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Storage of CO₂ at low temperature as liquid or solid gas hydrate **Application in the French and Spanish EEZ in North-East Atlantic** André Burnol⁽¹⁾, Isabelle Thinon⁽²⁾

(1) BRGM, Risks and risk Prevention Division (DRP)

(2) BRGM, Georesources Division (DGR)

Main objectives:

(1) Estimation of the CO₂ theoretical storage volume in the French and Spanish Exclusive Economic Zone (EEZ) in North-East Atlantic Comparison between the CO₂ storage capacity as liquid or as solid gas hydrate in the French and Spanish EEZ









NBZ using GERG-2008 (Kunz, 2012)

The CO₂ Storage Zone in French and Spanish EEZ is defined by three safety criteria using GMT (Wessel, 1998):

- 1) Seafloor Depth > 4000 m => Density (CO_2 +impurities) > (Sea Water)
- 2) Slope $< 4^{\circ} =>$ Safety criterium to avoid slumps on the continental slope
- 3) Sediment Thickness > 800 m => to avoid hydrate formation at injection



Z	<u>Source:</u> GHFD09 (re-calculated)	L149 897	L149 898	L149 900	L103 638	CH5	CH9	CH13	CH15	BD17	BD9	BD21
	Surface Thermal Conductivity	1.1	1.3	1.1	1.12	1.17	1.05	1.06	1.14	0.913	0.95	0.96

Wm ⁻¹ K ⁻¹											
Heat Flow mW m ⁻²	49.5	52 (53.8)	60	nd	33 (33)	40 (46.3)	50 (52.4)	46 (45.5)	58.	31.4 (33)	48.6 (48.8)

Thermal Conductivity of surface sediments is almost constant: TC = 1.1 Wm⁻¹K⁻¹ Heat Flow in the studied zone varies between two extreme values: Low $HF = 33 \text{ mW/m}^2 \text{ High } HF = 60 \text{ m W/m}^2$

Case with impurities (CO2-96) Pure CO₂ case —NBZ CO2 GHSZ CO2 ——NBZ CO2-96 GHSZ CO2-96 — Max depth French EEZ — Max depth Spanish EEZ ——Max depth French EEZ — —Max depth Spanish EEZ Seafloor depth (mbsl) Seafloor depth (mbsl) -4500 -5000 -5500 -4000 -4000 -4500 -5000 -5500 100 200 500 Gas Hydrate Zone thickness 300 (mbsf) 400 1000 Liquid I Liquid 500 Liquid 600 1500 700 800 2000

 CO_2 storage as liquid or gas hydrate (medium Heat Flow 46.5 mW/m²)

		Surface (km ²)	Mean thickness (m) ^a	Mean Porosity (%)	Theoretical Storage Volume (km ³)	Storage efficiency factor ^b (%)	Density (g/cm ³)	Storage capacity (GtCO ₂)
French EEZ (CO2-100)	Liquid	55 443	1213	0.3	20 173	2	1.045	422
French EEZ (CO2-96)	Gas Hydrate	55 442	115	0.53	3422	2	0.3	20.5
Spanish EEZ	Gas Hydrate	70 569	52	0.45	1728	2	0.3	10.4
(CO2-96)	Liquid	36 720	153	0.39	1972	2	1.045	41.2

^a as a liquid, the thickness is twice the depth difference between the neutral buoyancy level and the gas hydrate formation level; as gas hydrate, the thickness is the difference between the hydrate formation level and the neutral buoyancy level ^b a conservative estimate of 2% as explained in (Burnol et al., 2015)





- I. Physical conditions (P, T, depth, sediment thickness) in French/Spanish EEZ are favorable for a CO₂ storage in deep-sea sediments (deep offshore option)
- **II.** The Negative Buoyancy Zone (NBZ) and Gas Hydrate Stability Zone (GHSZ) calculated using the bisection method in a new code called are GASCO2 (Burnol et al., 2015)

III. GMT is then used to calculate the storage volume and capacity in both EEZ

- **IV.French EEZ theoretical storage volume (3422 km³) is of the same order of** magnitude as the total storage volume in the Spanish EEZ (3700 km³)
- V. Storage capacity estimate as Gas Hydrates is two times higher in the French EEZ (20.5 Gt) than in the Spanish EEZ (10.4 Gt)

VI.Total storage capacity in the Spanish EEZ (Gas Hydrates + Liquid) is higher than the storage capacity in the French EEZ (only Gas Hydrates)

Sloan Jr, E. D., & Koh, C., 2007, Clathrate hydrates of natural gases. CRC (CSMGem software included) Wessel P, Smith WHF, 1998, New, improved version of Generic Mapping Tools released. EOS Trans Am Geophys Union 79(47):579 Kunz, 0. and Wagner, W., 2012, The GERG-2008 Wide-Range Equation of State for Natural Gases and Other Mixtures: An Expansion of GERG-2004, J CHEM ENG DATA 57 (11), 3032-3091 Burnol A et al., 2015, Thinon, I., Ruffine, L., Herri, J. M., 2015. Influence of impurities (nitrogen and methane) on the CO₂ storage capacity as sediment-hosted gas hydrates IJGGC 35 96-109

a.burnol@brgm.fr