CO2 GEOLOGICAL STORAGE OPTIONS

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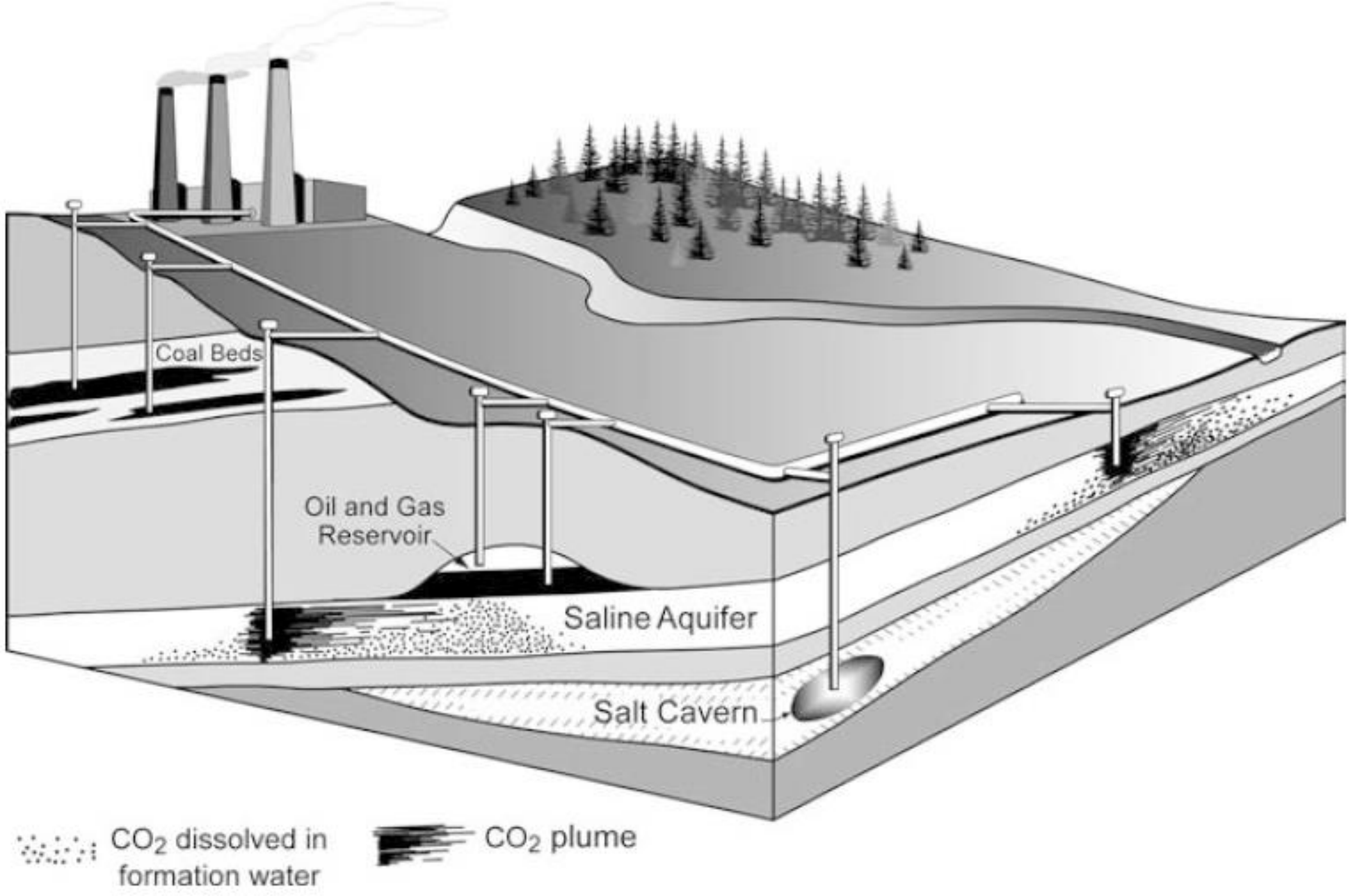
Returning carbon back into the subsurface

- Concieved strictly and the END of CCS chain
- Long-lasting and safe (modification of O&G upstream technologies)
- Reducing emissions from the LARGE STATIONARY SOURCES
- Public funding needed – differing concepts in development
- Long-term monitoring to ensure performance (and safety)
- Regulation system that uses experience from the mining industry

- In the esence – totally different … (!)

AN „ANTIMINING” CONCEPT

New resource – reliable estimates needed



Various means of storage in geological media dictate development of a portfolio of screening and ranking methodologies

– in short time

(Bachu, 2003)

What might be the slicky parts?

Competition - just a part of a portfolio of developing technologies

Renewables…

Energy efficiency, fuel switching…

Storage capacity – a new resource (generated by governmental planning)

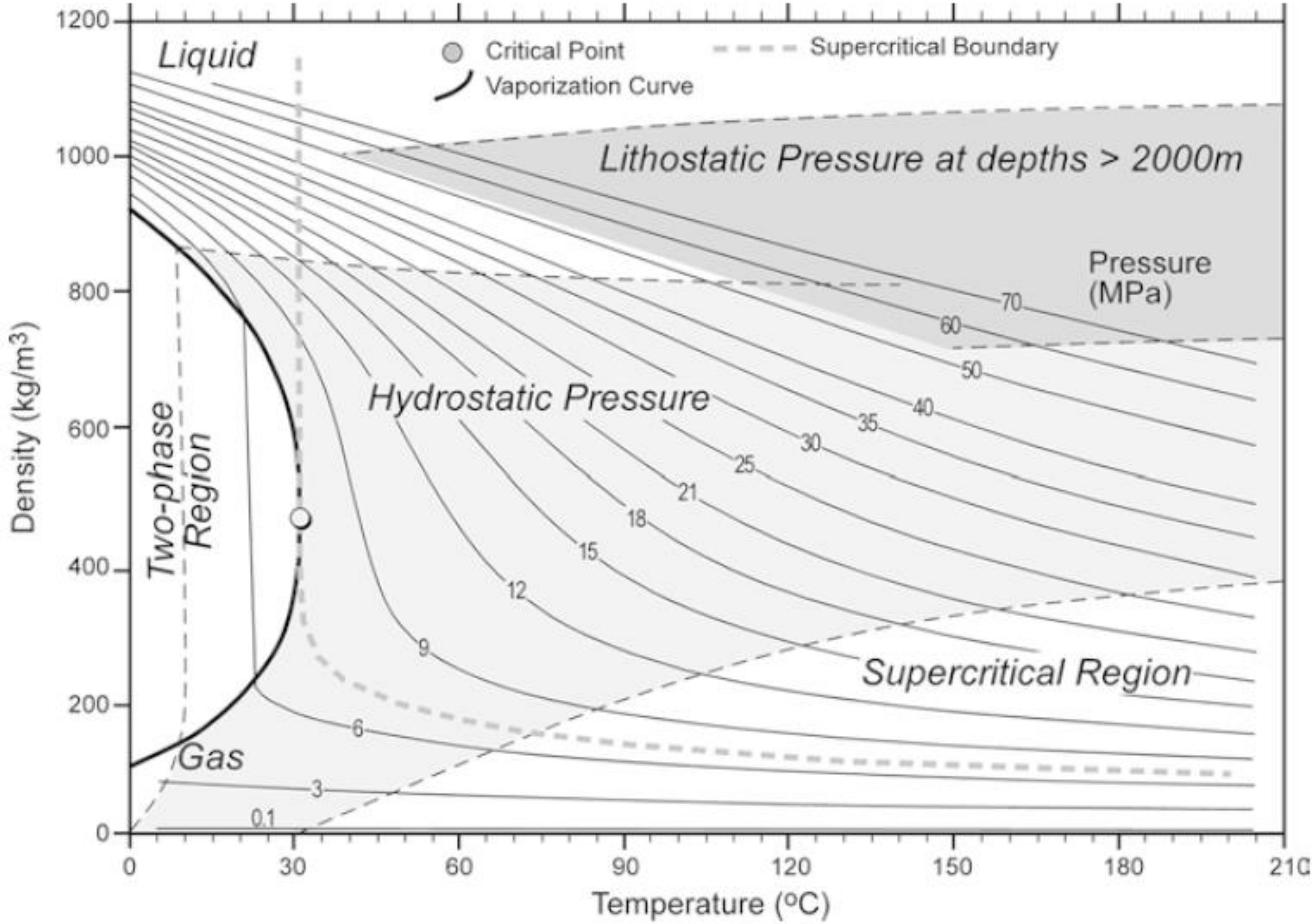
Large investment costs vs. future benefits

Who is to pay anyway?

Concept - **abstract** and **still unproven** (?)

Time (and money) needed to develop and test the technology

Conflicts of use… mainly with neighbors ☺



„Our material”

Chemical stability

Reactions with rock(s) and brine(s)

Phase changes

CO_2 density as a function of temperature and pressure

(Bachu, 2003)

Table 1

Criteria for assessing sedimentary basins for CO_2 geological sequestration

	Criterion	Classes				
		1	2	3	4	5
1	Tectonic setting	Convergent oceanic	Convergent intramontane	Divergent continental shelf	Divergent foredeep	Divergent cratonic
2	Size	Small	Medium	Large	Giant	
3	Depth	Shallow (<1,500 m)	Intermediate (1,500–3,500 m)	Deep (>3,500 m)		
4	Geology	Extensively faulted and fractured	Moderately faulted and fractured	Limited faulting and fracturing, extensive shales		
5	Hydrogeology	Shallow, short flow systems, or compaction flow	Intermediate flow systems	Regional, long-range flow systems; topography or erosional flow		
6	Geothermal	Warm basin	Moderate	Cold basin		
7	Hydrocarbon potential	None	Small	Medium	Large	Giant
8	Maturity	Unexplored	Exploration	Developing	Mature	Over mature
9	Coal and CBM	None	Deep (>800 m)	Shallow (200–800 m)		
10	Salts	None	Domes	Beds		
11	On/Off Shore	Deep offshore	Shallow offshore	Onshore		
12	Climate	Arctic	Sub-Arctic	Desert	Tropical	Temperate
13	Accessibility	Inaccessible	Difficult	Acceptable	Easy	
14	Infrastructure	None	Minor	Moderate	Extensive	
15	CO_2 Sources	None	Few	Moderate	Major	

„Parametric estimates of storage potential” (Bachu, 2013)

Table 3

Ranking of Canada’s sedimentary basins in terms of suitability for CO_2 geological sequestration

Rank	Basin(s)	Characteristics	Score
1	Alberta	Foredeep, giant, deep, mature, coals and salts, good infrastructure, temperate, large point CO_2 sources, large CO_2 emissions	0.96
2	Williston	Intracratonic, large, deep, mature, coals, good infrastructure, temperate, large point CO_2 sources	0.88
3	Beaufort-Mackenzie	Foredeep, large, deep, exploring, sub-arctic, large hydrocarbon potential	0.60
4	SW Ontario	Arch, shallow, small, over mature, good infrastructure, temperate, CO_2 sources	0.52
5	Atlantic shelf	Offshore, developing, oil and gas, coals, large CO_2 point sources	0.35
6	St. Lawrence River	Foredeep, small, temperate, CO_2 sources, no hydrocarbons and coals	0.31
7	Gulf of St. Lawrence	Off-shore, small, no CO_2 sources	0.26
8	Arctic islands	On/off shore, arctic, coals, no CO_2 sources and infrastructure	0.24
9	Intramontane	Convergent, small, coals, no CO_2 sources and infrastructure	0.20
10	Hudson Bay	Mostly offshore, intracratonic, sub-Arctic, no potential, no CO_2	0.18
11	Eastern Arctic	Offshore, arctic, no potential no CO_2 sources	0.13
12	Pacific	Convergent trench, off-shore, unexplored, no CO_2 sources, no infrastructure	0.09

Depleted Oil and Gas Reservoirs

Believing (?!) in sealing capacity of the cap rock (Zhaowen et al., 2006)

- Much lower interfacial tension of the CO_2/water system
- Cap rock sealing pressure must be determined
- Reservoir properties and volumes usually known

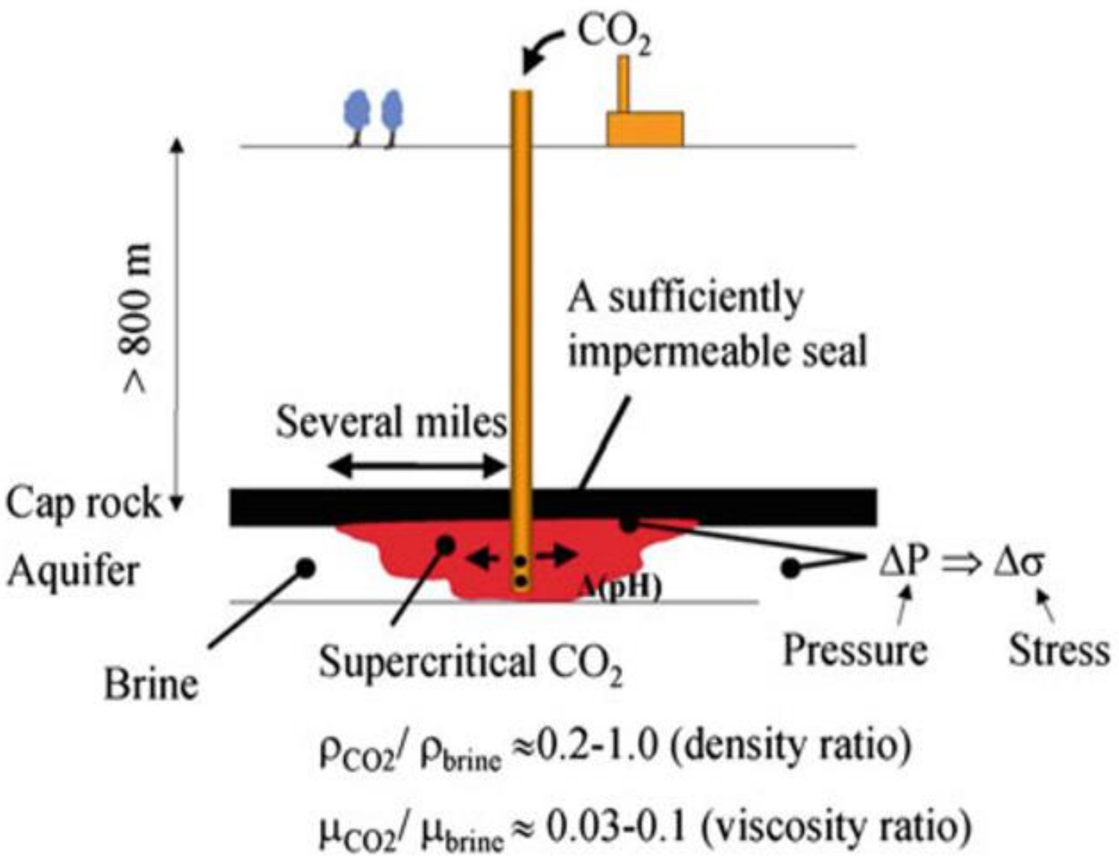
In oil reservoirs

- Complex interactions of fluids (phases)
- Usually a large number of old production wells

In gas reservoirs

- ✓ Large pressure difference
- ✓ Greater depths – (usually) larger capacity

Deep Saline Aquifers (Deep Saline Formations)



By far the largest POTENTIAL

By far UNDEREXPLORED

… Niemi et al. (2017)

Various trapping mechanisms

1. Physical (supercritical phase accumulation)
2. Residual (trapped after the plume
3. Chemical (reactions with pore water)
4. Mineralogical (new carbonates)

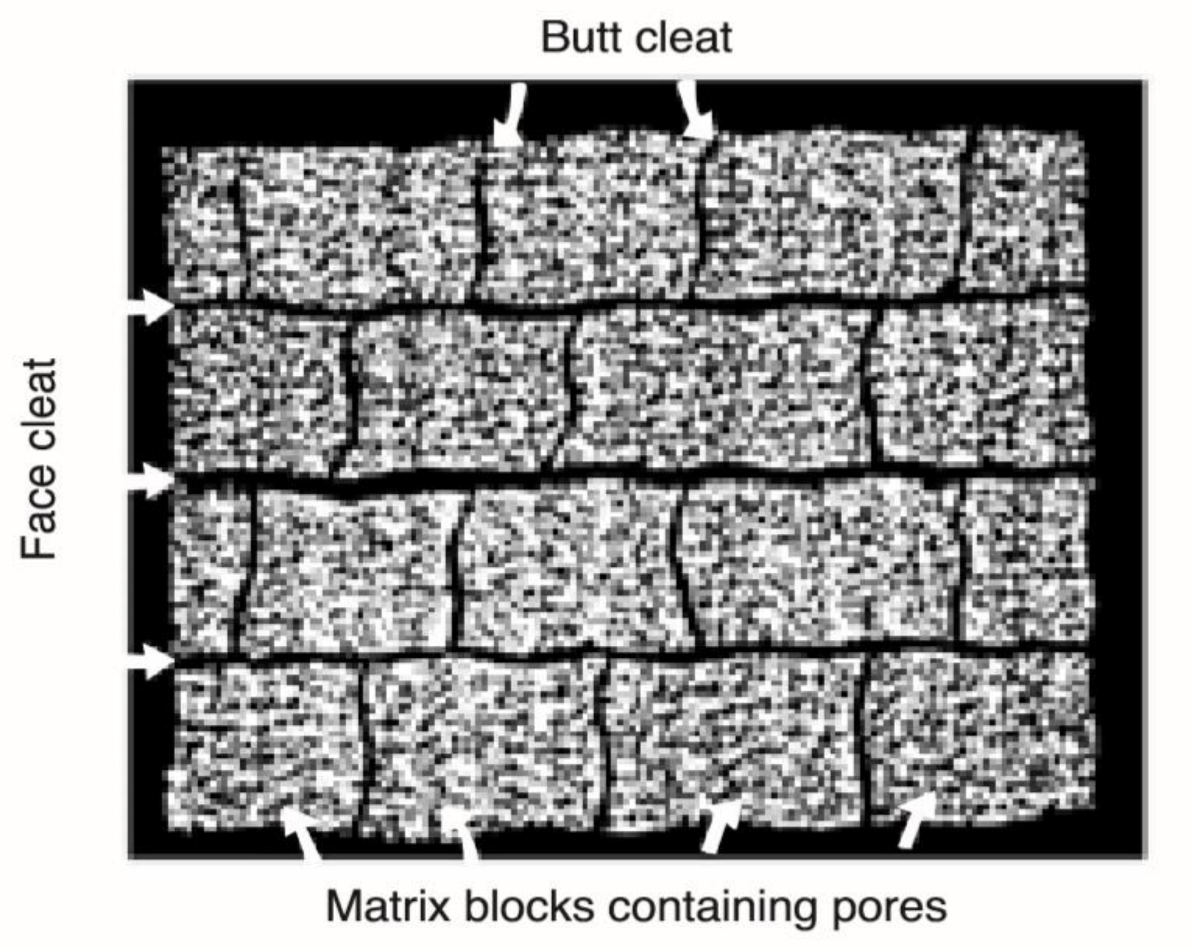
Large regional extension

- ✓ vicinity of sources
- ✓ avoiding conflicts of interest

Pressure increase/pressure front (?)

Definition of a storage complex

Deep Unminable Coal Seams



CO2-ECBM

Three mechanisms (Shi & Durucan, 2005):

– physically adsorbed compounds on the internal surfaces of coal

– absorbed within the molecular structure

– within pores and natural fractures

220 Gt of CO_2 (60 GtC) storage capacity worldwide (Stevens, 2002)

CO_2 replaces CH_4 by molecular and transitional diffusion

Enhanced Geothermal Systems

CO2-plume geothermal system (CPG)

- in a deep saline aquifer
- in (EOR) operations

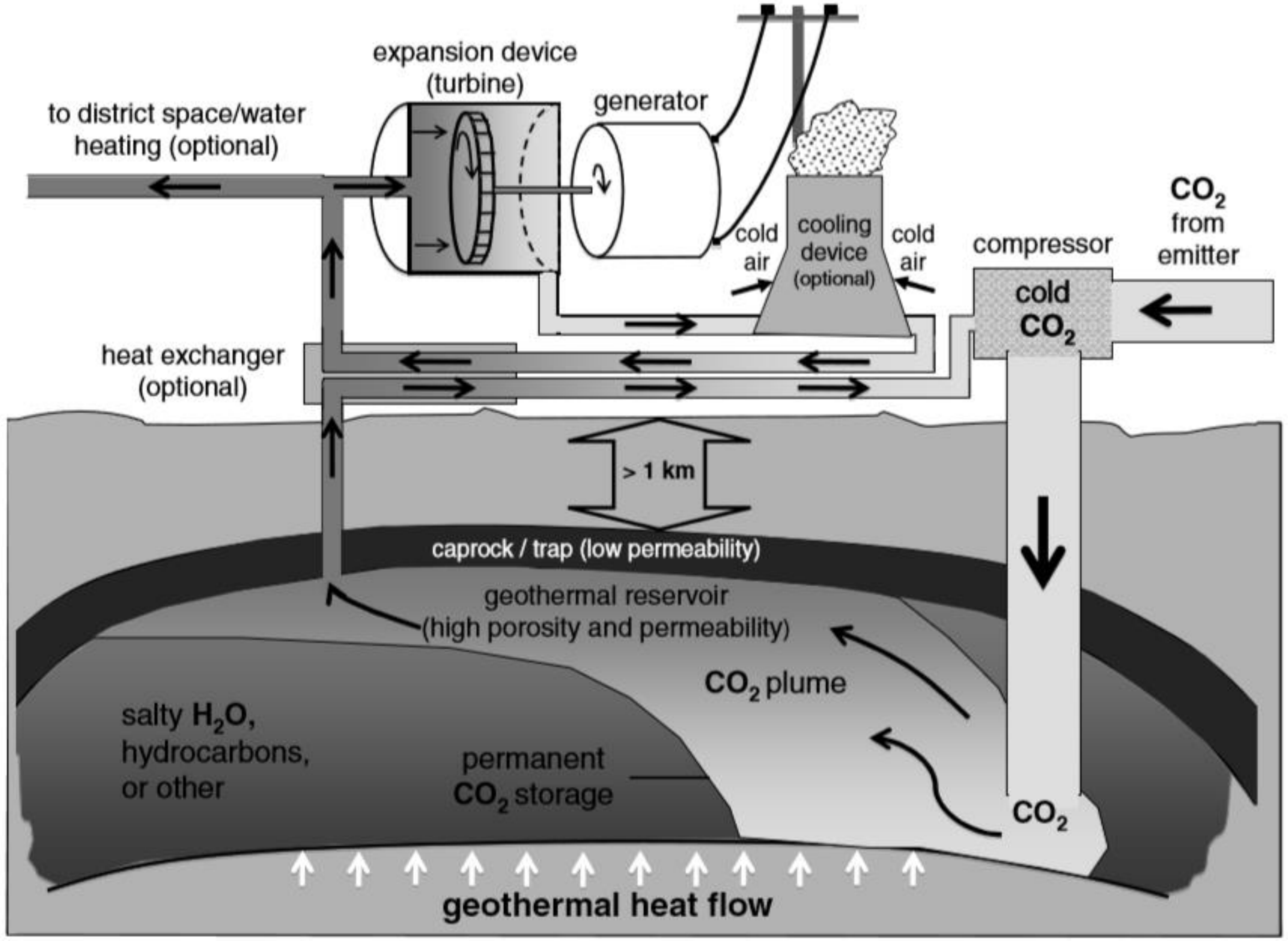
Energy recovered from CPG systems could be used both for electricity generation and for space/water heating

Heat extraction rates up to 3 times greater than those of traditional water-based systems

A model (Randolph & Saar, 2011):

1. Initial temperature of 100 °C, pressure of 250 bar
2. Permeability 5x10^{-14}m^2 Porosity 20%
3. Rock specific heat 1000 J/kg/ °C
4. Thermal conductivity 2.1 W/m/ °C

In average in 25 years with 1 injector ad 4 producers this could give 47 MW of <u>heat energy.</u>



New resource – reliable estimates needed

Table 1.1 Storage capacity for several geological storage options (IEAGHG 2011a)

Reservoir type	Lower estimate of storage capacity ($GtCO_2$)	Upper estimate of storage capacity ($GtCO_2$)
Oil and gas fields	675[a]	900[a]
Unminable coal seams (ECBM)	3–15	200
Deep saline formations	1000	Uncertain but possibly 10^4

[a]These numbers would increase by 25 % if 'undiscovered' oil and gas fields were included in this assessment. *Source* IPCC SRCCS (2005)

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ENOS

Enabling Onshore CO_2 Storage

www.enos-project.eu

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