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Expected fatalities for one wedge of CCS mitigation

Actuarial risk assessment of carbon capture and storage at the global scale in 2050

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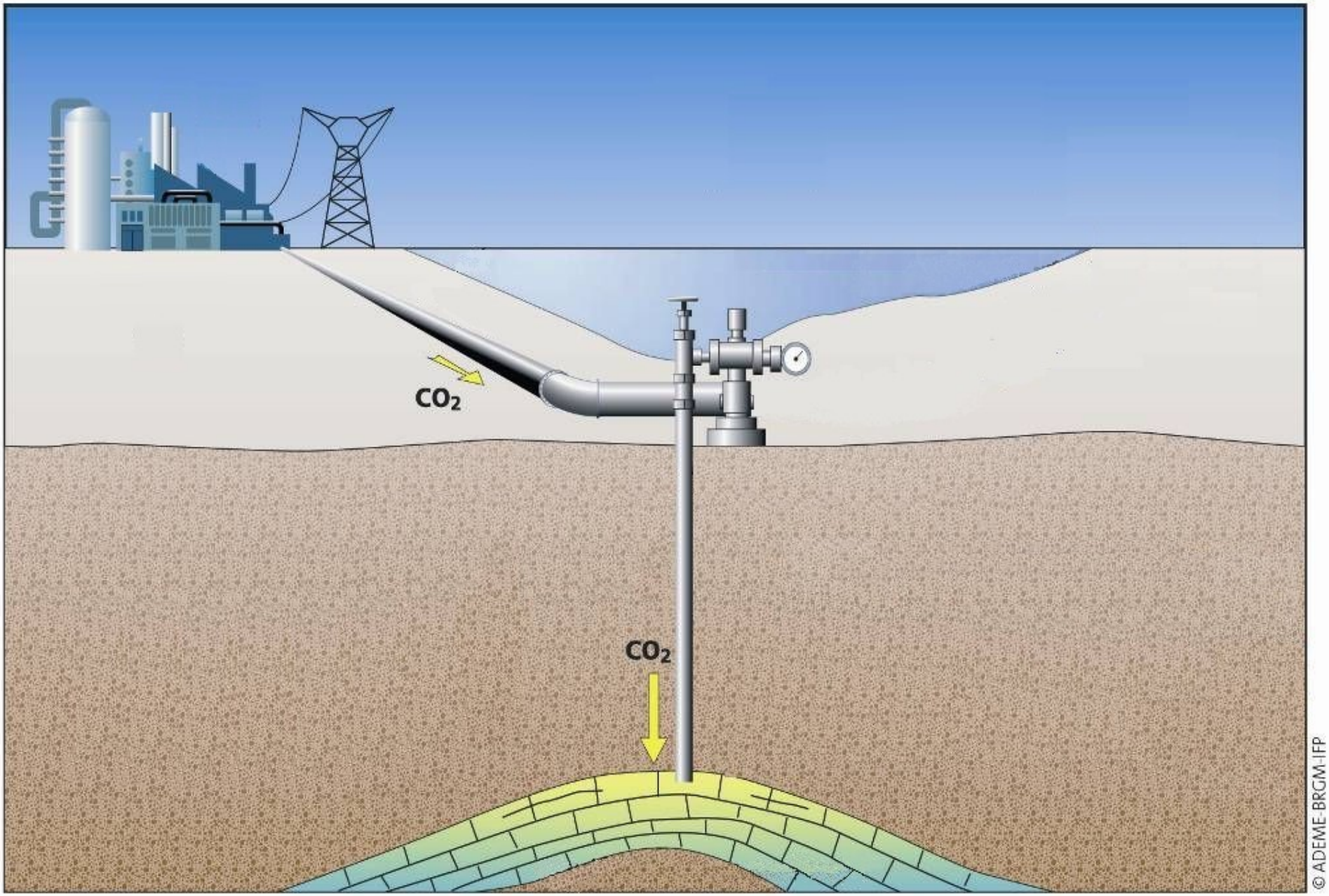
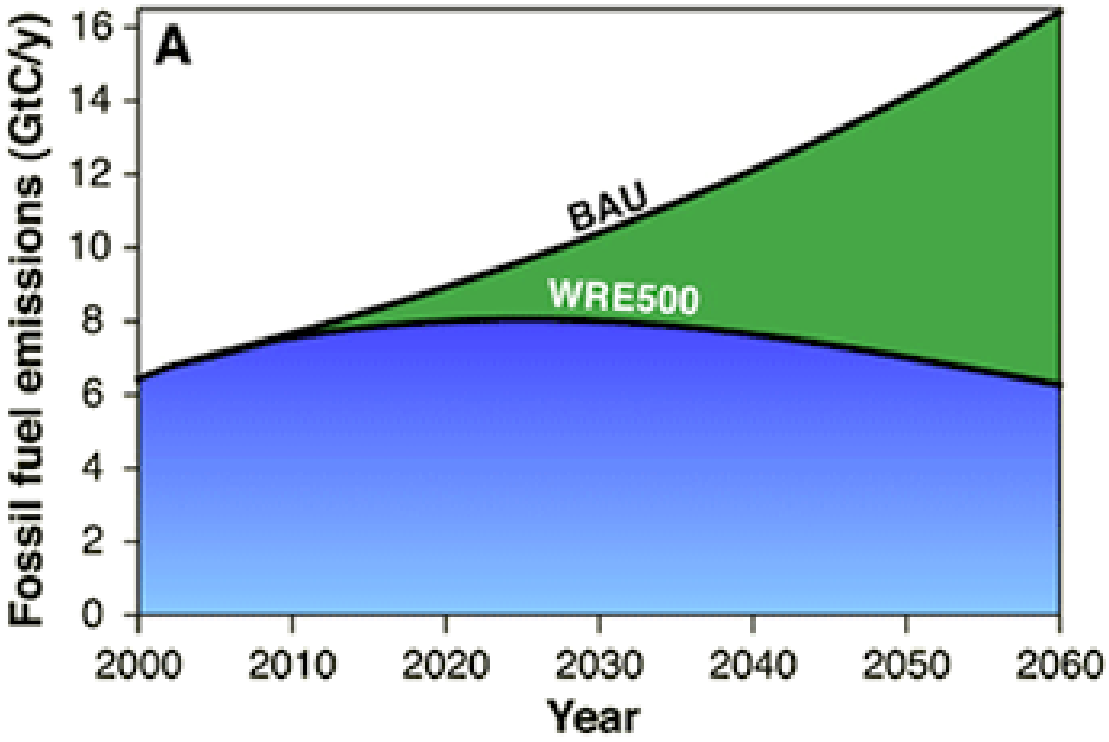
Talk (and paper) outline

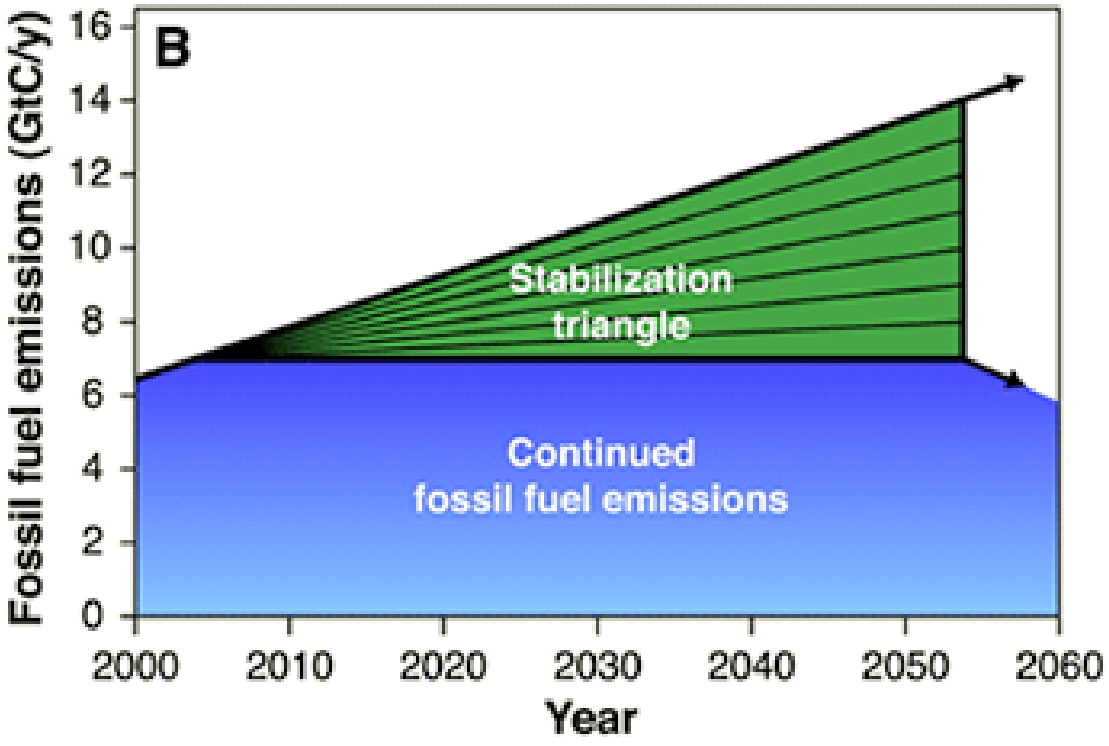
1. Introduction : what is CCS, what is a wedge?
2. What is Actuarial risk assessment?
3. Our CCS wedge scenario
4. Mining, capture, transport risks
5. Injection and storage risks
6. Summary and discussion

1. Captage et stockage du CO2

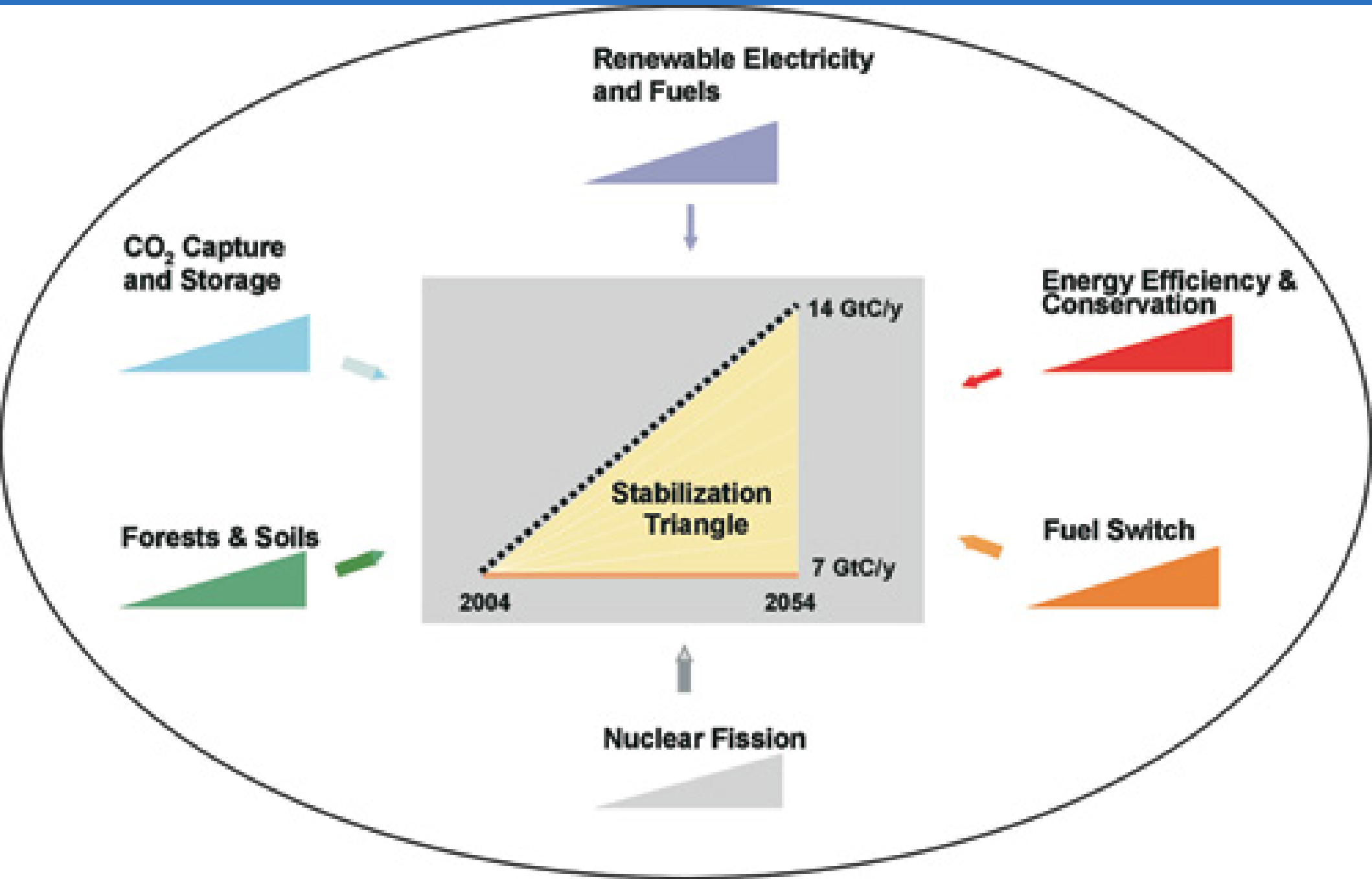


Wedge = coin de stabilisation





CCS is one of many options



2. Risk assessment methods

Constructivist

- Psycho
- Socio
- Eco

Realist (get expected values)

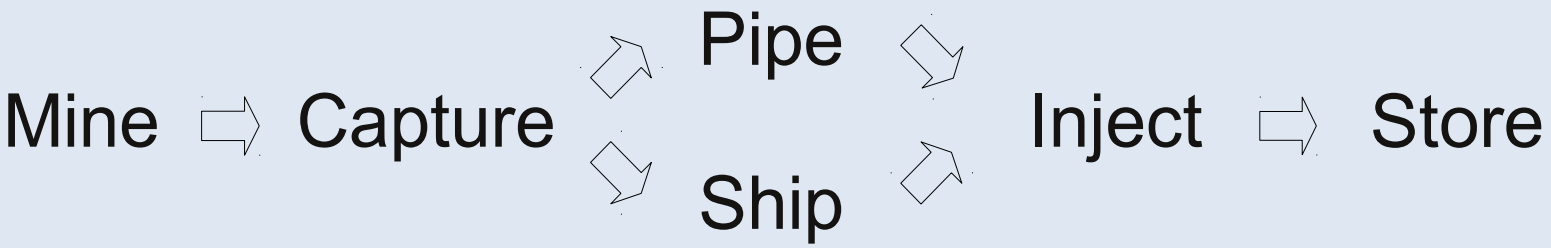
- Probabilistic Risk Analysis (failure trees)
- Toxico/Epidemio (experiments)
- **Actuarial** (extrapolates from empirical data on analogues)

For example, we look at accidents data for natural gas transmission and hazardous liquids pipelines, then :

Expected fatalities = Extrapolated rate x Activity level

3. The CCS wedge scenario

« Avoiding 1 GtC of CO_2 emissions in 2050
by using CCS in baseload coal-fired power plants. »



1 500 coal-fired power plants

- Burn 5.4 Gt of lignite
- Capture and store 4.5 Gt of CO2 (out of 5 Gt)
- Each produces 3 Mt of CO2 per year

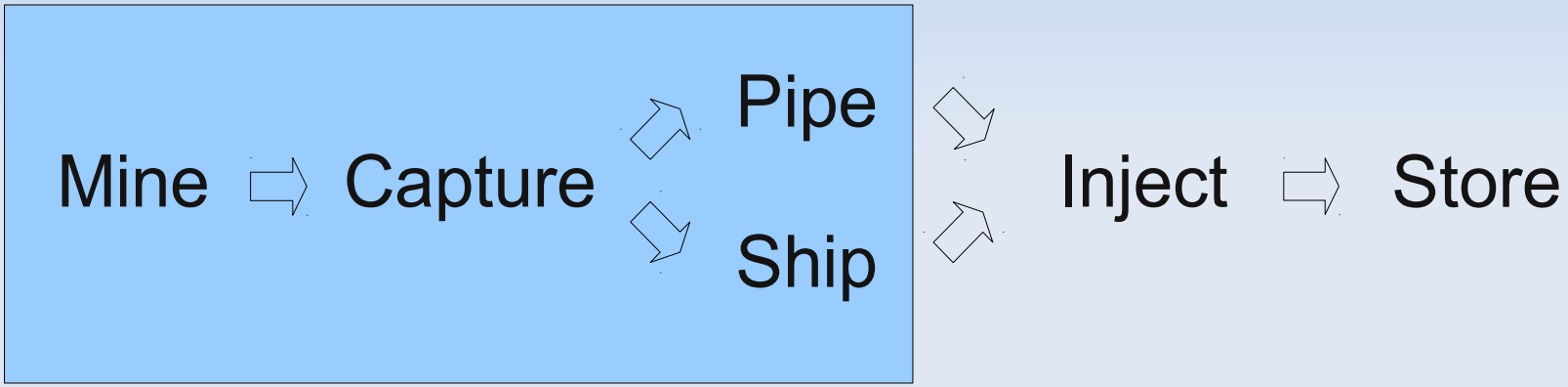
Transportation scenario

- Coal
  - 15% shipped for 4 500 Nm
  - 85% transported safely
- CO_2
  - 90% pipelined, 100 km per site
  - 10% shipped, 5 000 Nm

Storage scenario

- 500 sites, 90% onshore
- 8.8 Mt yr^{-1} injected per site (8 wells * 1.1 Mt yr^{-1})
- 25 to 100 km² footprint each

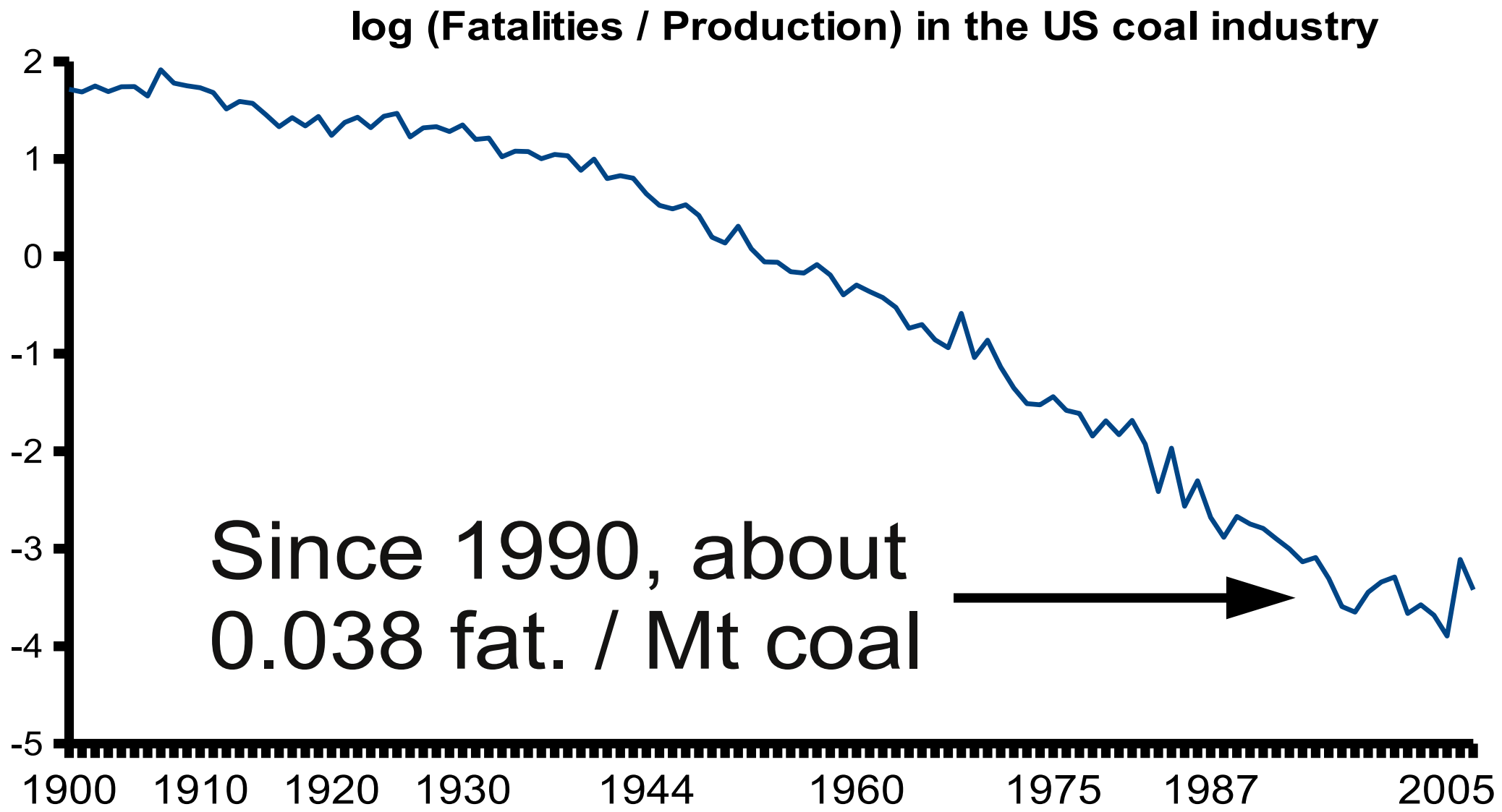
4. Mining, capture, transportation risks



4.1 Mining 5.38 Gt of lignite

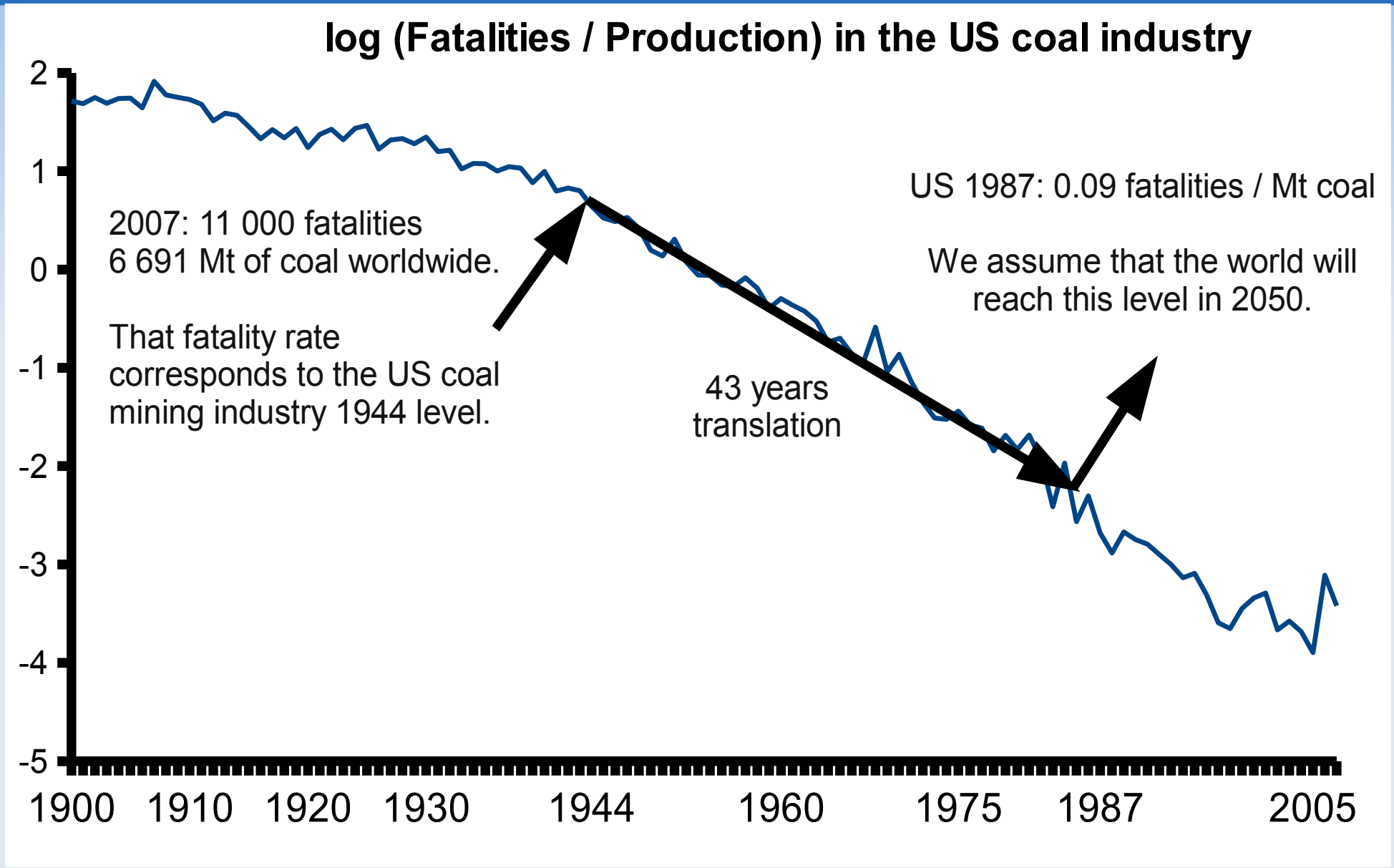
- Less than what is mined today
- Risk levels are unequal
  - Dozens of fatalities per year in the US
  - Hundreds in China, for a production only 2.5x higher

4.1a US coal industry record



0.038 * 5380 = 206 expected fatalities

4.1b A less optimistic outlook



0.094 * 5380 = 503 expected fatalities

4.2 CO2 capture risks

- Intoxication, drowning
- Frost, moving machinery
- Boiling Liquid Explosive Vapor Explosion (BLEVE)

4.2a Accident record

- Industry uses 100-115 Mt CO_2 each year
- 2 accidents over 1926 – 2007
- 12 fatalities
- 0.0017 fat. per Mt per year
- Extrapolates to 7.5 expected fatalities in 2050

4.2b Workers's safety records

- 3 to 14 fatalities / 100 000 workers / year in the *Electricity, gas and water supply* sector.
- Assume 7 500 to 15 000 exposed workers for the 1 500 sites
- 0.2 to 2.1 expected fatality in 2050

4.3 Pipelines safety in the USA

	Natural gas transmission (1986-2009)	Hazardous liquids (1986-2009)	CO_2 (1990-2009)
Serious incidents	2 318	4 088	20
Fatalities	65	54	0
Avg. network length (1000km)	522	255	6.2
Fatalities / 10^6 km / yr	5.2	8.8	0
95% confidence interval	4.0 - 6.6	6.6 - 11.5	0 - 24.3

No more than 24 fatalities per Mkm on CO2 pipelines.

CO2 pipeline risk in 2050

- Accounting for less favorable
  - Population density
  - Technology
  - Social context

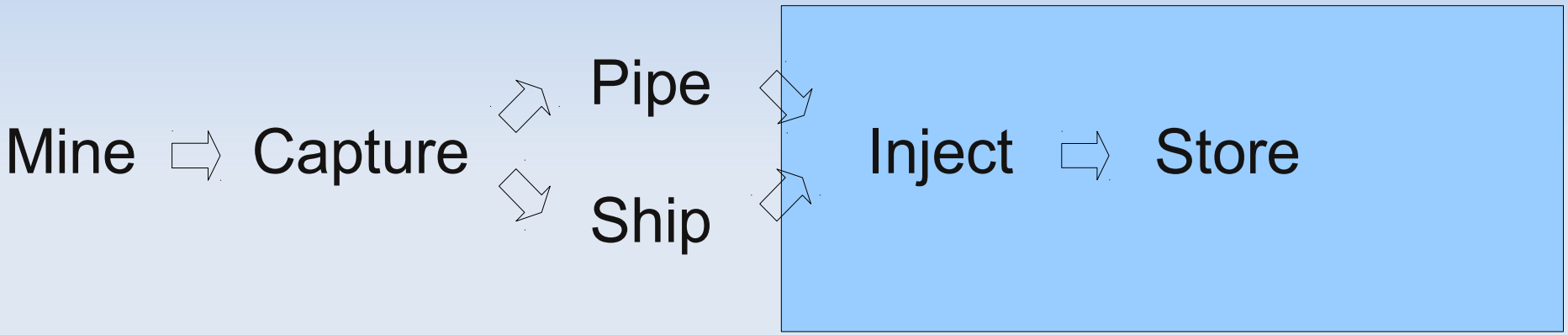
- We use 5 to 50 fat./Mkm/yr
- Scenario: 0.15 Mkm
- Result : 0.75 to 7.5 expected fatality in 2050

4.4 Shipping casualties in 2050

	Risk now	Risk extrapolated	CO2 ships Exp. fat.	Coal ships Exp. fat.
Tankers	11.7	2.9	6.6	10
All goods	28.6	10.9	24.6	40

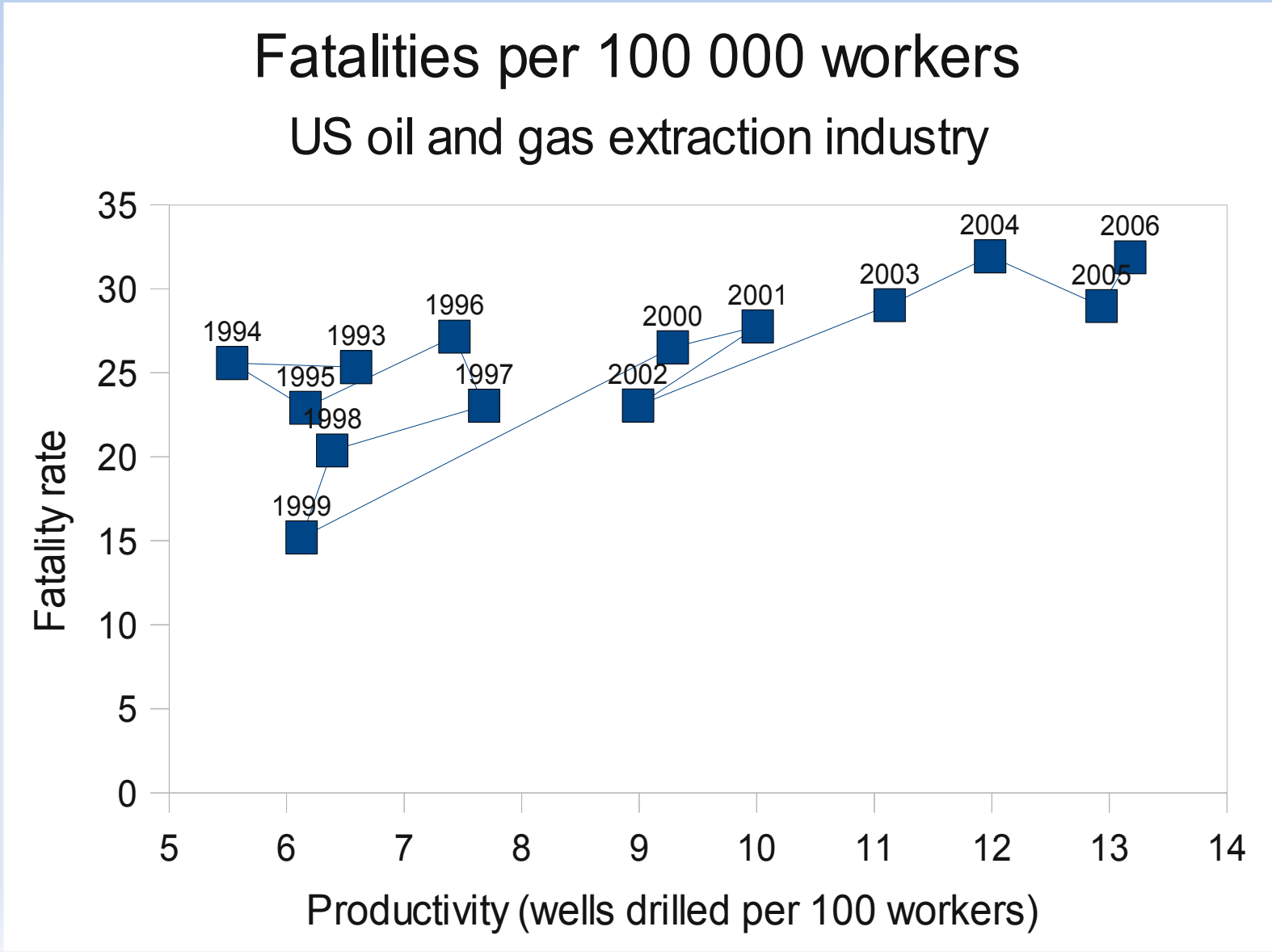
Unit in columns 2 and 3 :
Risk is in expected fatalities per billion ton * nautical mile of shipping.

5. Injection and storage risks



5.1 Injection at 500 sites

5 000 to 15 000 workers * 20 to 30 10^{-5} = 1 to 4.5 expected fatalities



5.2 Storage, engineering estimates

Hazard event	Saripalli's Frequency estimates	Saripalli's Consequences index	Expected fatalities per event	Expected fatalities per 100 000 storage year
1. Well-head failure				
1A. Major wellhead failure	0.00002	1	1	2
1B. Moderate, sustained leak	0.0001	0.5	0.1	1
1C. Minor leaks of joints	0.001	0.1	0.01	1
2. Cap rock failure				
2A. Fractured cap rock	0.01	0.3	0.05	50
2B. High permeability zones	0.01	0.1	0.01	10
2C. Seismic induced failure	0.0001	0.8	0.5	5
TOTAL				**69**

5.3a Storage, negligible individual risk

- Minimum Endogenous Mortality criteria
  - How much is a negligible increase in your risk of dying next year?
  - 1 micromort (10^{-6})
- Application to storage : 0.2 to 0.9 expected fat.
  - 25-100 km² impact area per site
  - 20 targets (people) / km²
  - 450 sites

5.3b Storage, tolerable risk

- In France, an industrial gas release risk with
  - Probability 10^{-3}
  - Consequence 1% lethal concentration
  - For less than 10 exposed persons

  ⇨ May be compatible with its environment

- That is, 10^{-4} fat. yr^{-1} is tolerable
- 450 sites, 0.045 expected fatalities

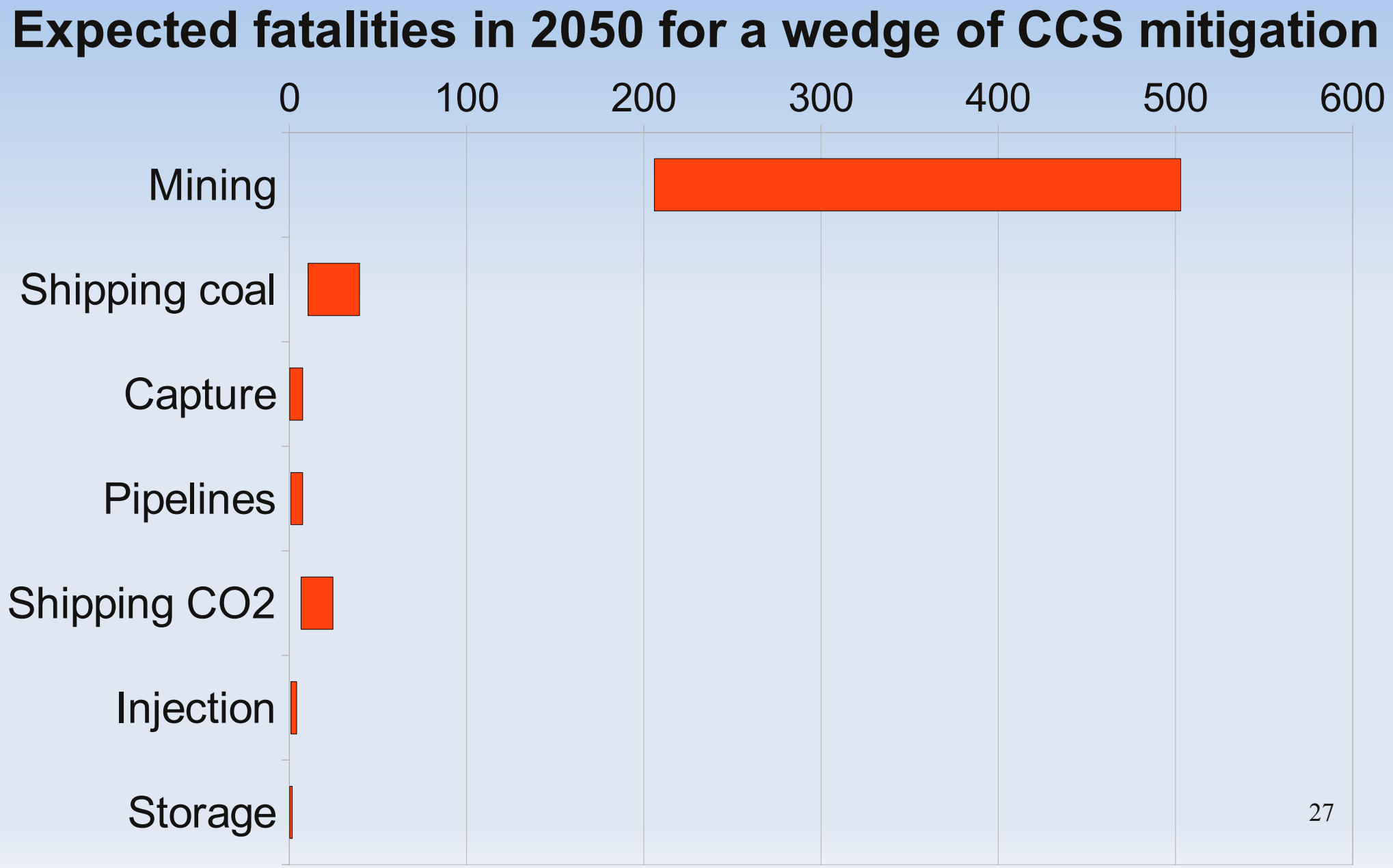
5.4 Storage, social analogues

- For SEVESO plants : 10^{-2} fatality per year
- For ICPE : 10^{-4} fatality per year
- Storage seems regulated between these two classes of installations : 10^{-3}

- 450 sites, 0.45 expected fatalities

(tolerable risk << historical risk)

6.1 Summary of results



6.2 Is the storage risk negligible?

- People can inflate a risk 1000 times, if it is artificial, imposed and unfamiliar.

- We need to observe the storage system during 3000 site*years to accept with 95% confidence that safety is at 10^{-3} fatality per year. This means no fatality before 2030.

6.3 CCS vs. Other risks

- Fossil energy technologies have a lower record of big catastrophic accidents than nuclear or large hydro.

- If mitigating climate change saves 10 000s of lives per year, then each wedge saves 1 000s. CCS passes this cost-benefit test.

Thanks !