NEW SYNERGY CONCEPT OF GEOTHERMAL ENERGY RECOVERY, CO_2 & GREEN HYDROGEN GEOLOGICAL STORAGE IN THE BALTIC OFFSHORE STRUCTURE

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PAPER

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Funded by the European Union

INTRODUCTION

The human civilization of the 21st century today faces serious challenges: wars, environmental, energy and economic crises. The demand for energy and our planet Earth's sources (fossil fuels, metals and minerals) today is the highest in the known history of mankind. The consequence of unregulated use of energy and sources is the deficit of materials, the highest energy prices and the hardest point is uncontrolled climate change caused by artificial greenhouse gases due to using of fossil fuels for energy production. Energy prices for users in Europe at the end of 2021 are incredible and much higher than ever.

Only in the last decade, a global community has begun to refocus its priorities on renewable and carbon-neutral technologies for energy production, circular economy for resource use and climate change control concepts. Carbon-neutral technologies are supported by the European Commission's circular economy action plan (CEAP), the main building block of the European Green Deal, Europe's new agenda for sustainable growth (*EC, 2020*). There is no doubt that the dependence of 21st-century society on combustible fuel is so intense and renewable energy efficiency is so insignificant according to civilization's needs, that it is critical importance to find a key concept to win this fight against global crises.

NEW SYNERGY CONCEPT

E6 structure circular economy concept of the closed cycle of processes proposed includes **five phases**:

(1) Transport of captured CO_2 to E6 site (*Fig.2, Shogenov & Shogenova, 2021*)
(2) CO_2 injection for CGS and CPG in E6-A (*Shogenov et al., 2021, 2022*)
(3) H_2 production from techno-ecological energy (geothermal, wind, solar, and sea current energy) collected in the circular system "Power banking"
(4) Geological Power Bank (Geo-PB) in E6-B
(5) H_2 transport by the same ships to the customers (*Fig. 3b*)

AIM

- **To find and propose the key concept** which will **support a transition from fossil fuels** emitting CO_2 **to the next generation of energy production**

The concept must be:

- **Techno-ecological**
- **Eco-friendly**
- **Self-supporting**
- **Cost-competitive**
- **Economically feasible**
- **Circular economic**

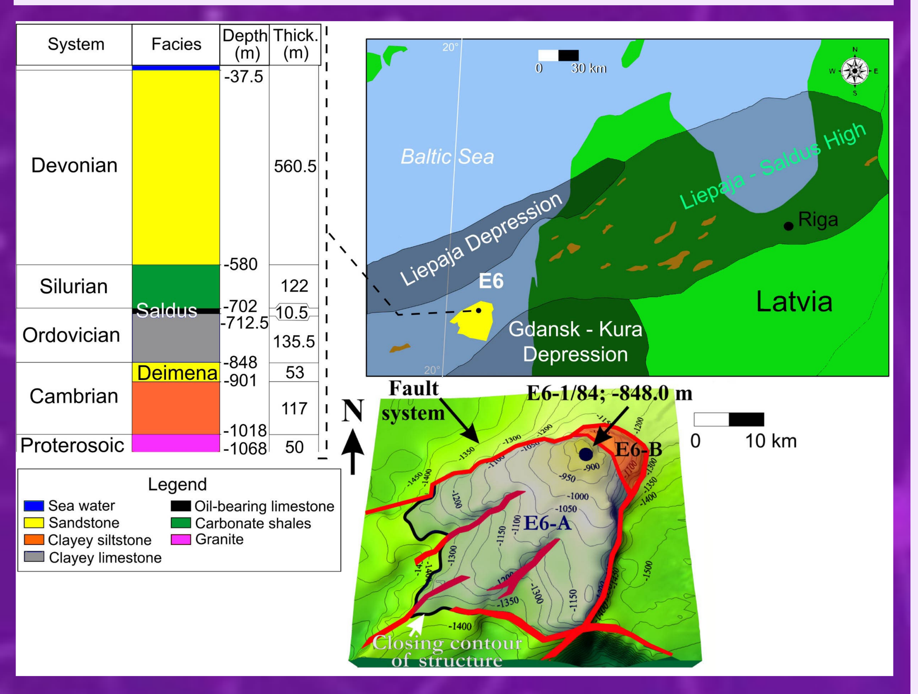


Fig. 1. Location of the studied E6 structure offshore Latvia (yellow), with the location of the well, lithological cross-section and the 3D geological model of the top of the Cambrian Deimena Formation of the E6 structure (*Shogenov & Shogenova, 2021*)

GEOLOGY

- The most prospective structures for CO_2 geological storage (CGS) in the Baltic region are available in Latvia (*Fig. 1, Shogenov et al., 2013, 2022*)
- **E6** offshore structure was found by seismic exploration and explored in 1984 by one well E6-1 (depth 1068 m), located **37 km from the coast** of Latvia
- Prospective for the CGS reservoir of the Cambrian Series 3 Deimena Formation (**848–901 m depth** at the well E6-1/84) in the **E6 structure** was assessed as the largest storage site, among all the studied in the Baltic Region structures
- Reservoir av. **thickness: 53 m**
- Rocks: **quartz oil-impregnated sandstones, saline aquifer**
- E6 structure: **anticline fold** bounded on three sides by faults. The structure consists of two different compartments divided by the inner fault (E6-A and E6-B)
- Total area: **600 km²**
- Trap area of compartment **E6-A: 553km²** (prosp. for CGS & CPG) and **E6-B: 47km²** (prosp. for Geo-PB), (*Fig. 3a*)
- Reservoir: Porosity (**14–33%, av. 21%**); Permeability (**10–440 mD, av. 170 mD**).
- Silurian-Ordovician **shale cap rock of 400–1000 m thick**
- Reservoir temperature: **36°C**

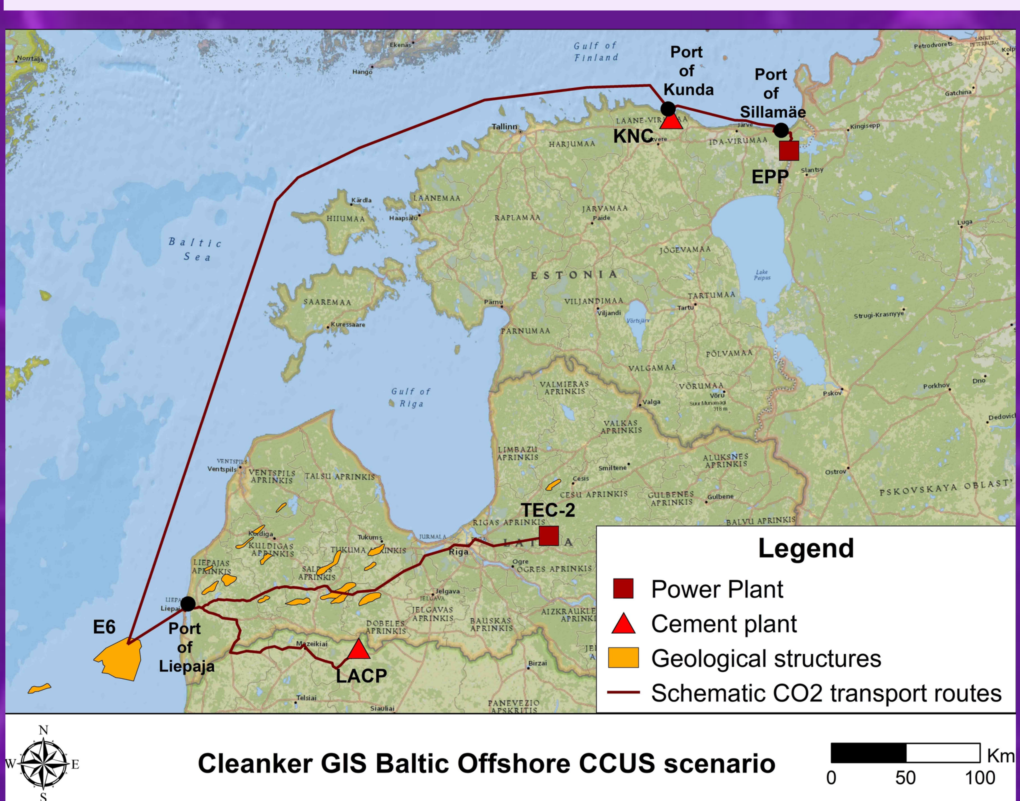
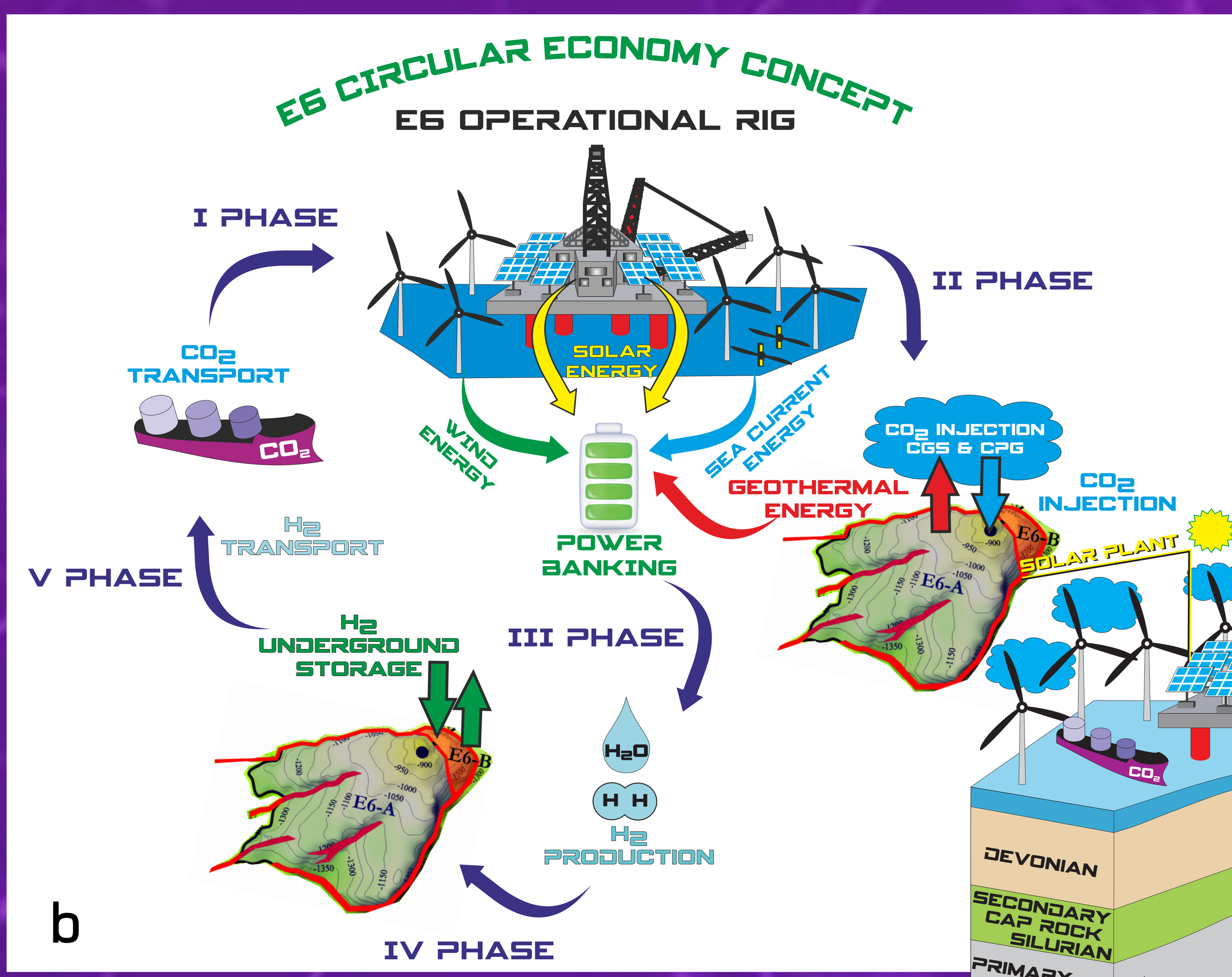


Fig. 2. Transport model of the proposed innovative synergy CCUS and renewable energy project offshore Baltic using CO_2 emissions from the cement industry and energy production from Estonia, Latvia and Lithuania. The red line is showing the transport model (*Shogenov & Shogenova, 2021*)



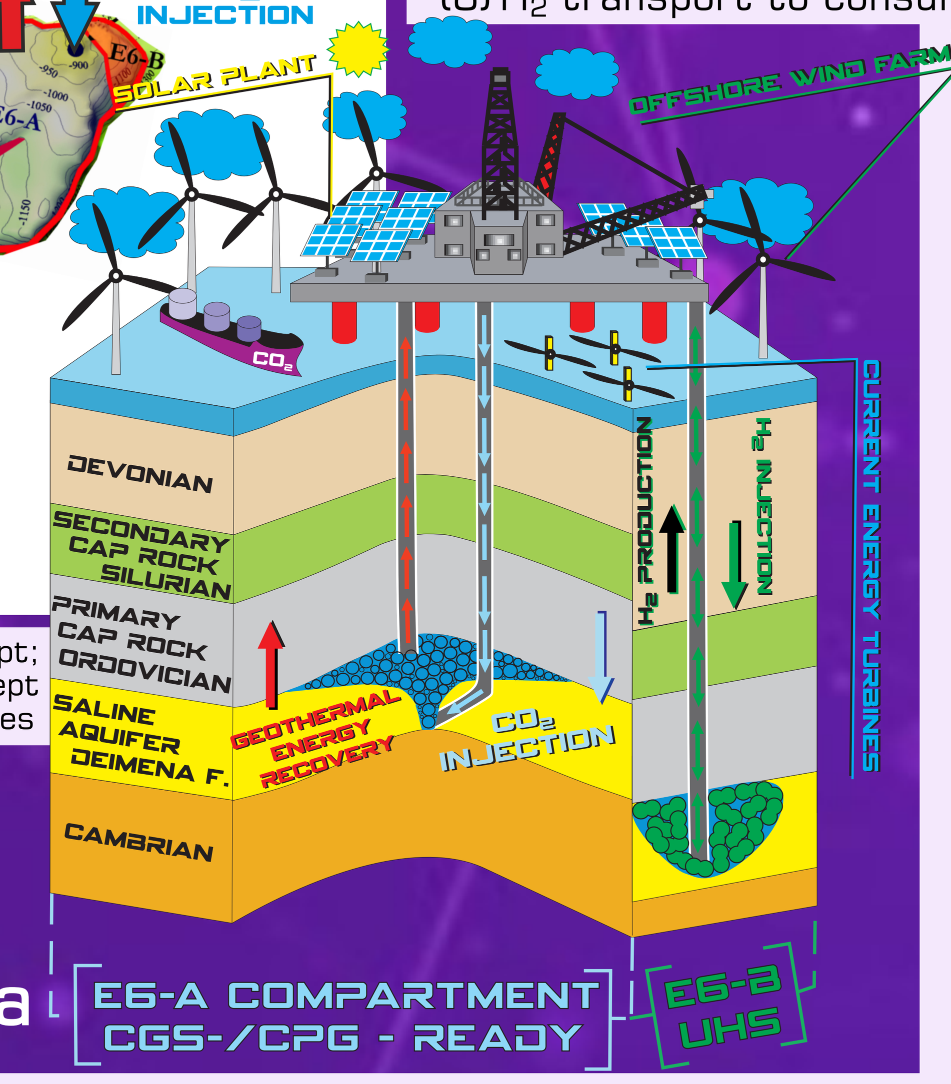


Fig. 3: (a) Demonstrative geological cross-section of the concept; (b) E6 structure energy and CO_2 storage hub circular economy concept workflow of the closed cycle of processes proposed, demonstrating five phases

REVIEW OF TECHNOLOGIES

All proposed technologies applied to the synergy concept are briefly reviewed with possible benefits, barriers and uncertainties in **Table 1**.

Technology	Benefits	Challenges	Cost per unit by 2030
CCUS +bio-CCS (BECCS)	Able to reduce industrial emissions directly and remove CO_2 that cannot be avoided.	High technology costs; low public acceptance; weak legal framework; need for complex research in each case.	100–200 €/t CO_2 (in EU ETS)- revenues for not emitted and negative emissions.
CPG (CO_2 Plume Geothermal)	Not intermittent; with time all the injected CO_2 is stored underground; increased electric power production; minimized water use; increases prospects in dry and lower temperature areas; power systems are very compact, reducing costs.	CO_2 is more expensive and more difficult to work with than water.	3.3 €/kWh (Estimated by *TeraCOH, 2018*)
Solar energy	The cost of technology is falling down every year.	Volatility or intermittent.	20–80 €/MWh
Wind energy	The price of electricity generated by offshore wind is going down every year and will be as onshore by 2030. Multiple turbines could be mounted on a single floating foundation.	Volatility or intermittent.	30 €/MWh
Sea currents energy	Water flows have a permanent direction, more constant and predictable; more stable than wind and solar energy; turbines can be installed by small, relatively simple vessels under the water.	Waves' speed may vary from 4–9 km/h (2–5 knots in water speed); Not yet mature technology.	Cost will be compatible with offshore wind energy 30 €/MWh
H_2 production	1 m^3 of H_2 produces 12.7 MJ of energy; has 2.5–3 times more energy content than natural gas; H_2 could be produced and stored; seasonal-based energy storage application	A large amount of energy is needed to produce the H_2; high cost for H_2 production.	1–2 €/kg of H_2
Geo-PB/UHS (Geological Power Bank/ Underground Hydrogen Storage)	A huge capacity for energy storage; lower cost; safety due to the absence of contact of H_2 with oxygen.	Risks are similar to CGS; the need to use a cushion gas; H_2 can be dissolved in the aquifer waters; lower density of H_2 compared to CO_2; biochemical, microbial and geochemical reactions of H_2 with minerals; monitoring of H_2 storage is not matured; avoiding or considering water coning, gas fingering and capillary hysteresis phenomenon.	1€/kWh

Table 1. References: *IRENA, 2022; IPCC, 2022; Offshore Energy, 2022; Krevor et al., 2023; Phadke 2021*

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CONCLUSIONS

The concept includes eight innovative elements of techno-ecological synergy:
(1) CGS (CO_2 Geological Storage)
(2) CPG (CO_2 Plume Geothermal)
(3) solar energy
(4) wind energy
(5) sea currents energy
(6) H_2 production
(7) Geo-PB (Geological Power Bank)
(8) H_2 transport to consumers

The proposed cycle is closed, demonstrating the principles of circular economy, which will increase the total efficiency of the concept.
CGS and CPG are planned in the **E6-A** compartment of the E6 geological structure with an average storage capacity of **365 Mt** in an optimistic approach and **Geo-PB** is planned in **E6-B** with an H_2 **storage** capacity of **119 kt**.

Our study demonstrates the **new generation of concepts** of optimization of the efficiency of the **underground energy** and **CO_2 storage** projects, which include four **renewable energy** options, and **negative-emissions** technologies making it **self-supporting** and circular economic. We believe that this synergy solution **will increase the public and policymakers' acceptance of new CGS and energy storage technologies**. As well as will become an **example for oil, gas, energy and CCUS players** in the market showing the attractiveness of this kind of business for investors and will push the **development of new technologies, energy transition and mitigation of climate change**.

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