ELECTROLYSIS-METHANATION-OXYFUEL (EMO) CONCEPT An overview of the ANR FLUIDSTORY project.

A.G. Bader; B. Bazargan, A. Burnol with the help of the FluidSTORY team 7/11/2019





FLUIDSTORY ?

Massive and Reversible Underground Storage of FLUIDs (O₂, CO₂, CH₄) for Energy STOrage and RecoveRY

Energy Storage (and recovery) ?

In the context of energy transition, massive energy storage is a key issue for the integration of renewable sources in the energy mix since the renewable sources with greatest potential (wind, solar) are intermittent.

Fluids ?

Power-to-Gas (P2G) technology : conversion of the electricity energy to gas fuel (H_2) by water electrolysis.

- H₂ can be directly used (injection into the gas grid, used in transport or industry)
- or, combining with CO_2 , it can be converted to methane (methanation process).

P2G links electric and gas network and increases flexibility of their use.





Electrolysis-Methenation-Oxycombustion is a P2G2P concept which include underground gas storage step.

This concept responds to the need for massive inter-seasonal energy storage to cope with intermittency of the electricity production (e.g. anticyclonic weather situation)

EMO is a **closed-loop** solution able to absorb electricity surplus (due in particular to renewable sources integration) and to recover it later, via the temporary storage of O_2 , CO_2 and CH_4 .



EMO?

The EMO addresses two major concerns of the "power to methane" electric energy storage systems:

- 1. the massive supply of CO_2 to feed the methanation and
- 2. the release of CO_2 into the atmosphere after methane oxycombustion.

In this concept, the oxygen generated by the electrolysis is used to burn the stored methane produced through combination of hydrogen and CO_2 , in an oxy-fuel power generator.

Due to its relative purity, the emitted CO_2 is then easily captured and reused in methane production.



ANR FLUIDSTORY PROJECT

This ANR co funded project studies the operability, safety and the integrity of O_2 and CO_2 storage in salt cavities. It investigates also the medium to long term requirements for reaching the energy efficiency and economic profitability of EMO concept.

Taking into account realistic scenarios for electricity production in 2030-2050, FluidSTORY provide:

- a first evaluation of O₂-CO₂ storage capacity in French salt caverns,
- a comprehensive assessment of the feasibility and a first risk evaluation associated to such a storage,
- a first evaluation of the energy and economic costs and profitability of the EMO concept in the French case.



- 1. BRGM : Coordination, risk, geology
- 2. ARMINES : Thermodynamics, geochemistry and process engineering
- 3. X-LMS Ecole Polytechnique : Themomechanics, modelling and lab. Experiments
- 4. Brouard Consulting : Thermodynamics, modelling
- 5. Geostock : Solution mining, geotechnics
- 6. Geogreen : Economics, Dev. strategy
- 7. ENEA consulting : Economics, Energetic scenarii
- 8. AREVA H2-GEN : Electrolysis







AREVA H₂Gen

Scientific and technical barriers

Reversibility of a massive O₂ and CO₂ storage in a salt cavern

- O₂ is a highly reactant oxidizer, which can potentially interact with the reducing underground environment,
- CO₂ is much more soluble in brine than CH₄, so that cumulative losses by dissolution in the brine at the bottom of the salt cavern could be quantitatively much more significant.

Potential gas losses were identified and quantified, as well as reversibility's conditions (injection/extraction rate) and composition of the in/out fluids.

Thermo-mechanical integrity of a massive storage in a salt cavern

Investigations have been carried out to assess thermal and mechanical loading effects on the time-dependent properties and behavior of soft and creeping salt rock.

Safety of a massive storage during the exploitation and post-closure periods

Leakages are of major concern for the safety of underground gas storage. A large feedback on CH_4 storage is available but EMO concept raises new challenges, as far as O_2 and CO_2 storage are concerned. Safety issues relative to post-closure period have also to be considered.

Interactions between the underground storage and surface installations

The project addressed links between all surface technology bricks, but also between the underground reservoir and surface facilities through process simulations of the integrated system.



PROJECT ORGANISATION



Geoscience for a sustainable Earth

TASK 1: Inventory of salt caverns for storage and estimation of the geological potential.

Availability of storage volumes was investigated through systematic inventory of the existing salt caverns and geological study of suitable salt formations in France.

This inventory allows drawing two main conclusions:

- 1. Salt bearing series of the Paris Basin (Lorraine region) are shallow and thin enough to satisfy the operational constraints of storages operating at **low pressures**.
- 2. Evaporitic series of Valence, Bresse or Mulhouse basins may be interesting targets for **larger storages**.



Main salt formations in France. Circles : preferred storage location EMO concept



TASK 2: Estimation of required capacity for EMO storage concepts

Information on operating conditions of each process component and the use of ASPEN PLUS simulation tools enable to reach targets set.

- P2G phase
 - Electrolysis process : 200MW
 O₂ and H₂ @20 bars / 35°C
 - Methanation process: Production 155 MW of SNG. Energetic efficiency : 83%.
- Storage phase @ 35°C and 20bars
- Recovery process : combustion of the produced SNG and O₂
 - Output power : 480 MWe
 - Efficiency: 51,8%.



Scheme of the EMO unit concept

Detailed results : Process modelling and capacity building potential for application of EMO storage concept (N. Kezibri) : Tomorrow 8h30



TASK 3: Thermodynamical and geochemical behavior of salt cavern.

- Acquisition of experimental data (in red) for a very high salinity CO₂-H₂O-NaCl system,
- Comparison with 3 models (in black).



TASK 4: Thermo-mechanical integrity of salt cavern.

Computation of stresses and strain rates in the rock mass in which a salt cavern is operated are rather standard problems for which comprehensive theoretical and experimental studies exist. Numerical computations allow predicting cavern behaviour when gas pressure and temperature are known.

However, in an O_2 -CO₂ storage cavern, large and frequent pressure swings are expected, which require special treatment.

Several criteria must be considered in the assessment of stresses and displacements:

- Volume loss rate and subsidence rate
- Strains at casing shoe
- Tensile stresses can lead to the onset of fractures
- Effective stresses
- Thermal stress, dilation phenomena and evolution of salt permeability to O_2 and CO_2



Salt permeability tests on spherical sample



Detailed results : Thermo-mechanical integrity of salt cavern (P. Berest) : Tomorrow 8h50

TASK 5: Salt cavern safety and risk evaluation.

The work consisted to identify all the events that could happen in the case of storage CO_2 and O_2 in cavities.

These events are:

- Well eruption,
- Well leakage,
- · leakage through the cavity wall,
- non-compliant mechanical disturbances,
- non forecasted chemical disturbances,
- non forecasted thermal disturbances.

From the complete list of scenarios considered, recommendations were made to provide an assessment of each event.



Detailed results : Salt cavern safety and risk management (T. Le Guenan) : Tomorrow 9h30



TASK 6: Energy and economic profitability of the EMO concept.

To assess the competitiveness of EMO with similar options we compare the energy needed for the production of 1 MWhe



Block-flow diagram for P2M and P2G+fuel cell

This evaluation shows that less resource is needed for the energy recovery through EMO process (3.4MWh) than from classical methanation (4.3MWh), while this amount of energy is fairly comparable with hydrogen fuel cell process (3.1MWh).

Detailed results : Energy and profitability of the EMO concept (A. Reveillere) : Tomorrow 9h50









- First step of knowledge on the conditions of use of the salt cavities for the gas storage from P2G (O₂ and CO₂).
- Technical, safety and economic feasibility of the development of the P2P sector by (2030-) 2050.
- Acquisition of new experimental data and new developments for simulation of salt cavities behavior in storage conditions.
- Simulations of the entire closed-loop EMO process were performed during the project.

The next step is to prepare the conditions for the development of an EMO pilot in France or in Europe.







The **story** is not over...

