International Workshop on Modeling and Policy of CO2 Removal from the Atmosphere
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Modeling direct air capture

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On capture from the air

Figure 4: Artistic rendering of how the full scale contactor may look.

Mahmoudkhani M., Heidel K.R., Ferreira J.C., Keith D.W., Cherry R.S. *Low energy packed tower and caustic recovery for direct capture of CO2 from air.* GHGT-9, Energy Procedia 1 (2009) 1535–1542

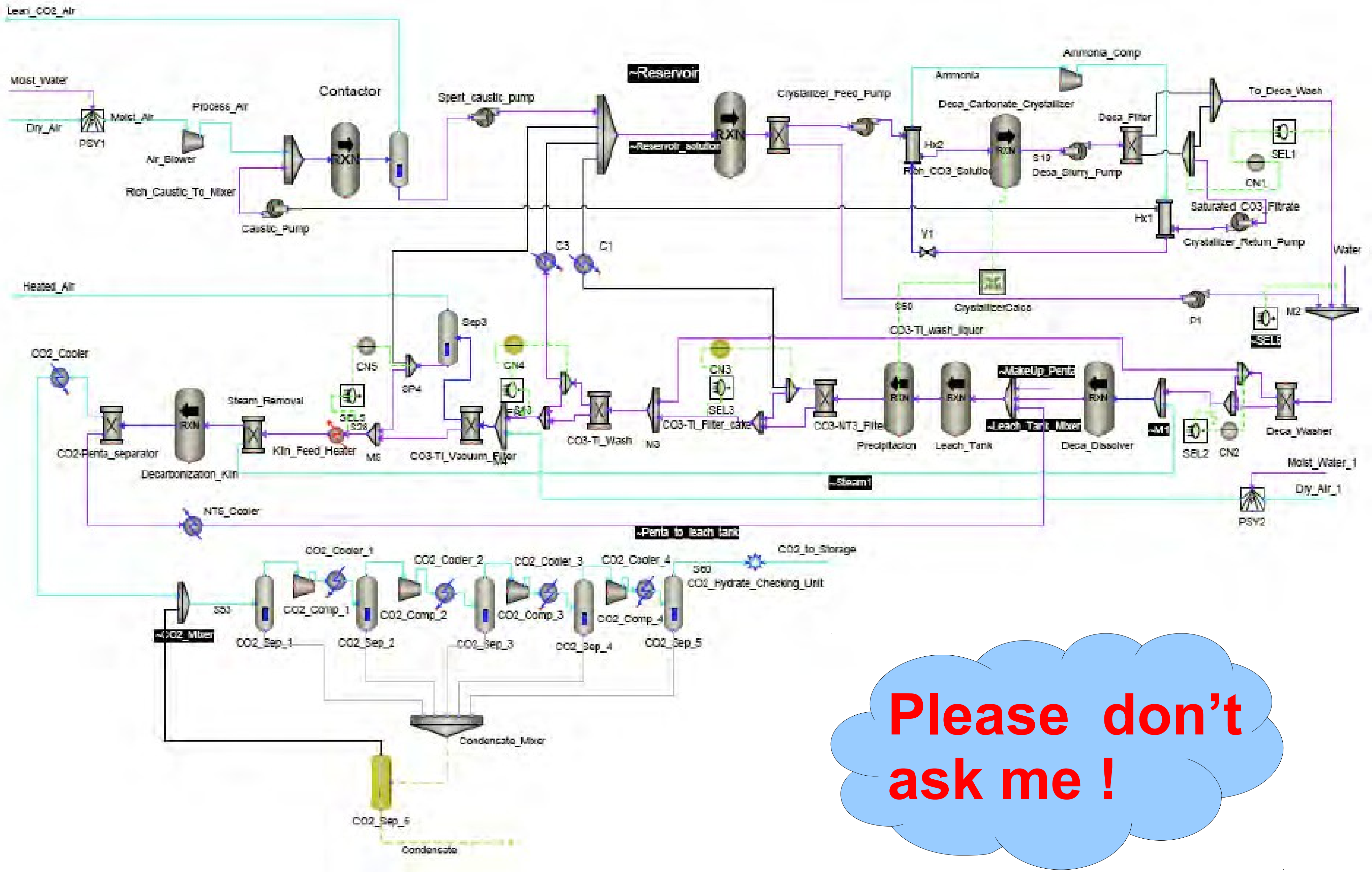


Figure 5: Process flowsheet for the CO_2 capture and caustic recovery

Flowsheet includes the contactor, crystallization cycle, leaching cycle, decarbonization and compression section.

The green dash lines represent the inter-links to Excel

The pink lines represent the material streams for slurry/liquid components (vapour fraction = 0).

The blue lines represent material stream for the components at mixed phase components (0<vapour fraction<1)

The cyan lines represent the material stream for the gaseous phase components (vapour fraction = 1)

Air capture vs. BECCS

- Optimal scaling regardless of power demand
- Siting may be further from population centers
- Sell to the top part of the reduction curve

- Some investors are ready to take high risks

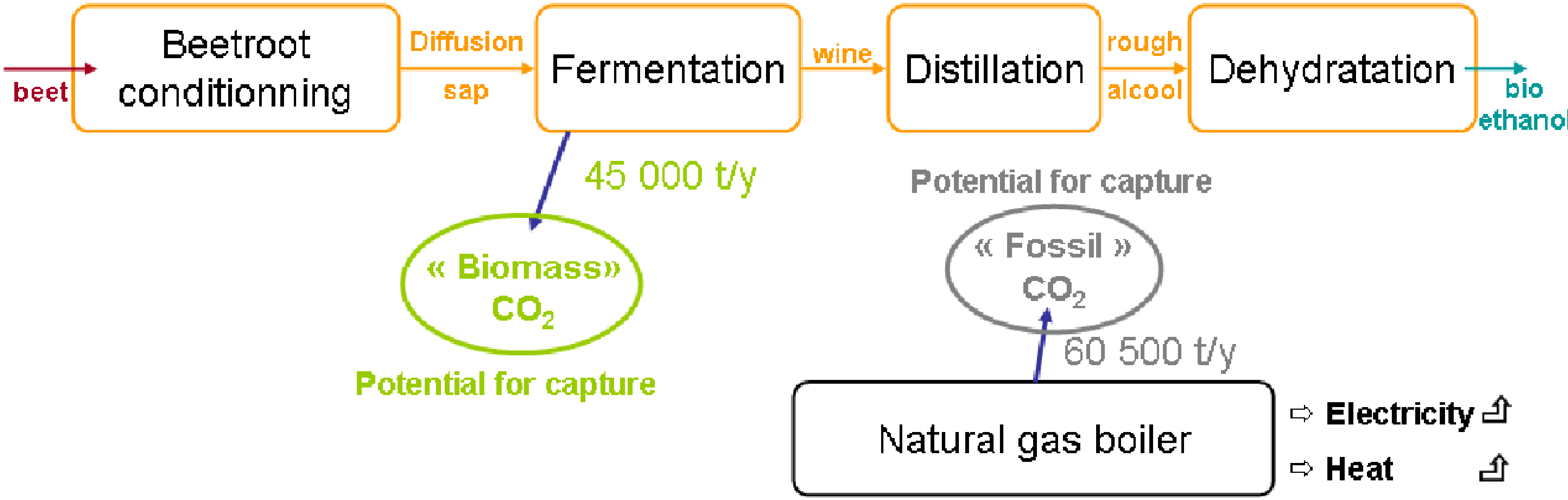
Outline

1. Analysis of a negative emissions project

2. Optimal climate policy implications

Tereos sugar/ethanol plant in Artenay, France

Capture in the bio-ethanol process



From Geology to Economics: Technico-economic feasibility of a biofuel-CCS system. (GHGT-10) A. Fabbria, D. Bonijolya, O. Bouca, G. Bureauc, C. Castagnaca, F. Chapuisa, X. Galiègueb, A. Laudeb, Y. Le Galloc, S. Grataloupa, O. Riccib, J. Royer-Adnotc, C. Zammita

Project : store 90.000 t CO2/yr

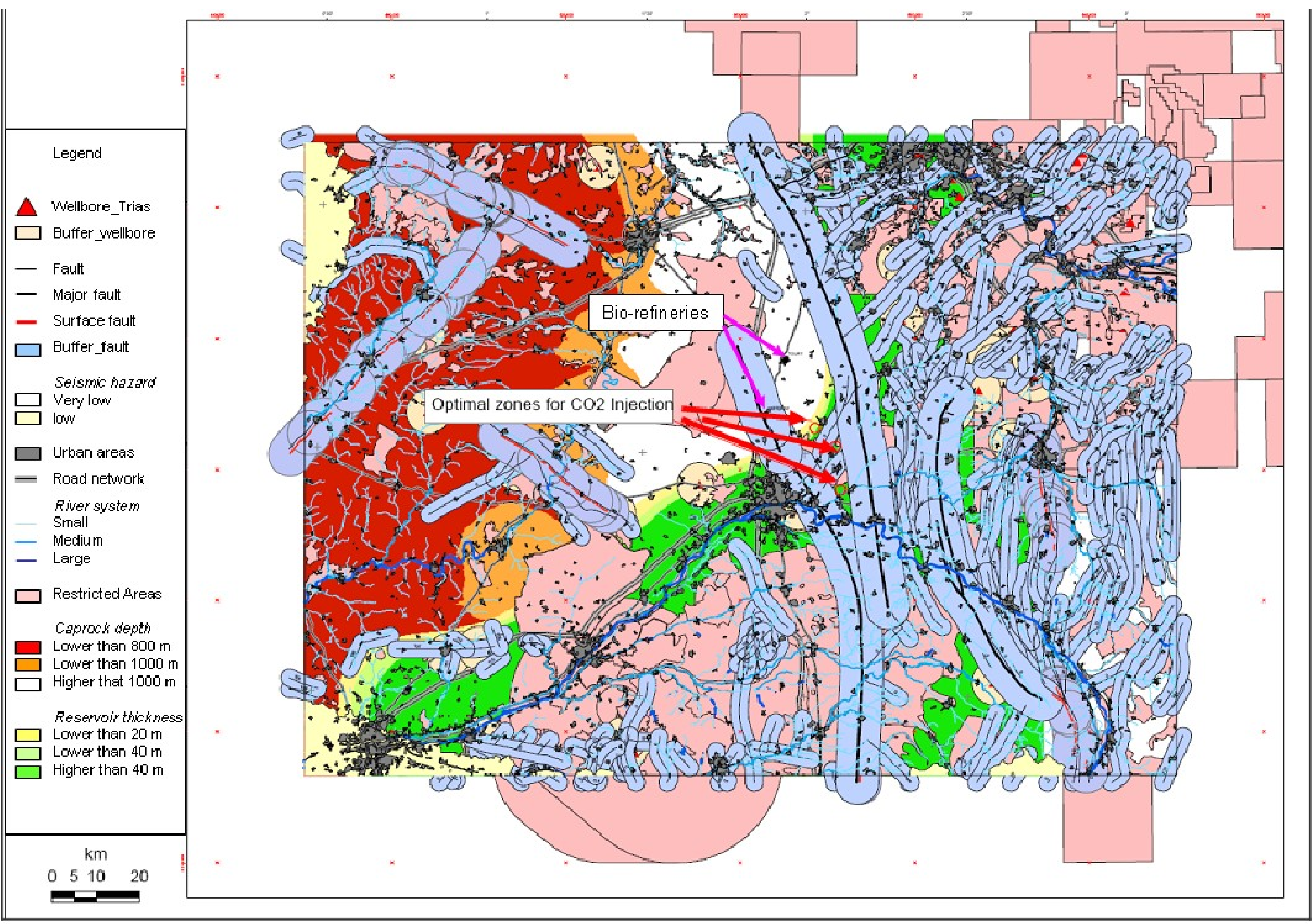
Capture only at the Fermentation step

Involve a second nearby bio-ethanol plant

Transport 30km pipeline

1 injection well, 2250 m aquifer

Maximum flow rate close to 350 000 t/y


Legend
Wellbore_Trias
Buffer_wellbore
Fault
Major fault
Surface fault
Buffer_fault
Seismic hazard
Very low
low
Urban areas
Road network
River system
Small
Medium
Large
Restricted Areas
Caprock depth
Lower than 800 m
Lower than 1000 m
Higher that 1000 m
Reservoir thickness
Lower than 20 m
Lower than 40 m
Higher than 40 m
km
0 5 10 20
Bio-refineries
Optimal zones for CO2 Injection

Environmental efficiency of bioethanol production

	GHG emissions (gCO_2eq/MJ)	Non renewable energy use (MJ/MJ)
Without CCS	54	0.79
With CCS on fermentation	21	0.83

Cost 57 € per ton of abated CO_2

Capture	37%
Transport	13%
Storage	50%

Need to remove the institutional and technical barriers preventing a common CO_2 transport network towards sinks

This capture project is NPV-negative at current CO2 prices

- Small scale of the French bioethanol plant
- Seasonality, sugar co-production
- € incentives for investment and operation, risk ?

Fermentation projects can be profitable soon.
Capture at boiler allows net negative emissions,
but is even more expensive

2. Optimal mitigation with air capture

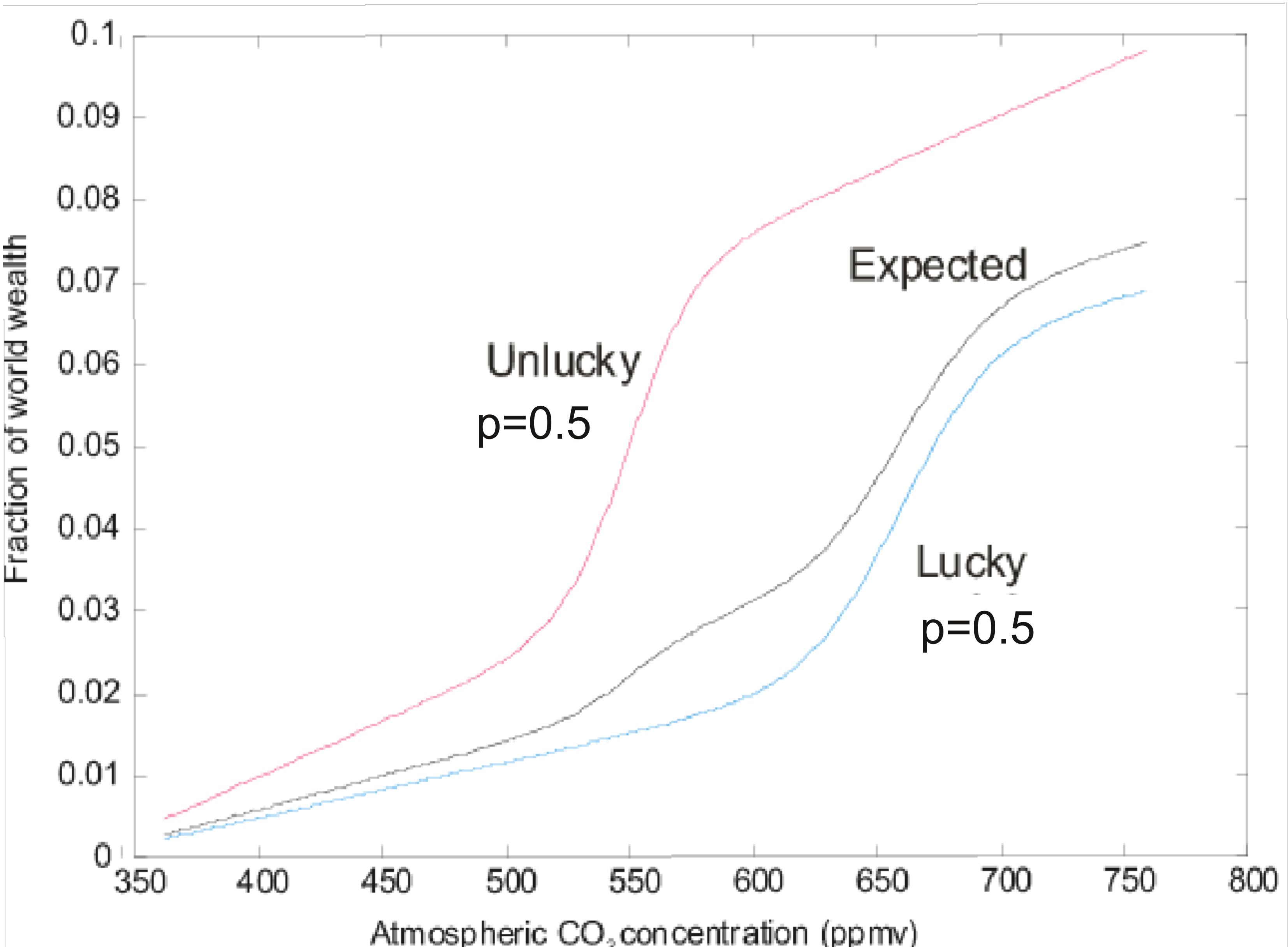
DIAM 2.4
Compact, numeric optimisation model
Cost-benefit, integrated assessment, stochastic
Recalibrated : capture costs & climate impacts up

- Risk of abrupt climate change vs.
- Abatement cost with or without air capture

David W. Keith, Minh Ha-Duong, and Joshua K. Stolaroff. *Climate strategy with CO2 capture from the air.* Climatic Change, 74 (1-3):17-45, January 2006.

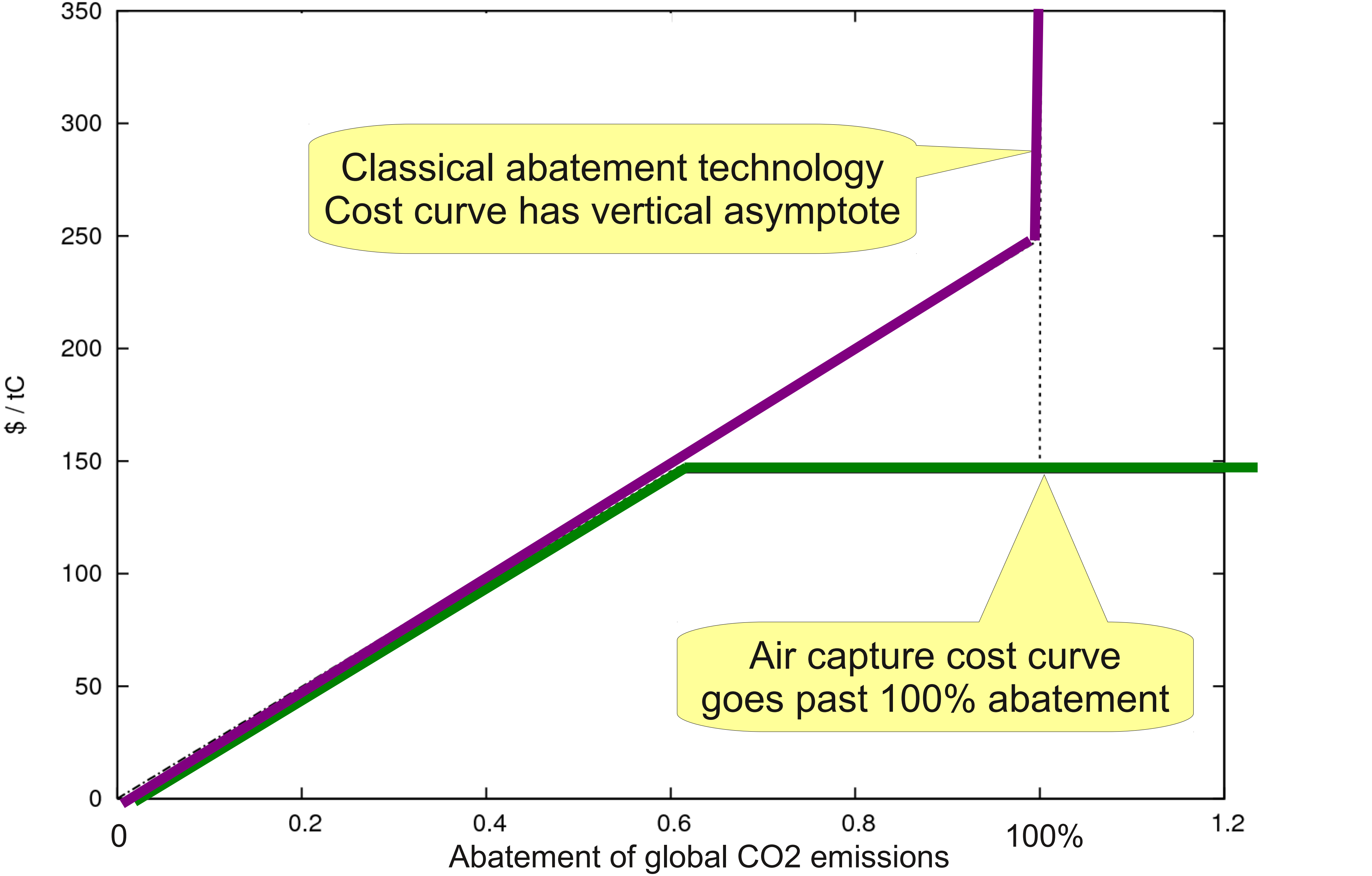
Stochastic abrupt damage function

Uncertainty until 2040

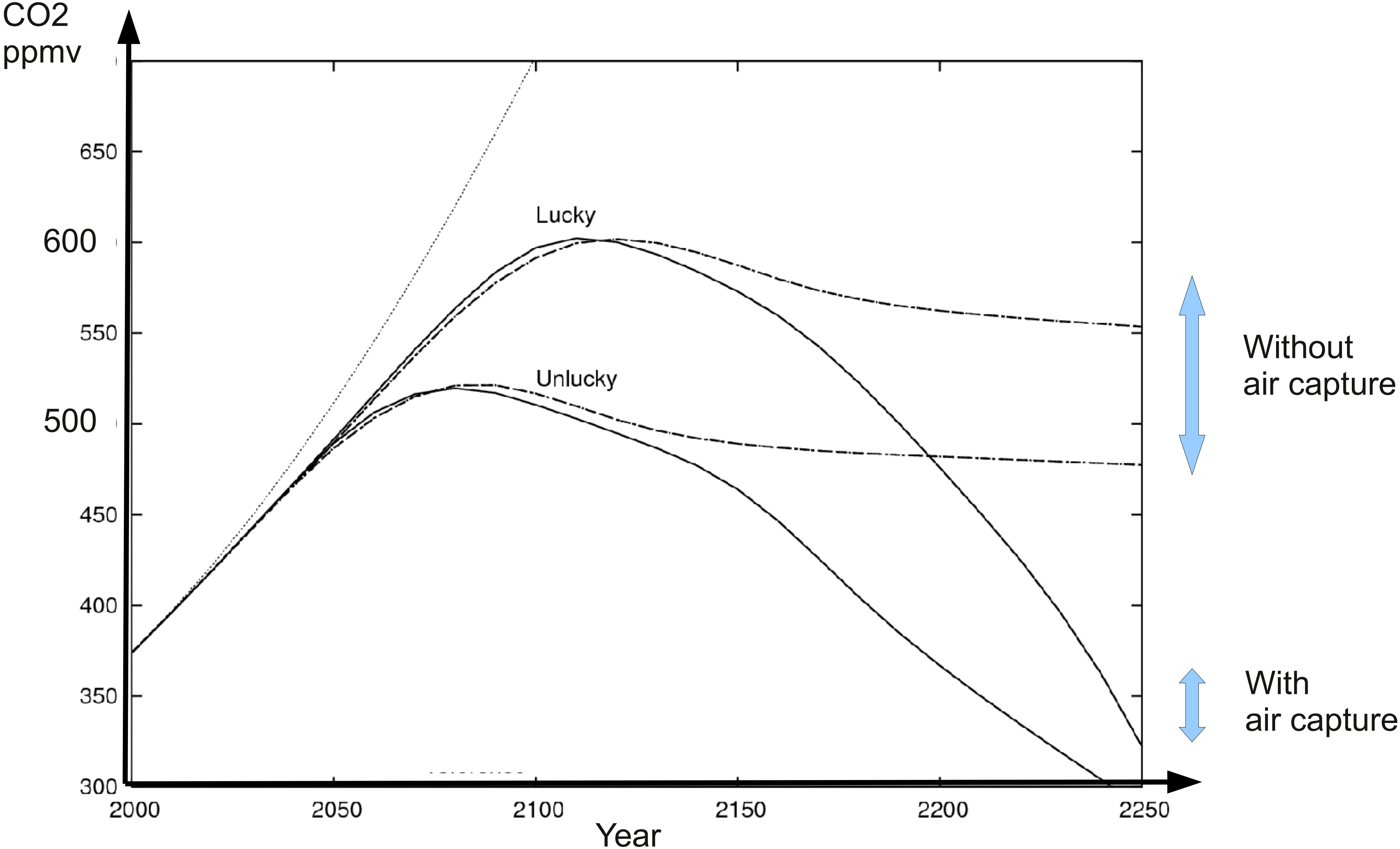


Marginal abatement costs

(double to include adiustment costs)



Optimal concentration strategies



Reasons for overshooting

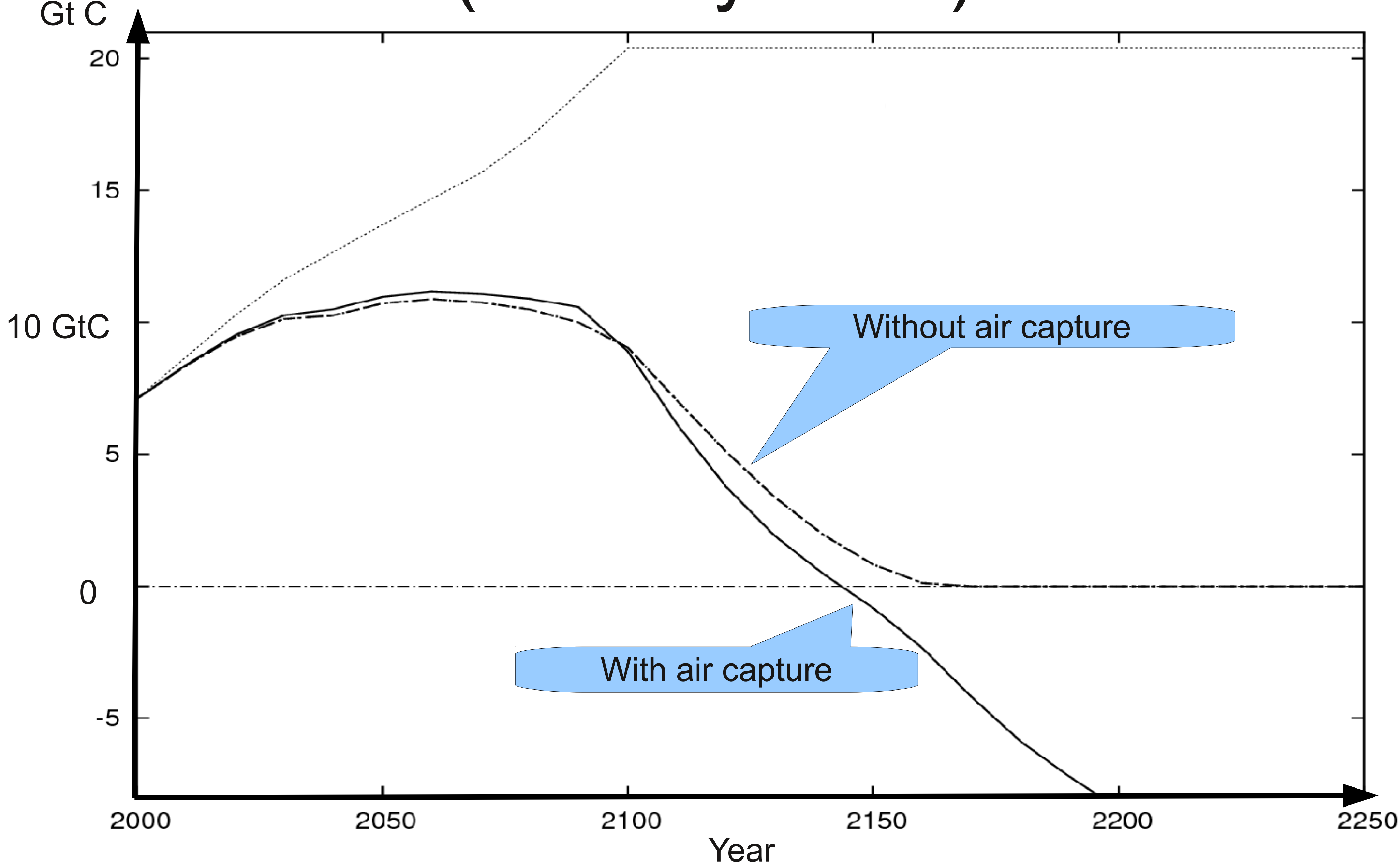
Consistent with historical records showing that managed atmospheric pollutants first increase and then decrease with time (Environmental Kuznets Curve)

The marginal cost-benefit balance is not stationary:
Technical progress, stocks depletion, structural changes in the economy, adjustment costs, discounting

In the model:

- Climate change impact is a fraction of wealth. Therefore the willingness to pay to solve the problem grows exponentially.
- Abatement costs are proportional to the amounts of pollution generated in the business-as-usual scenario, where reference emissions are assumed to grow only up to 2100 and linearly.

Optimal emissions
(unlucky case)



Qualitative results

Air capture plays no role in the short term, it enters after 2060.

Net negative emissions from middle of next century.

Optimal near-term targets not very sensitive to air capture availability, but ...

Pollute more now, cleanup later ?

Assume that we know with certainty the damage curve

Optimal % abatement in 2030

	Lucky
Without air capture	7.3
With air capture	7.0

Less abatement in 2030
if air capture is available

The ultimate objective matter more

Optimal % abatement in 2030

	Lucky	Risky (50/50)	Unlucky
Without air capture	7.3	12.9	16.9
With air capture	7.0	11.7	15.5

In both cases, the optimal abatement level under uncertainty cautiously leans towards the « worst case scenario »

Conclusion

Personal opinion on air capture

When typical industrial boilers do CO_2 capture and storage, net negative emissions will happen already in niches markets

Early learning, less effort

Optimal % abatement in 2030

	Act then Learn (2040)	Never learn (2200)
Without air capture	12.9	14.8
With air capture	11.7	13.8