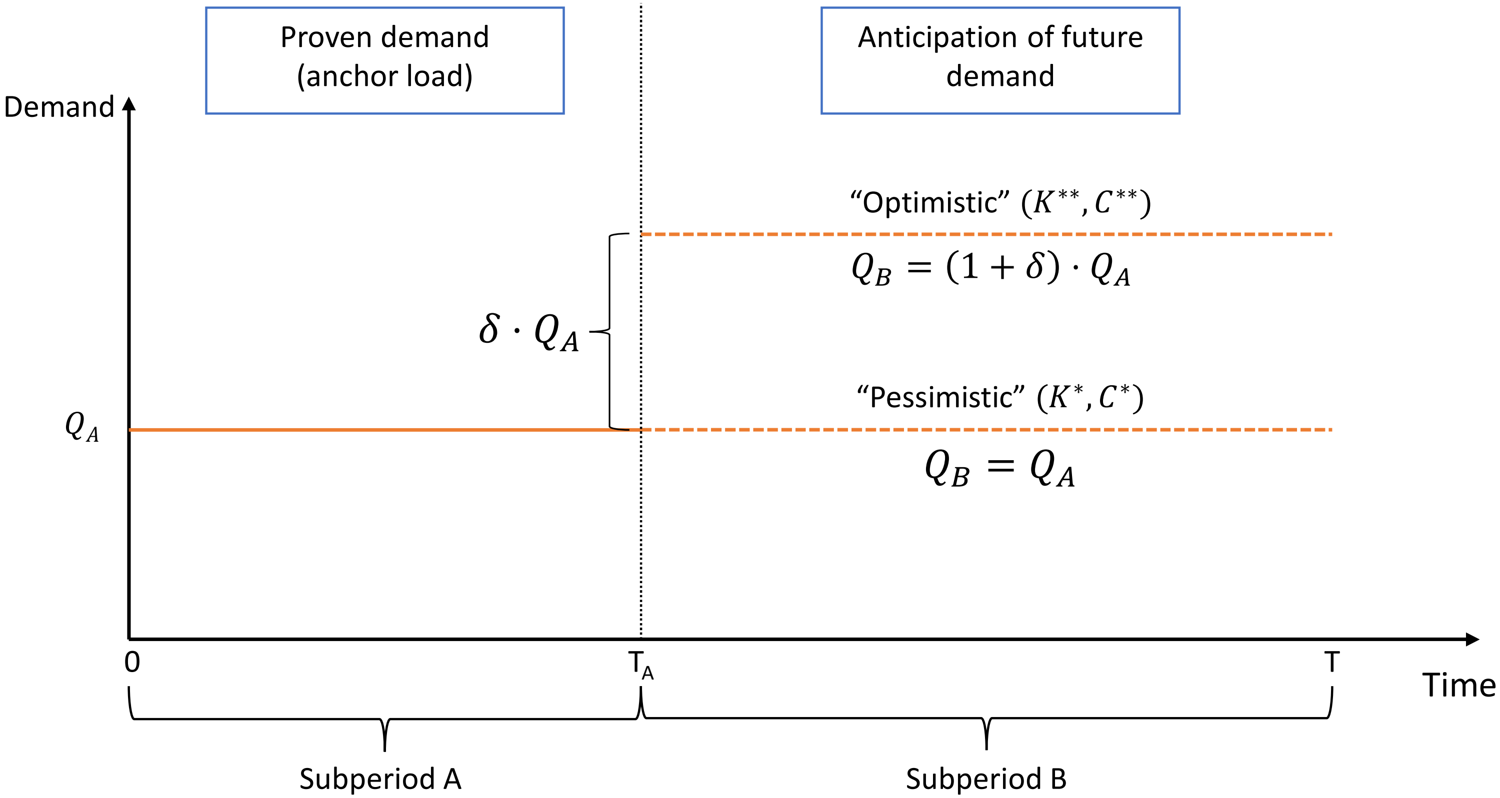
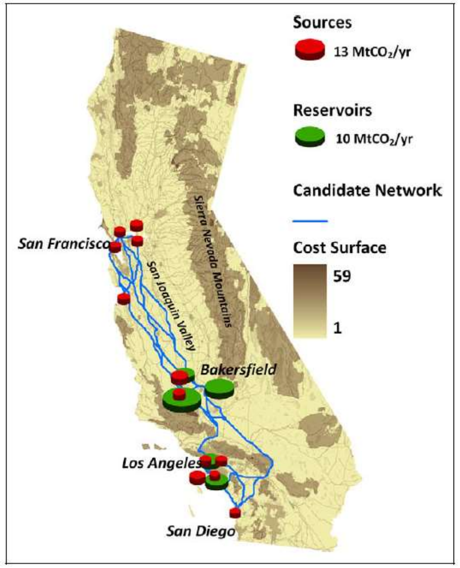


- Insights from **a MiniMax Regret decision** rule:

Building ahead of demand is regret-minimizing!

Insight #3: CO_2 transportation as a club good

Network optimization models



Candidate network for California example.

Source: Kuby et al. (2011)

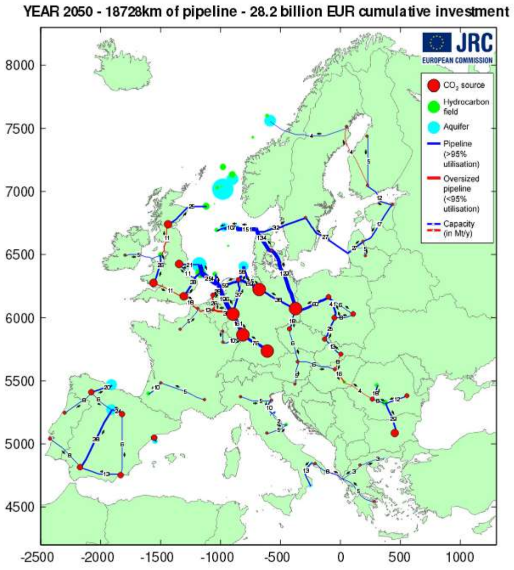


Figure 1 Optimal CO_2 pipeline network in 2050.

Source: Morbee et al. (2012)

The tale of a benevolent planer

Min total cost of pipeline infrastructure

s.t. node balance constraints

pipeline capacity constraints

storage capacity constraints

- However, CO_2 transportation is **a club good**

=> Do emitters obtain a fair share of the benefits?

=> a need for a **cooperative game theoretic approach**

Insight #3: CO_2 transportation as a club good

Contents lists available at ScienceDirect

European Journal of Operational Research (2015)

journal homepage: www.elsevier.com/locate/ejor

Innovative Applications of O.R.

Joining the CCS club! The economics of CO_2 pipeline projects

Olivier Massol[a,b,c,*], Stéphane Tchung-Ming[a,d], Albert Banal-Estañol[c,e,f]

Contents lists available at ScienceDirect

Energy Policy (2018)

journal homepage: www.elsevier.com/locate/enpol

Capturing industrial CO_2 emissions in Spain: Infrastructures, costs and break-even prices[☆]

Olivier Massol[a,b,c,d,*], Stéphane Tchung-Ming[a,b,c,d,e], Albert Banal-Estañol[c,e]

Energy Policy 171 (2022) 113265

Contents lists available at ScienceDirect

Energy Policy (2022)

journal homepage: www.elsevier.com/locate/enpol

Unlocking CO_2 infrastructure deployment: The impact of carbon removal accounting

Emma Jagu Schippers[a,b,c,*], Olivier Massol[a,b,c,d,e]

From the conditions for shared infrastructures

Finding #1: The conditions for a vertically integrated club are identical to the one of an independent pipeline operator

Finding #2: **non-discriminatory pricing** can kill some projects

Finding #3: when multiple storages are identified, the optimal community can have a **regional scale**

Finding #4: the inclusion of **BECCS** critically depends on carbon removal certification

Key messages to take away from these academic studies

I – The current regulatory framework governing CO_2 infrastructures is fuzzy

II – Despite the technology's simple nature, economic implications are overlooked

- CO_2 transportation has elements of a natural monopoly
- Regulatory rules and priorities affect environmental performance
- Do we need to impose uniform pricing?

III – Building ahead of demand can be justified

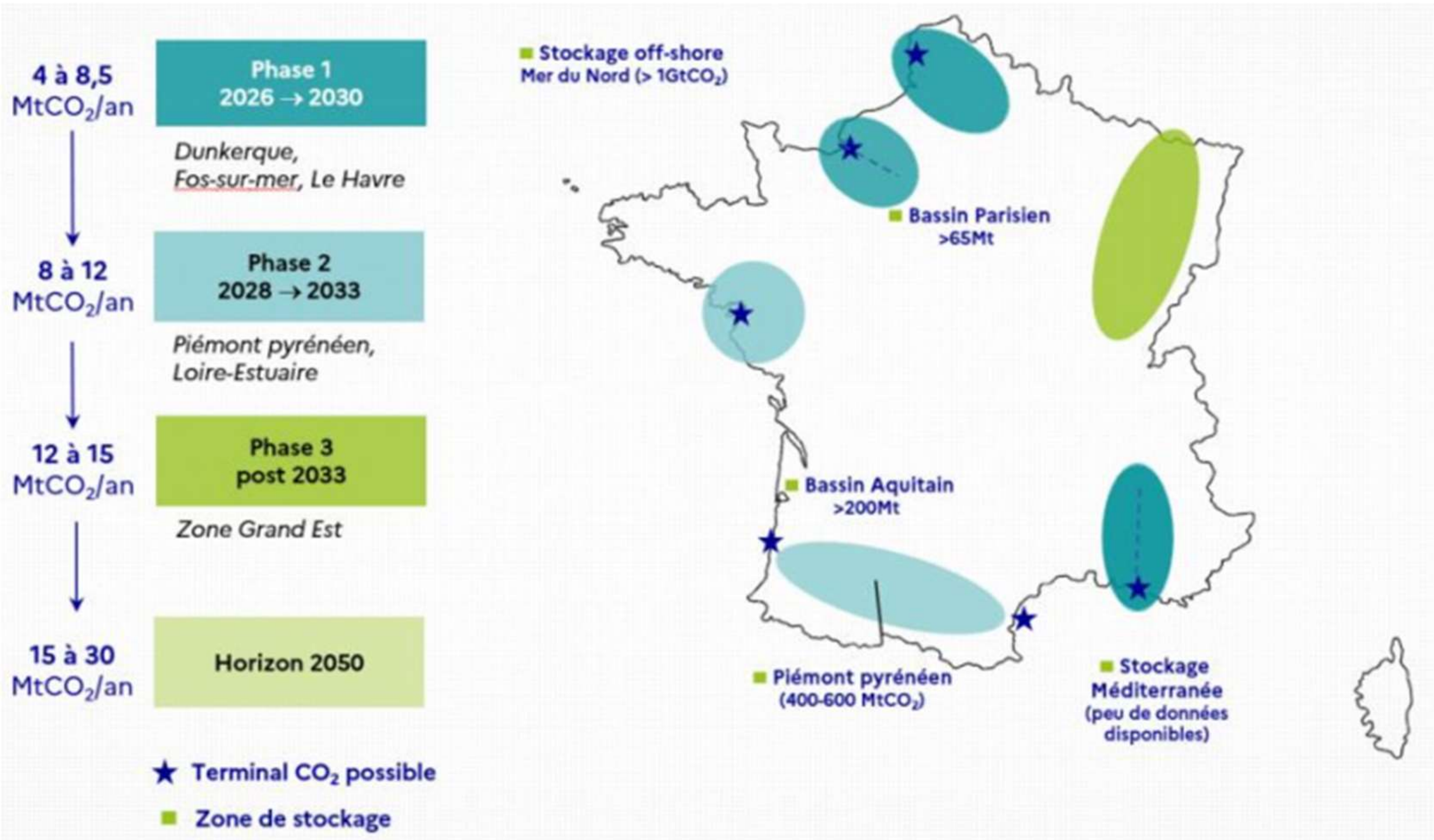
- The knowledge of the technology can help in preventing strategic overcapitalization

IV – A Club perspective yields major insights

- Again non-discriminatory pricing is not justified
- Focusing on simple communities can be preferable
- The feasibility to include BECCS & DACCS critically depend on carbon removal certification

II – Some recent news from the French front

CCS in France:
A three phase Rollout



Source: DGEC. (2023)

Phase 1: storage in neighboring countries (Norway and Italy)

→ bilateral agreements

Phase 2: national storage or in neighboring countries

→ assessment of the potential of storage by the end of 2023

→ initial seismic tests starting in 2024-2025

Phase 3: 15-30 $MtCO_2$/year

The contemporary discussion in France

Strategy CCUS (July 2023)

- **Risk-sharing through "Take or Pay" Contracts**
  → Partial coverage of potential penalties by the State
- **Transportation regulated by CRE**
  → Third-party access
- **Public support through Carbon Contract for Difference (CCfD), awarded by tenders**
  → Launch date : 2024

Consultation Response (Bellona, Oct 2023)

- **Storage objective too low**
  → Nation-wide potential of **90 MtCO_2/y** by 2050
- **Supporting CCS and Balancing risk**
  → State should take an active role (similar to Norway, Denmark or the Netherlands)
  → Avoid privately owned **natural monopolies**
- **CCfD**
  → Based on **CO_2 reduced**, **not captured**

Remaining questions

I – What policy instruments?

- **Subsidies** for…
  - … pipeline/infrastructure ?
  - … or for capture adopters?
- CCFD: increasingly popular but its economics have to be clarified for some sectors
- State-participation?
- **Binding emission mandates?**
  - By acknowledging possible differences in the sectors' obligations

II – What regulatory regime for CO2 infrastructures?

- **Third-Party access**: OK
- **Discriminatory pricing**?
- **Regulated profitability**?

III – Clarifying the feasibility of CCS in polluting countries

- Europe: Germany, Poland
- ROW: India, Gulf, China, Indonesia, Vietnam?

IV – Clarifying the unknown economics of emerging technologies

- CCS: learning effects?
- BECCS: what incentives?
- CC**U**S: what business case? What implications?

Thank you for your attention

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