AKADEMIA GÓRNICZO-HUTNICZA
IM. STANISŁAWA STASZICA W KRAKOWIE

AGH UNIVERSITY OF SCIENCE
AND TECHNOLOGY

New attempt of the implementation of CCS technology in Poland

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CCS/CCUS in Poland

- After 2013 when the PGE Bełchatów demo CCS project was canceled and the EU CCS directive implemented into Polish law (in a way generally obstructing the development of CCS projects in Poland), no significant effects in that field have occurred till 2021.
- In 2021 the draft of a new law on change of Polish geological and mining law and some other laws (Polish CCS law) was prepared and is being proceeded – it is expected to be accepted soon by the Council of Ministers and then submitted to the Parliament.

CCS/CCUS in Poland

Polish Geological Law

- Generally, the law is to facilitate the development of CCUS technologies in Poland (commercial projects, both onshore and offshore storage in saline aquifers and depleted/depleting hydrocarbon fields - including EHR, no exploration permits/concessions, just storage permits as required by the directive, transport modes).

CCS/CCUS in Poland

- Concurrently, in August/September 2021 Polish Minister of Climate and Environment appointed an advisory board - the Team on Development of CCUS technologies, where representatives of government, industry and research organizations were invited to facilitate CCUS technologies implementation in Poland.
- Geological and reservoir engineering teams from
  - AGH University of Science & Technology (Krakow),
  - Polish Geological Institute (Warsaw) and
  - Oil-Gas Institute (Krakow)

  are resposible for real activity in CCUS in Poland (transport & storage part)

CCS/CCUS in Poland

- One of the Team's tasks resulted in the development of several prefeasibility studies on the full CCS value chain of newly constructed power and CHP blocks (mainly gas fired) carried out by a consortium led by AGH.
- Similar studies are being developed or considered in the case of other industry sectors, especially cement and chemical plants.
- In the storage part of these studies, the national project "Assessment of formations and structures for CO2 geological storage including monitoring plans" (completed in 2012/2013 by a consortium led by PGI-NRI) and its update completed upon request of the Ministry in 2021 have been utilized.

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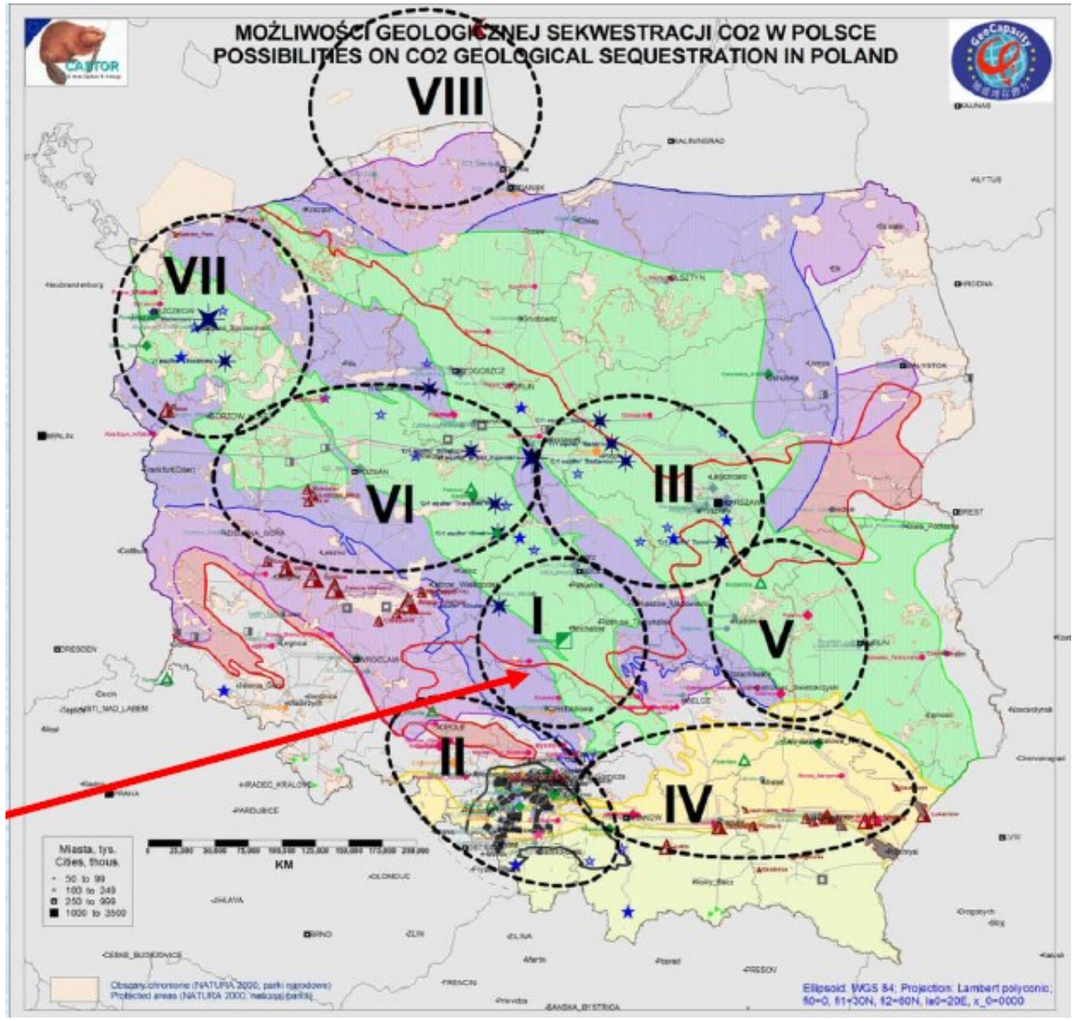
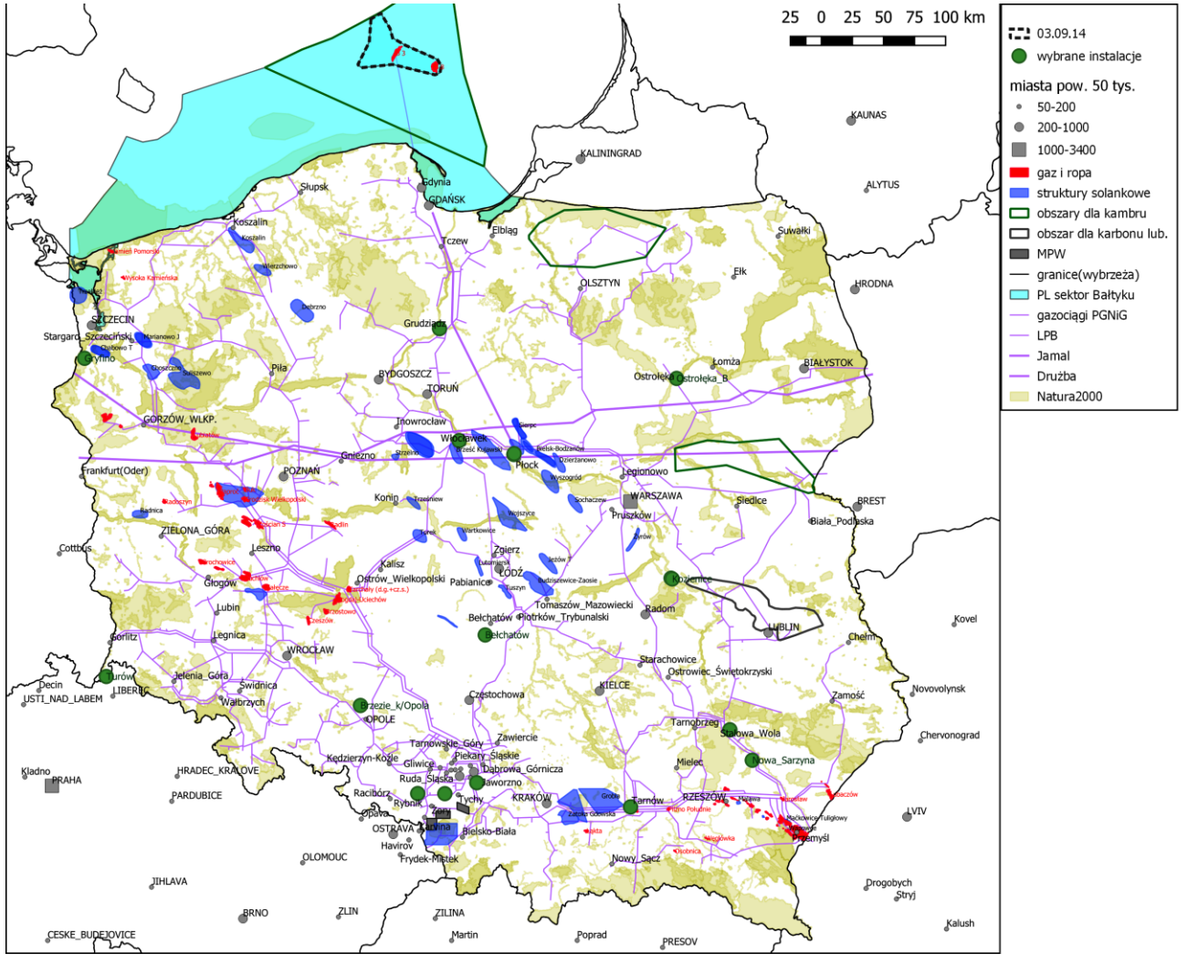


Ordered by (Min. of Environment)

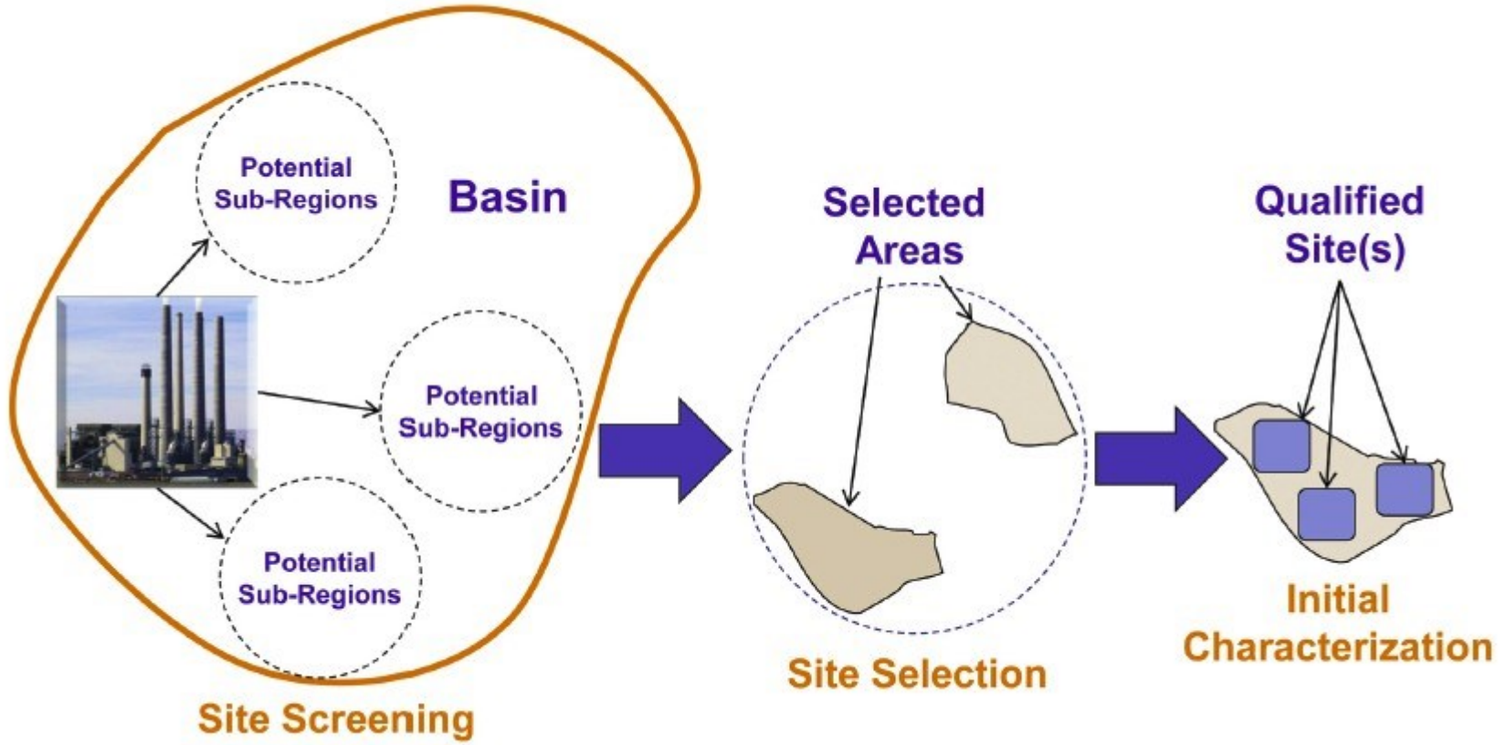
Funding

Potential map of geological CO2 storage/storage sites



source: A. Wojcicki (PGI)

Decision diagram of CO_2 storage (DOE) location



Źródło: Site Screening, Selection, and Initial Characterization for Storage of CO2 in Deep Geologic Formations DOE/NETL-401/090808, 2010).

Analytic Hierarchy Process for pre selecting structure

Diagram of the decision-making system for the selection of the geological structure in aquifers for the geological storage/storage of carbon dioxide:

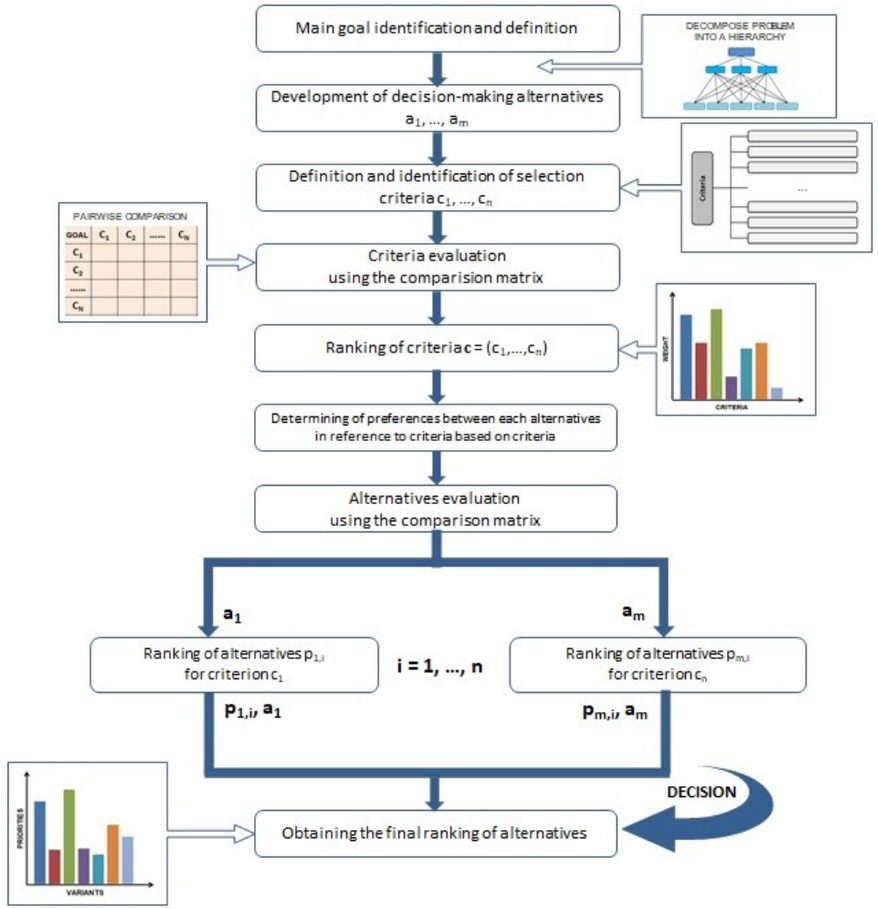
w - weight,

c - criterion,

a - variant,

1, ... m – number of decision variants,

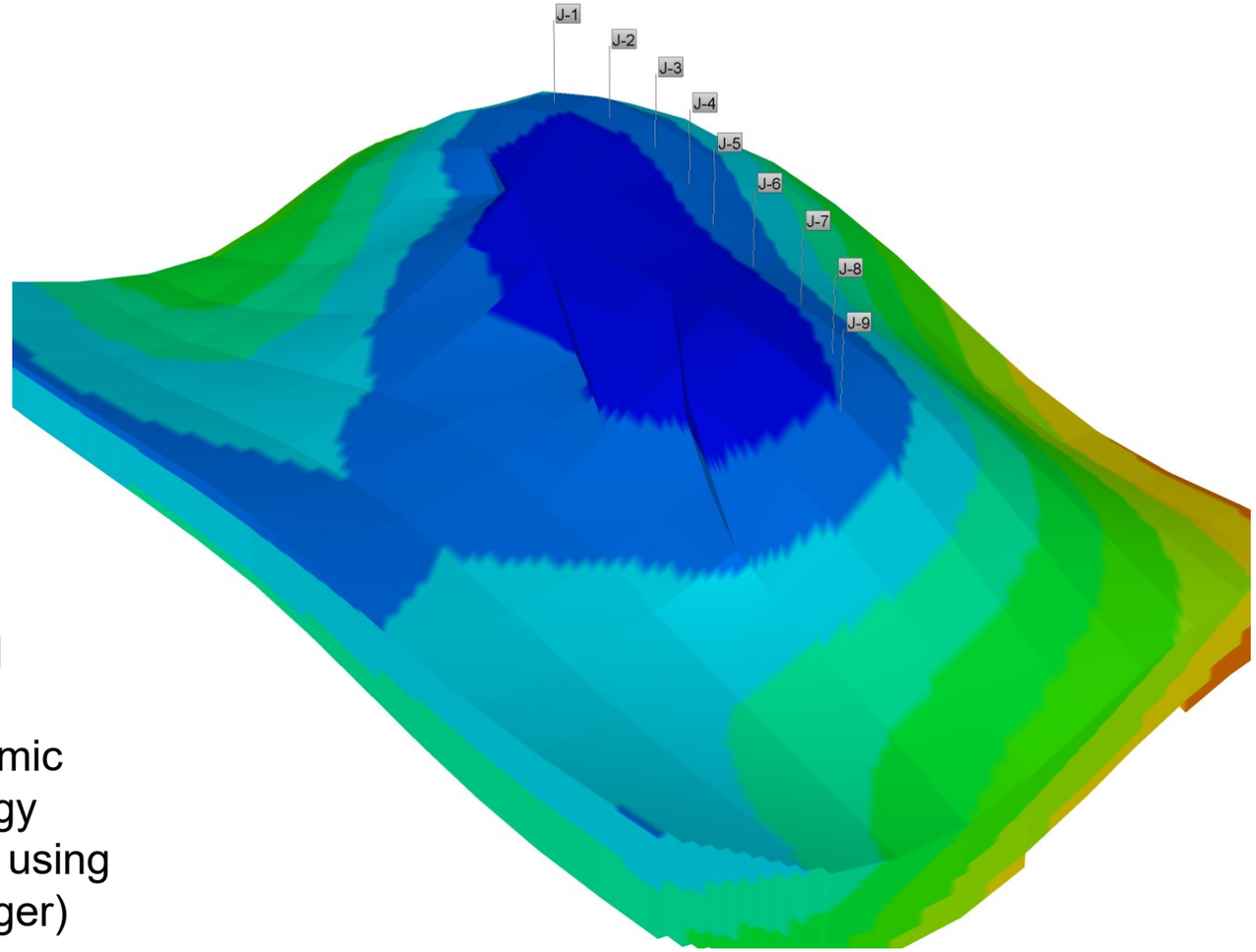
1, ... n – number of decision criteria.



Recommendations of structures for power plant in West Northern part of Polnd

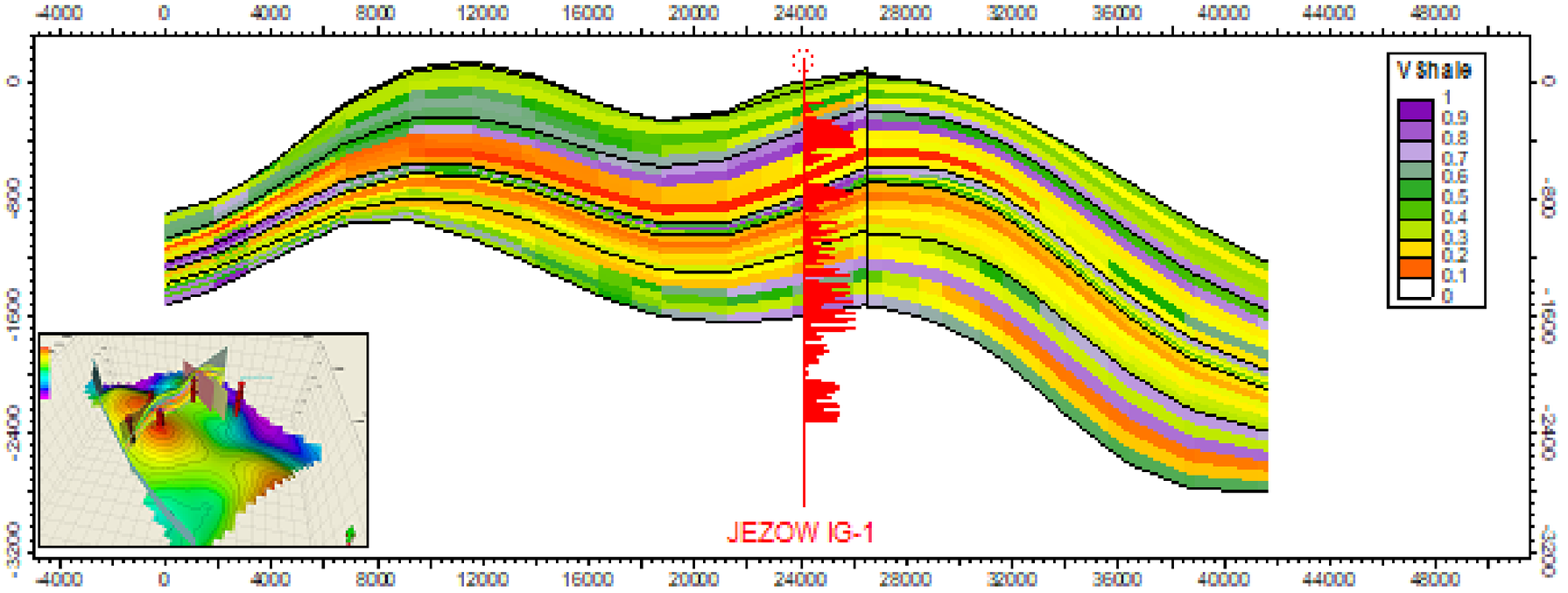
struktury	pojemność struktury (sumaryczna) [Mt]	głębokość zalegania (strop) [m ppt]	przepuszczalność [mD]	powierzchnia struktury [km2]	miąższość skał uszczelniających [m]	integralność warstw uszczelniających	mineralizacja wód [g/dm3]	odległość od poziomów wód pitnych	instniejąca infrastruktura transportowa [km]	gęstość zaludnienia	sposób użytkowania terenów	lokalizacja w pobliżu emitenta [km]	stan rozpoznania struktury (otwory + profil)
	ilościowe (max)	ilościowe (max)	ilościowe (max)	ilościowe (max)	ilościowe (max)	jakościowe	ilościowe (max)	ilościowe (max)	ilościowe (min)	ilościowe (min)	jakościowe	ilościowe (min)	ilościowe (max)
Antyklina Marianowa - J	170	1436	1000	101	46	tak (uskoki w cechsztynie i triasie)	110	1300	na obszarze struktury	79	80% nienawadniane grunty orne; 10% pastwiska; 8% lasy, 2% nieciągła zabudowa	70	13
Antyklina Choszczna - J	398	1235	1000	102	67,5	tak (brak uskoków)	1120	1040	na obszarze struktury	36	70% nienawadniane grunty orne; 15% pastwiska; 8% lasy; 5% nieciągła zabudowa	63	6
BMB oil field	40	2982	60	29,7	400	tak	340	2700	2700m	55	Złoże r. naftowej	70	>15

3D view of the simulation model*
„Jeżów" structures – marked planned injection wells

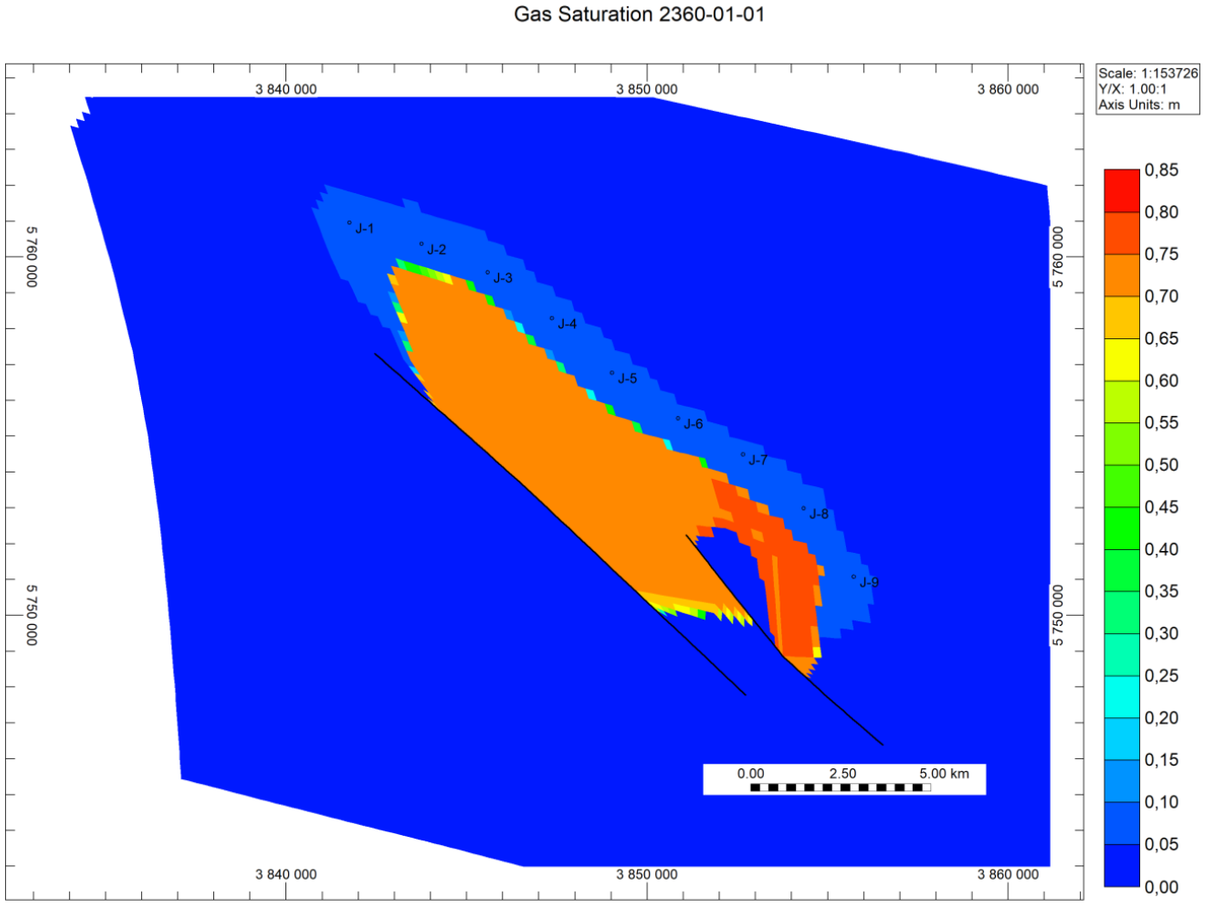


- The simulation model for the anclinical structure of „Jeżów" was made in the Department of Gas Engineering (dynamic model) and in the Department of Energy Resources (static model) of AGH UST using specialist modeling Petrel (Schlumberger) and GEM (Computer Modeling Group)

Static model*, vertical cross-section structure of „Jeżów” – Lower Jurrasic

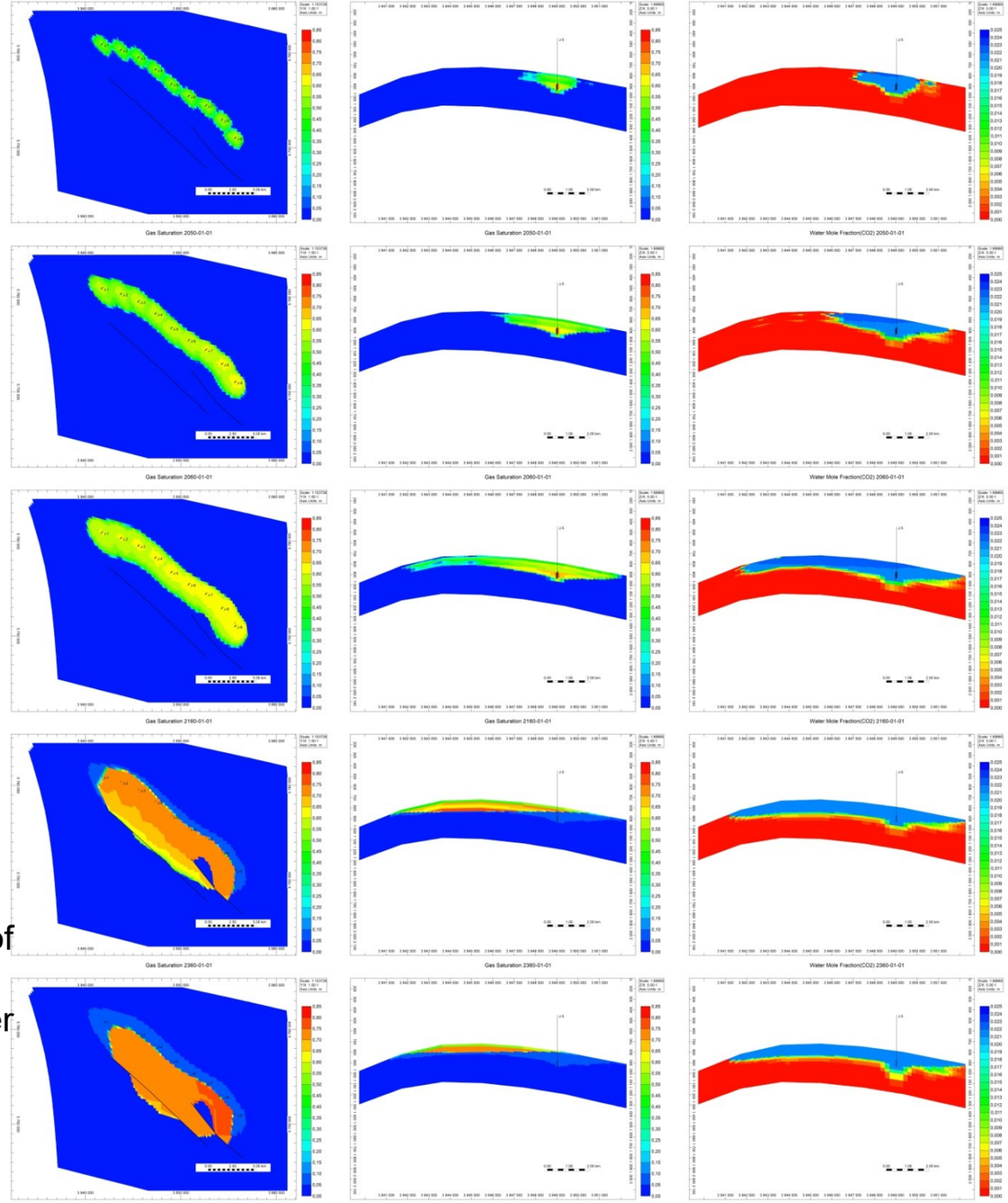


Dynamic model* "Jeżów". Carbonation in the model ceiling layer 300 years after completion of injection at a capacity of 9.2 Mt/year for the fault hydrodynamic barrier variant



- The dynamic model for the anticlinal structure of has been made at the Department of Gas Engineering of AGH UST using GEM (Computer Modeling Group) software.
-

Dynamic model* "Jeżów".
Gas saturation in the ceiling of the model (left column) and cross-section through the Jeżów-5 well (central column) and the molar share of CO2 in this cross-section (right column) after 10, 20 and 30 years of injection and 100 and 300 years after the end of injection – variant 18.5 Mt / year



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-

Next steps for reservoir studies

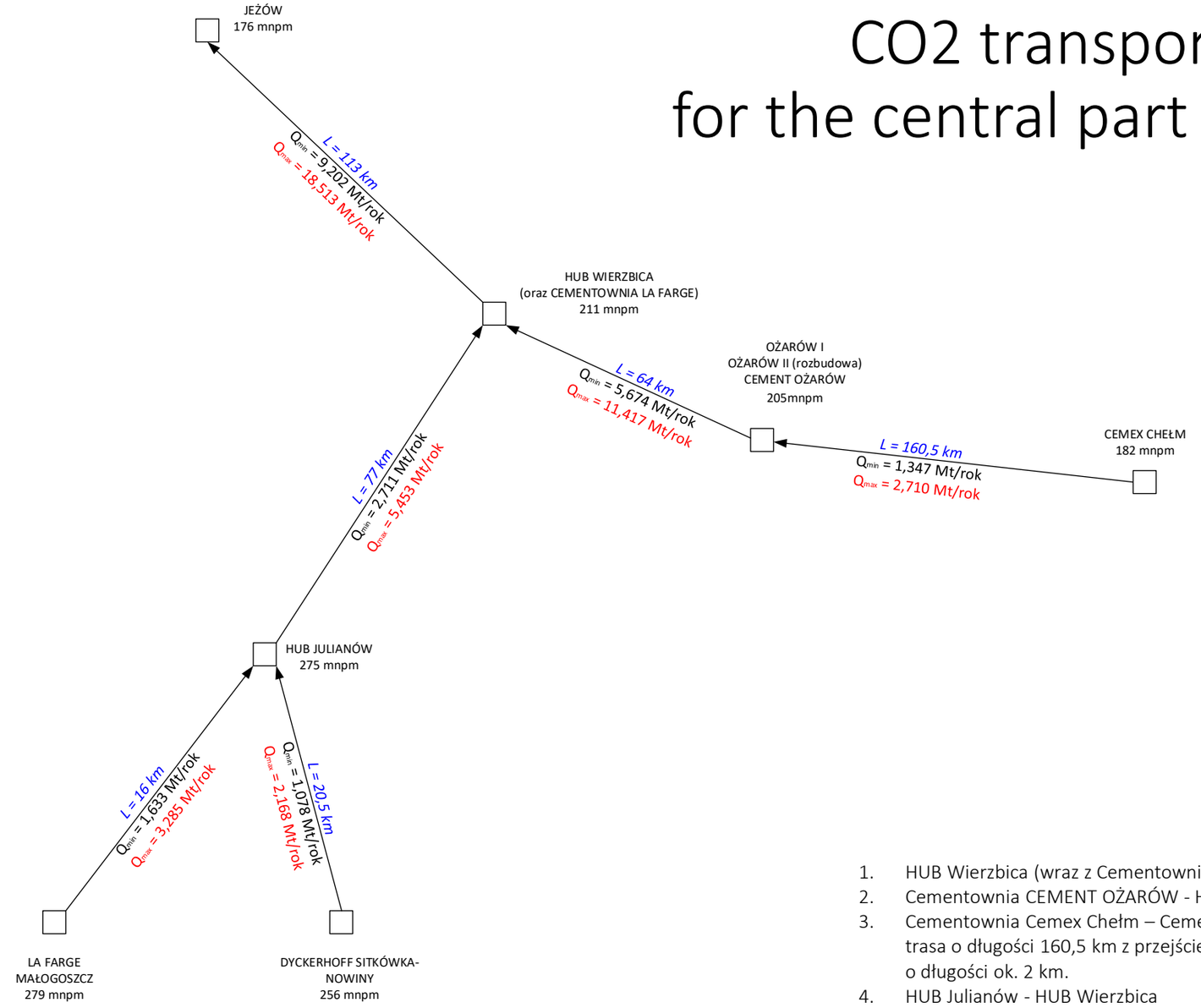
Preliminary geological analyses, static and dynamic modelling of the anticlinal structures confirm (theoretically) the possibility of congestion of the assumed CO2 streams in the period of 20-25 years with minimum yields, also with maximum yields

The analyses indicate the need to start extended studies (new 2D profiles, 3D image, exploratory drilling (at least two wells) and long-term hydrodynamic production and pulsation-interference tests) before making the right investment decision and before submitting an application for obtaining a concession for underground storage of CO2.

Transport of CO2 in Poland

- Only few analysis relevant to the transportation process of CO2 has been done in Poland.
- One of the last analysis (2022) has been done for chemical, power generation and cement industry system

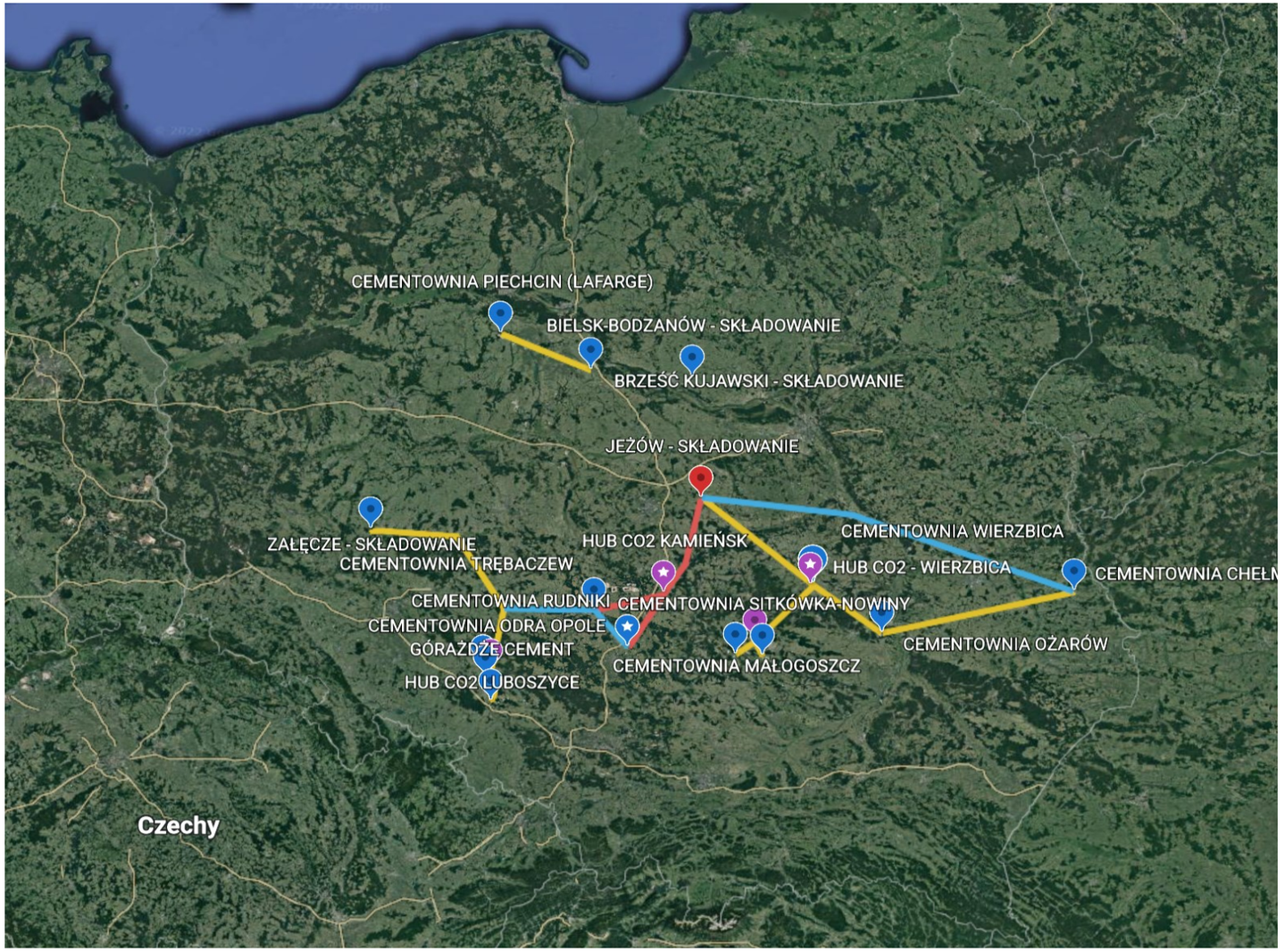
CO2 transport scheme for the central part of Poland



1. HUB Wierzbica (wraz z Cementownią Lafarge) - Jeżów – trasa o dł. 113 km
2. Cementownia CEMENT OŻARÓW - HUB Wierzbica – trasa o długości 64 km
3. Cementownia Cemex Chełm – Cementownia CEMENT OŻARÓW
   trasa o długości 160,5 km z przejściem przewiertem pod rzeką Wisłą
   o długości ok. 2 km.
4. HUB Julianów - HUB Wierzbica
   trasa o długości 77 km

Pipeline transport hubs system

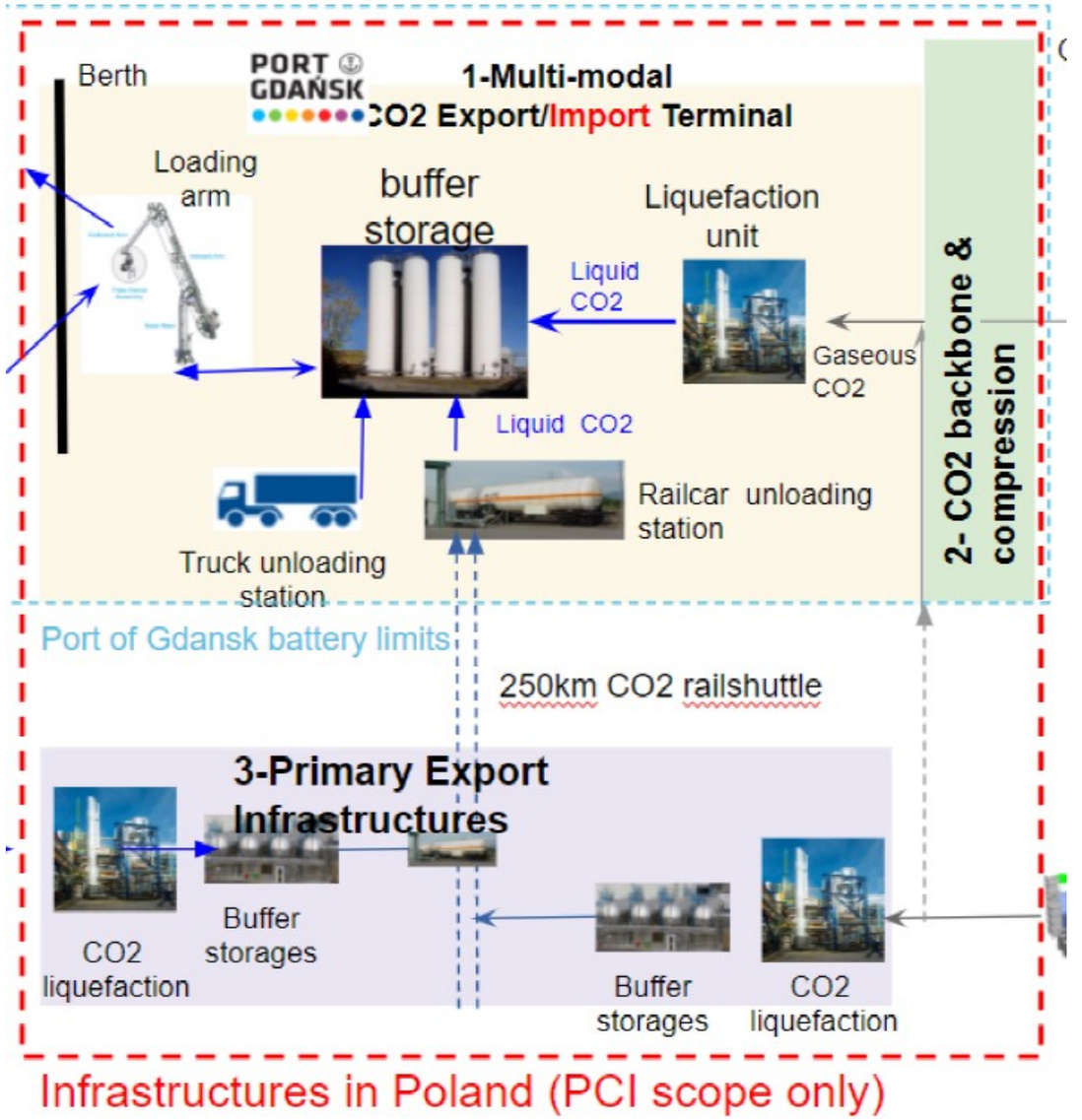
Cement Industry CCS program



Industrial CCS projects in Poland

- PCI - Poland EU CCS Interconnector - multi-modal CO2 Import-Export Hub in Port in Northern Poland CCS

INTERKONEKTOR CCS POLSKA-EU



High level CO2 Storage feasibility statement

Central Poland Kujawy area

Prepared for Kujawy Go4ECOPLANET

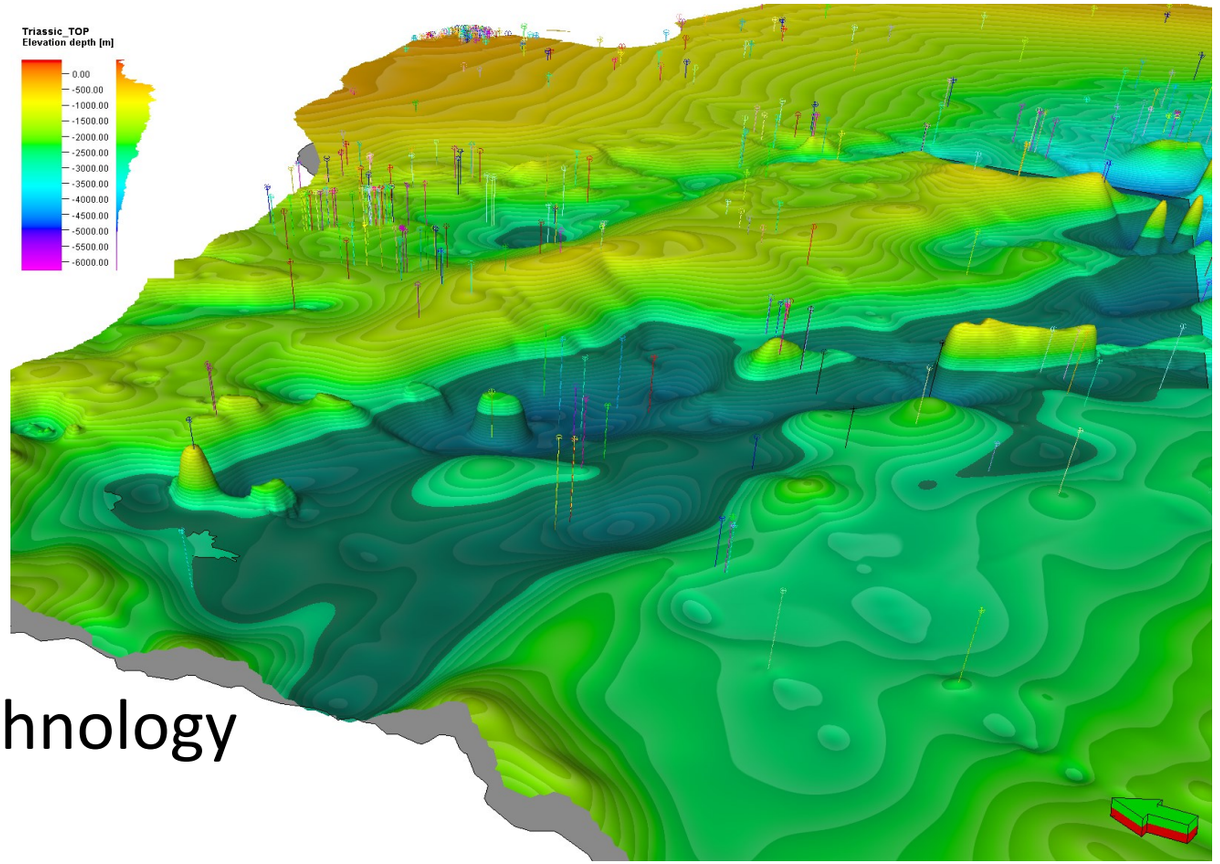
CCS Projects at AGH University

- Several other international projects (financed by Norway Funds) oriented on CCS/CCS have been started (e.g., Agastor, SltPreCO2 project) in Poland. These developments might contribute to creating Polish CCS clusters (or clusters) where various emission sources and transport and storage infrastructure will be integrated, possibly within a decade.

CCUS.pl – Strategy program oriented for capture proces in Poland

- In the case of the complete CCS value chain, results of pre-feasibility studies carried out in 2009-2013, together with assumptions and results of the new AGH-important project CCUS.pl initiated in May 2021, have been utilized.

Advanced Gas and Carbon Dioxide Storage in Aquifer - AGASTOR

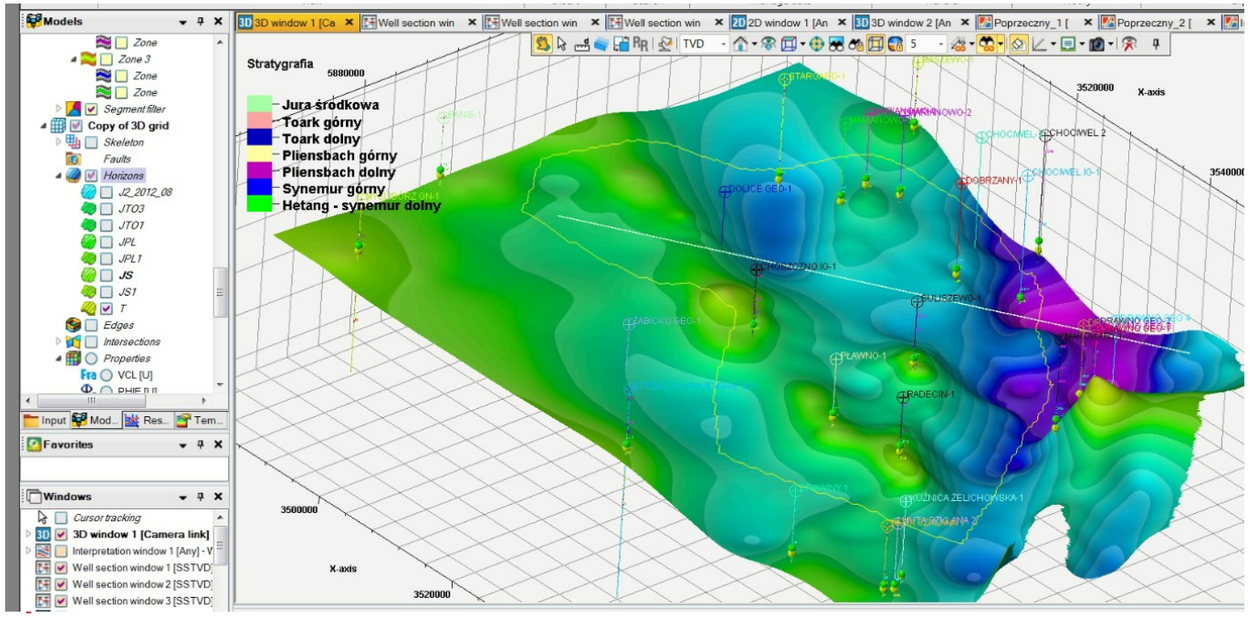


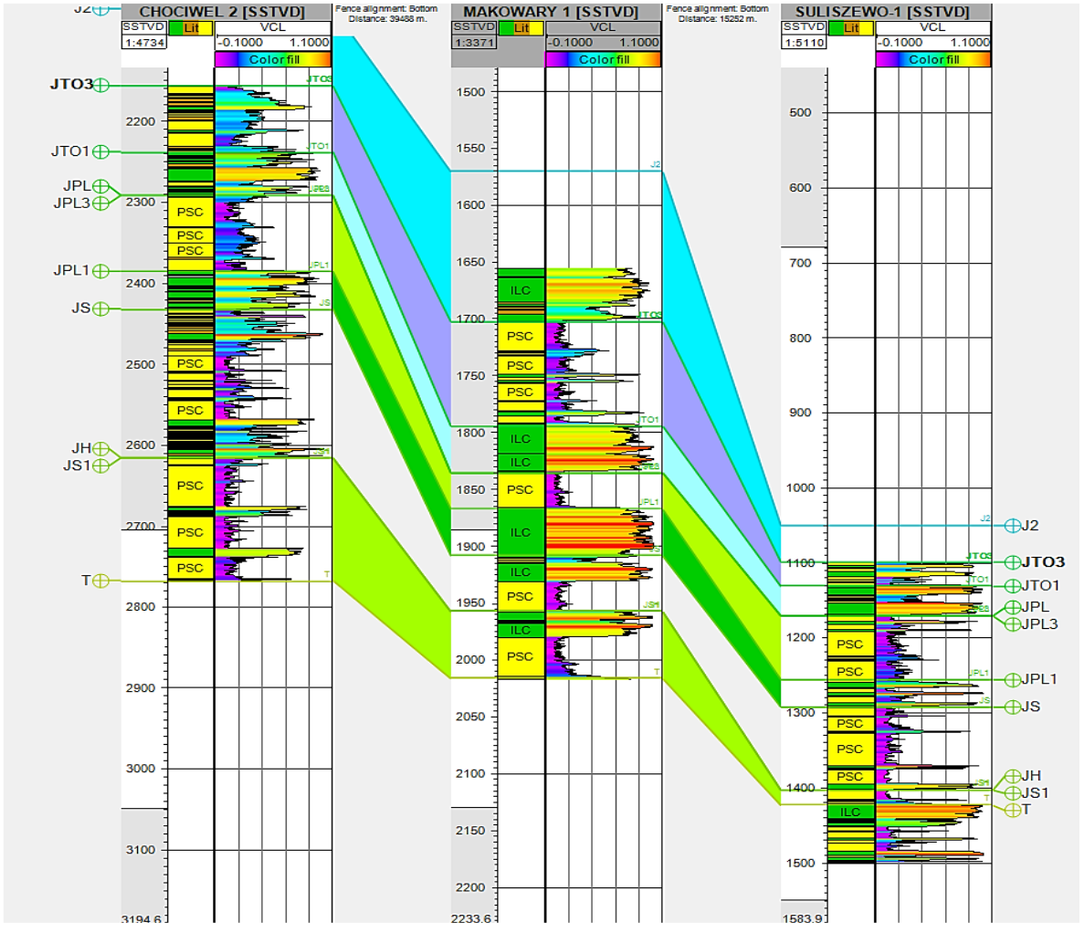
- AGH University of Science and Technology
- University of Stavanger

Norway grants

Universitetet i Stavanger

Suliszewo – Marianowo - Choszczno region (central part of Szczecin Trough) semiregional model





Norway grants

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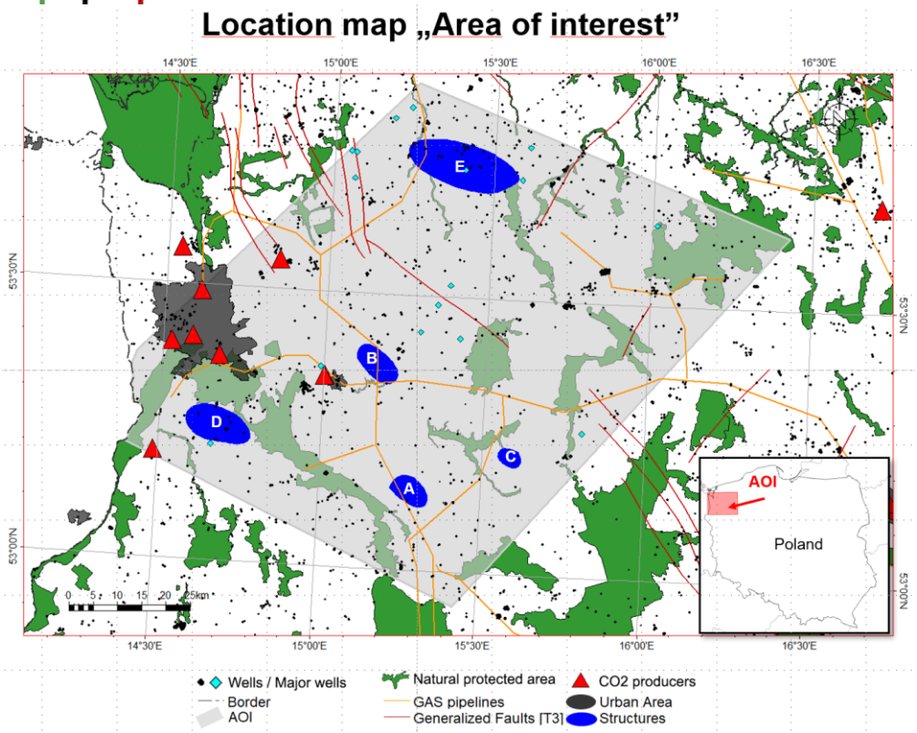
Advanced Aquifer Gas Storage (AGASTOR)

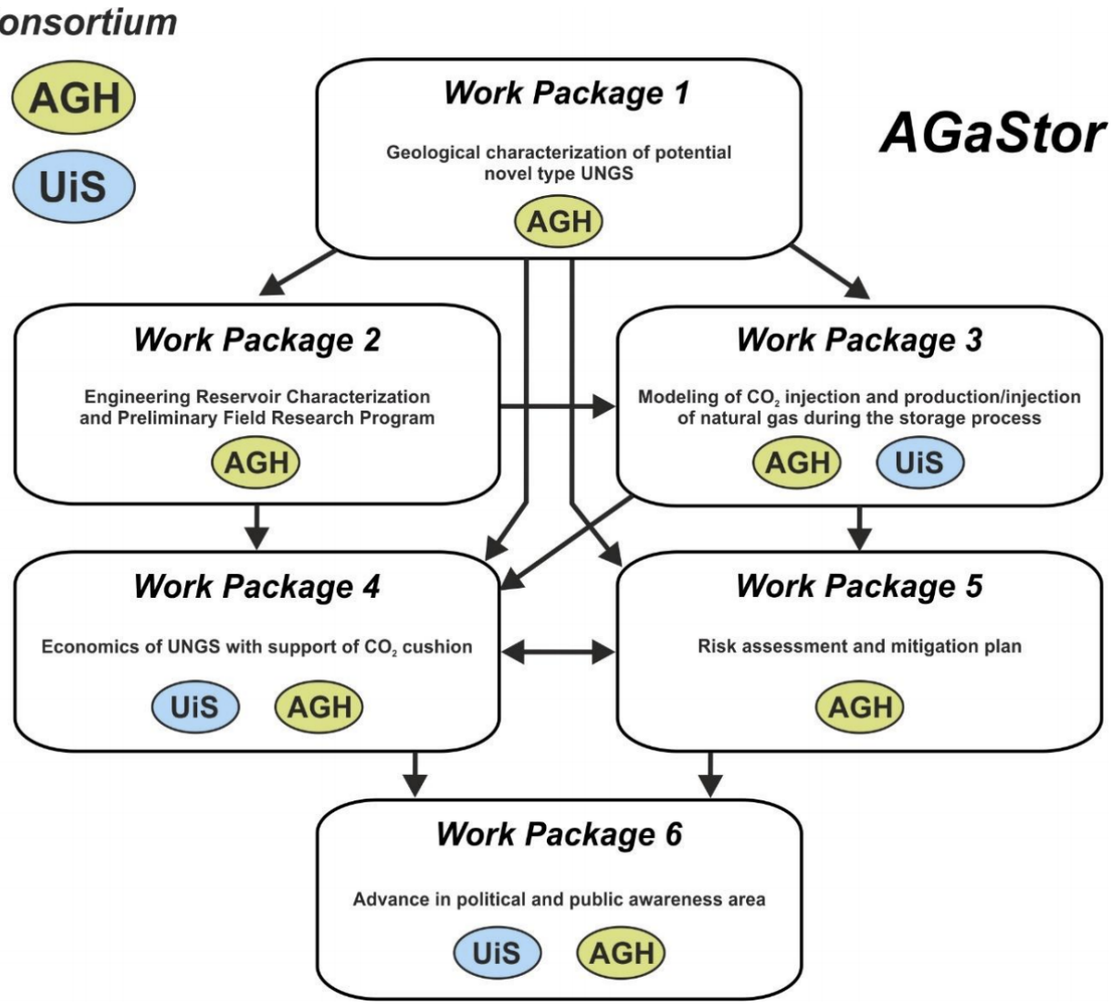
- A preliminary assessment of storage containment risks is prepared. This assessment uses all current data availability and will therefore rely on information developed in the project, including considering environmental issues (release of CO2 to pot aquifers layers, water production for pressure control) based on generic results produced in similar projects.
- Identified containment risks will be addressed through the development of preliminary mitigation. A monitoring plan is being developed to meet regulatory requirements defined in Poland.

Advanced Aquifer Gas Storage (AGASTOR)

- The research carried out as part of the AGASTOR project is a prelude to the fundamental optimization of locating drilling well for storing natural gas and wells whose primary purpose is the geological storage of carbon dioxide after the gas storage process.
- An appropriate Framework for Risk Assessment and Management is being developed for this gas storage site, within which these uncertainties will be evaluated and prioritized in an iterative process.

AGASTOR
Implemented tasks and research





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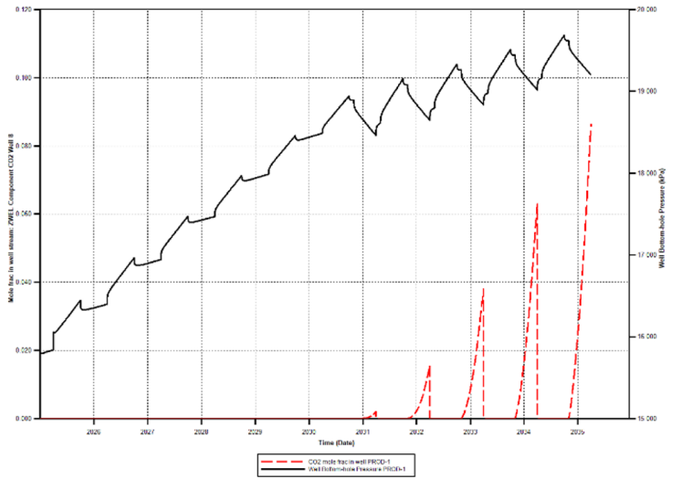
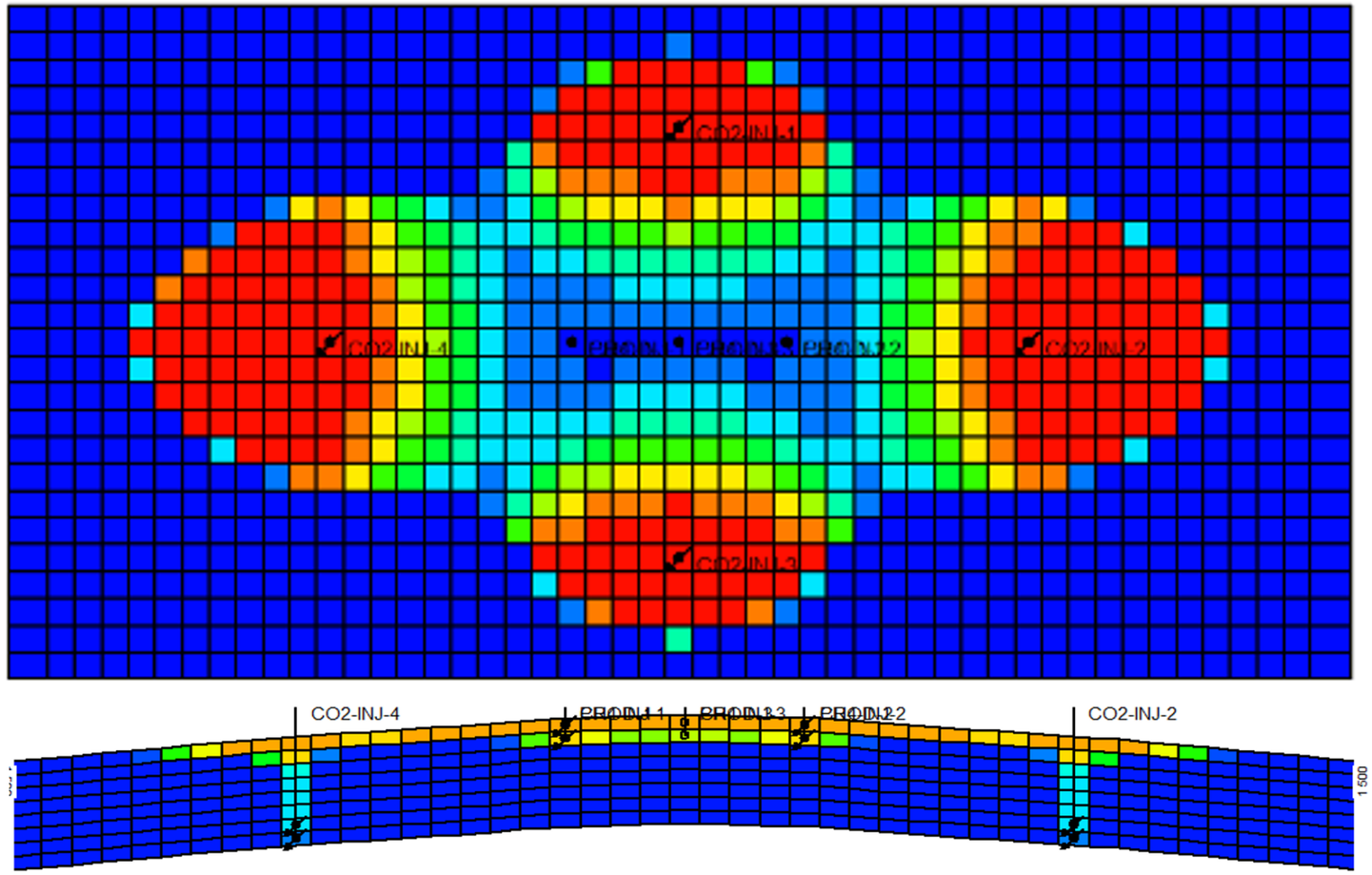
Modeling of CO2 injection & Production -Agastor

T3.1 Dynamic modeling of injection of Carbon dioxide for cushion creation (AGH) (in progres) – an example

1. Laboratory research of mixing CH4/CO2
2. Laboratory research CH4/CO2/brine/rock reactions
3. Thermodynamic phenomena relevant to near well injection CO2 zone
4. Upscaling or effective integration of detailed multi-mechanism core scale model to field scale

Advanced Aquifer Gas Storage with Carbon Dioxide Geological Storage





Model CO_2 mole fraction in the top layer (10 years after first gas injection).
Synthetic anticline model

Key environmental selection criteria for gas storage (with CO2 in cushion)location

ENVIRONMENTAL REQUIREMENTS	Positive indicators	Cautionary indicators	Data source
Protected areas	Absence of : • National parks • Nature reserves • Landscape parks • Natura 2000 areas Birds Directive • Natura 2000 areas Habitats Directive	Presence of : • National parks • Nature reserves • Landscape parks • Natura 2000 areas Birds Directive • Natura 2000 areas Habitats Directive	
Population (Human health)	Unpopulated areas	Populated areas	Directive 2009/31/EC; S.I. No. 2221
Surface water	Absence of rivers and lakes	Presence of rivers and lakes	Directive 2009/31/EC; EPHC; S.I. No. 2221
Groundwater	Absence of Major Groundwater Reservoirs	Presence of Major Groundwater Reservoirs	Directive 2009/31/EC; EPHC; S.I. No. 2221
Wetlands	Absence of wetlands	Presence of wetlands	(GB 16889-2008); US CWA section 404
Source development	Presence of deep boreholes made in new technology with high quality cement sealing	Presence of old, leaky boreholes	NETL2019
Pipeline row-of-ways	< 300 km transportation distance Presence of pipeline infrastructure suitable for supercritical CO2 service,	> 300 km transportation distance	Meyer, et al. (2008); NETL2019

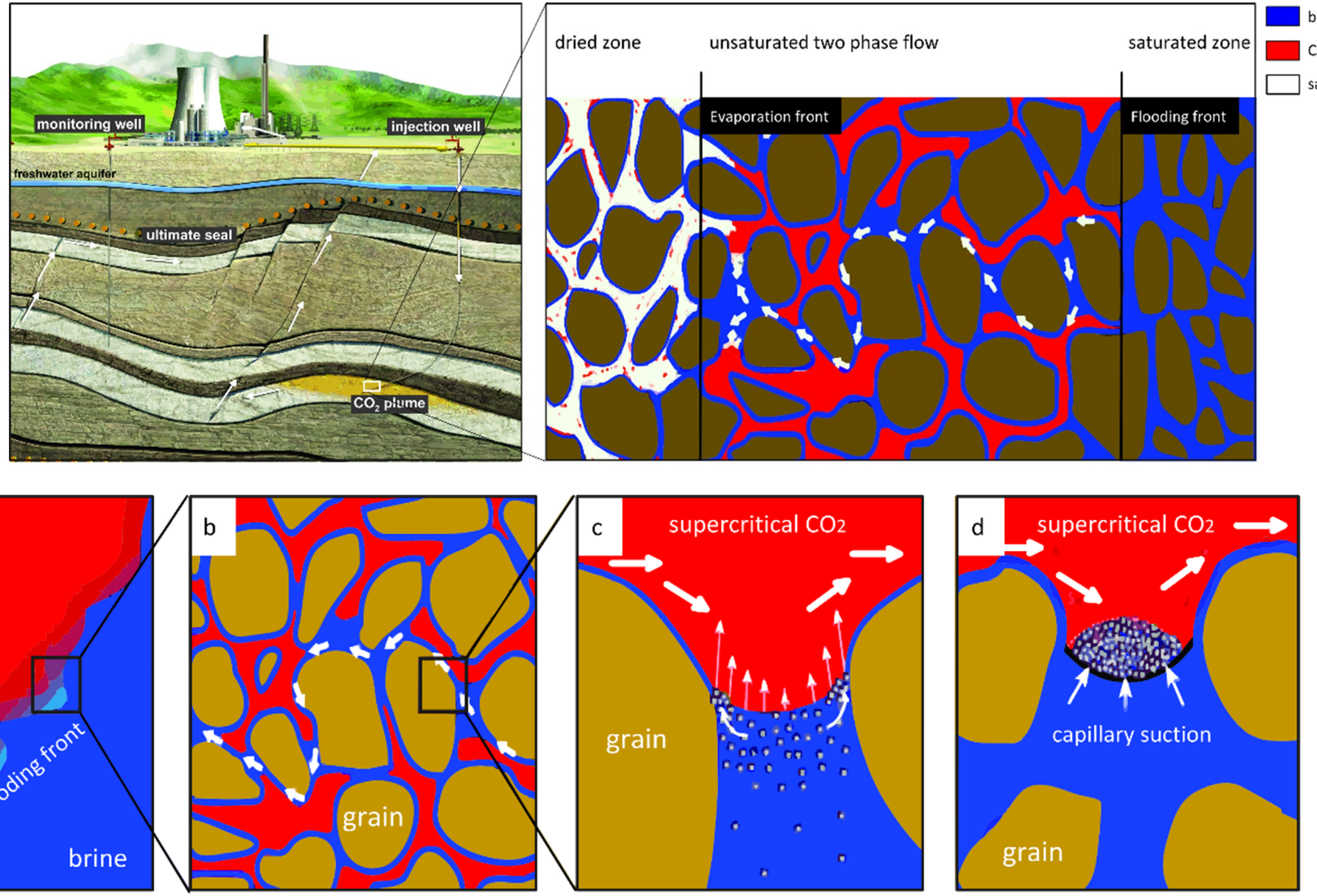


Figure 3. Schematic representation of physical mechanisms affecting precipitation of salt crystals, modified from [16, 17]. (a) two-phase viscous displacement and evaporation, (b) capillary-driven backflow, (c) salt diffusion, and (d) self-enhancing

SaltPreCO2 project 2020-2023

Conclusions

- Possible start of first commercial injection – no before 2028 year
- Industry is waiting for new, better regulation in CCS process.
- Probably small pilot as an element of Reservoir study before obtaining concession for CO_2 storage may start in 2023 – in central or west part of Poland

Thank you

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