Ordered by (Min. of Environment) MINISTERSTWO ŚRODOWISKA

Funding

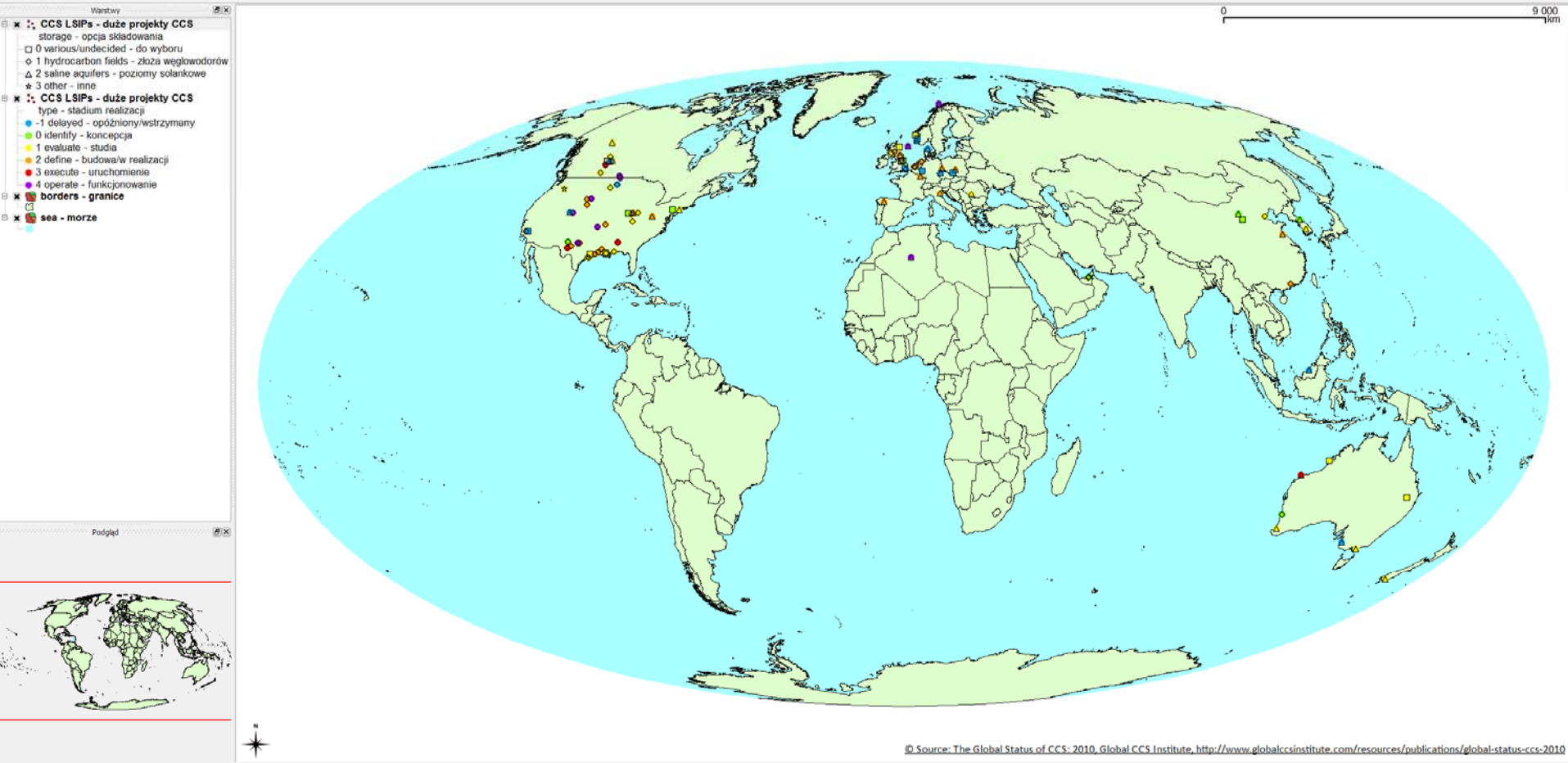
Sfinansowano ze środków Narodowego Funduszu Ochrony Środowiska i Gospodarki Wodnej

PROJECTS OF CCS IN POLAND

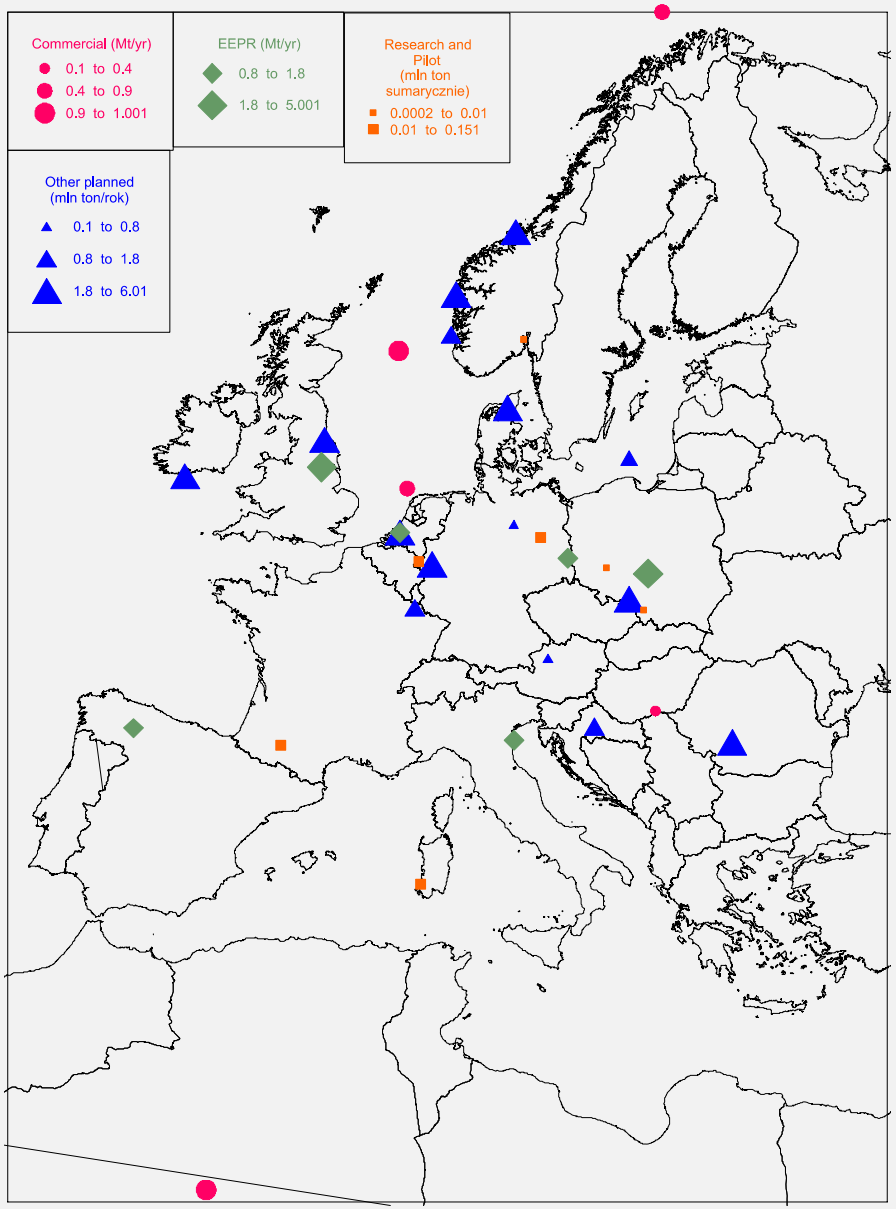
Adam Wójcicki, PGI-NRI

LCOIR-UA Seminar at Donetsk University
23.10.2012

CCS projects worldwide – commercial and large demos (0.5-5 Mt/yr)

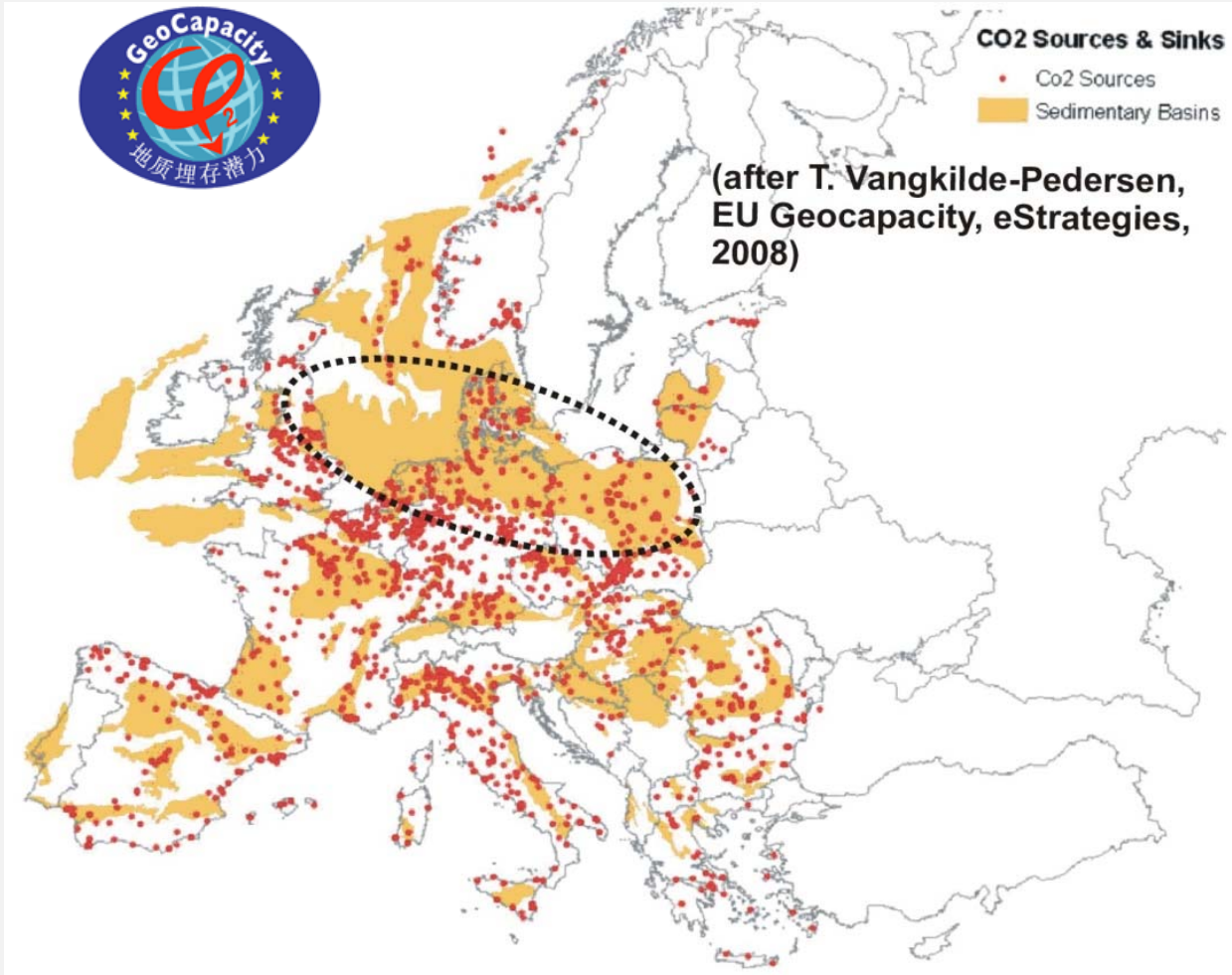


CO2 storage projects – Poland and Europe



- 1995-..**Borzęcin** gas field (acidic gas – 60% CO2; INiG – Oil and Gas Institute, POGC)
- 2004-2008 **Kaniów** coal beds (RECOPOL& MoVeCBM; GIG – Central Mining Institute)
- **Bełchatów** demo CCS project (EEPR funding; PGI-NRI involvement)
- **Kędzierzyn** demo CCS project suspended (to be relocated?) **LOTOS EOR**? (ECO2 project)
- New power blocks – CCS ready to be proven
- Regional studies

CO2 storage prospects in Europe



- EU GeoCapacity project mapped perspective sedimentary basins of Europe,
- (southern) Permian-Mezozoic basin is the biggest one,
- It covers a large portion of Poland, so the country (onshore) CO2 storage potential is above the average.

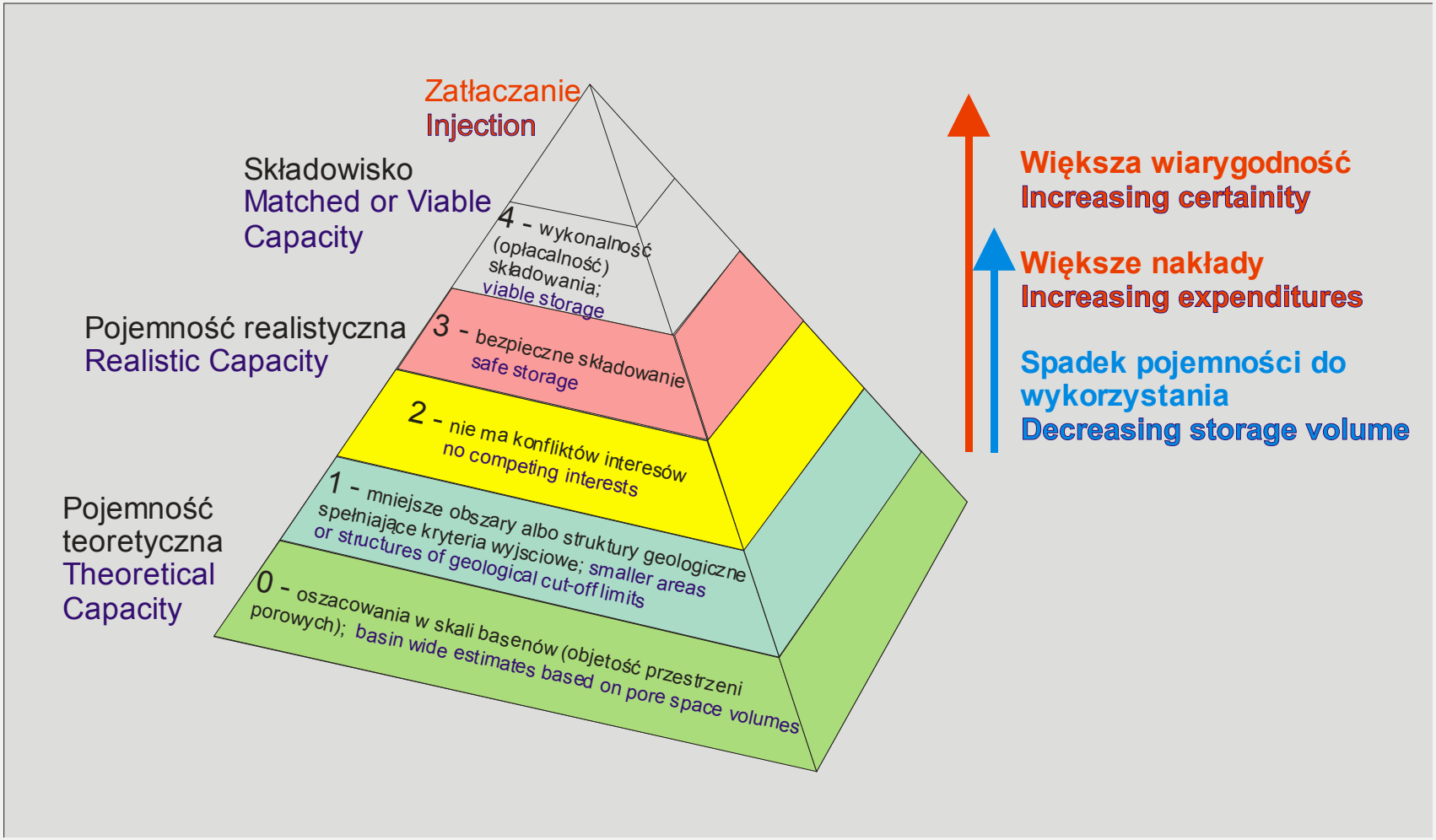
Estimations of CO2 storage capacity (PL)*

Type	*Storage potential, Mt*
CASTOR	**3 752**
EU GeoCapacity	**3 522**
CO2 Atlas of Poland	**8 299**
Cr1, J1, T formations (upper limits)	*~90 000*
Hydrocarbon fields (31 structures)	**764**
Coal seams (selected CBM fields at depth of 1-2 km)	**414**
Coal seams within Polish SCB at depth of 1-2 km	*1 254*
SUM	**5-9.5 Gt**
SUM	*~92 Gt*

- Saline (Mezozoic) aquifers are of biggest potential and sufficient to store emissions of big plants,
- Hydrocarbon fields (mostly gas) are of small capacity,
- Coal seams (methane recovery) are of local importance (SCB), the technology is not mature yet.

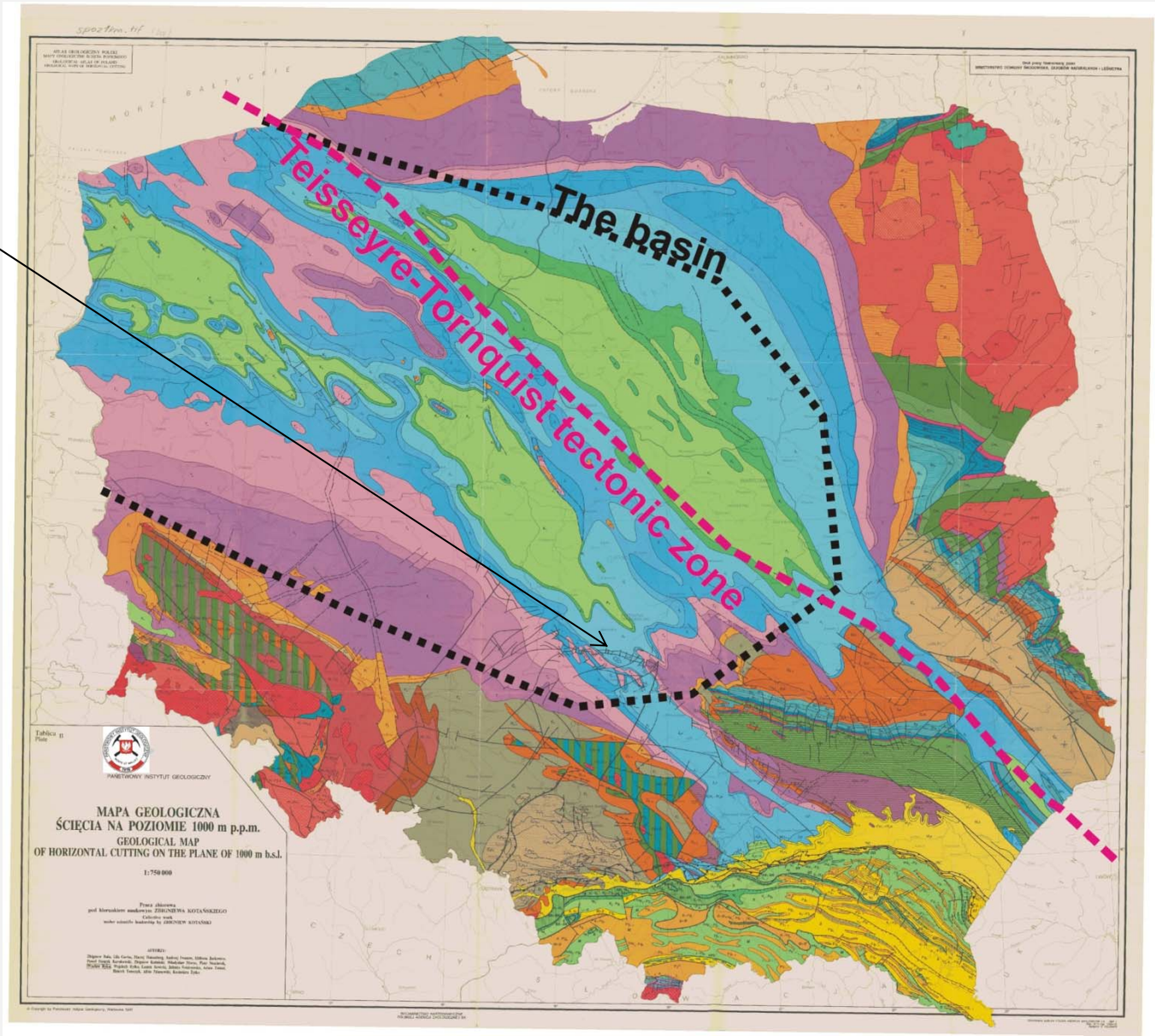
***Emission of industrial installations – 200 Mt/yr**

Qualification of CO2 storage potential



CO2 storage capacity pyramid for the key option - saline aquifers (based on Bachu, 2003 and others)

The Polish basin aquifers (z= 1km; Kotański, 1997)



The most important:

- **Lower Jurassic**
- **Triassic**
- **Lower Cretaceous**

Legal issues

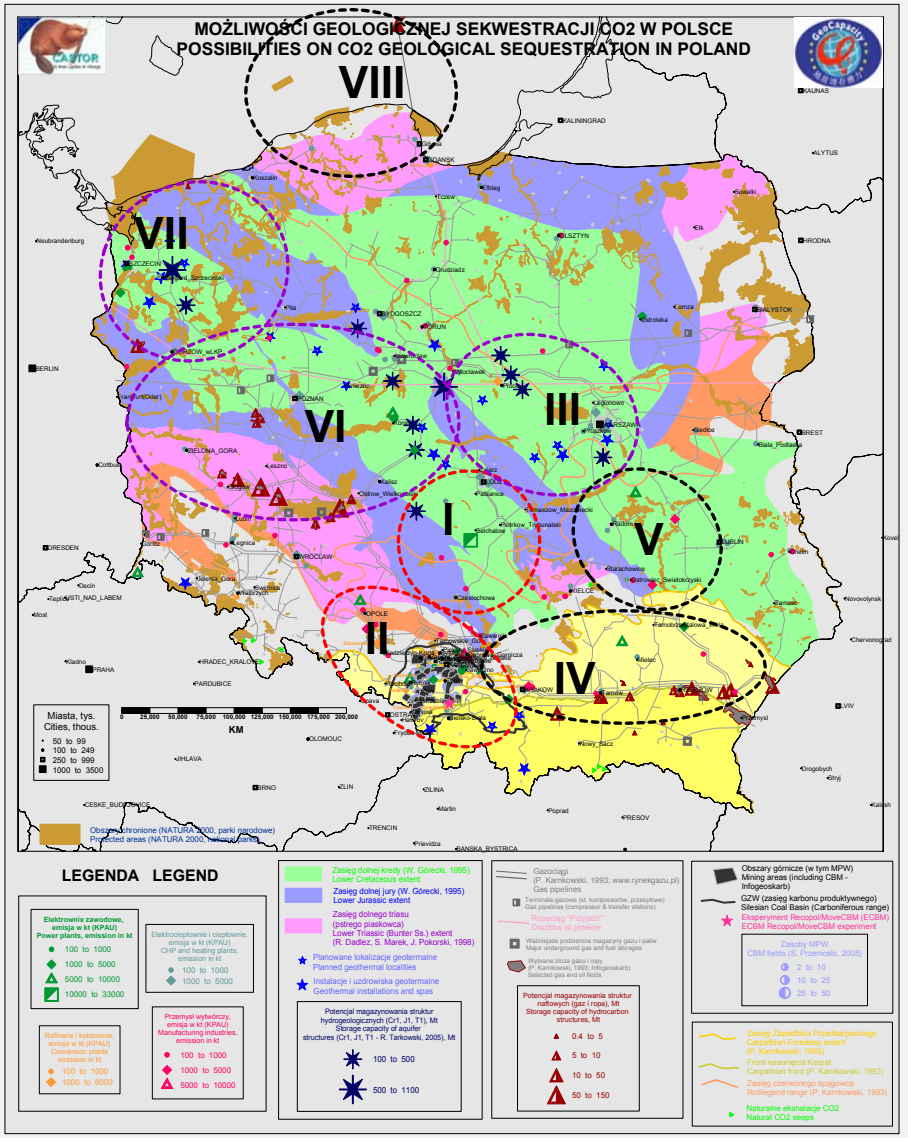
- The Directive on CO2 geological storage is still being implemented in Poland (delayed);
- The assumptions on relevant amendments of geological and mining law, environmental, economic law, etc., accepted by the Council of Ministers, after a long process of consultations with public and government agendas (PGI-NRI and other project partners were involved) and the law proposal has been prepared but not presented to the Parliament;
- By now research CO2 injection up to 100 kt per well allowed; unlimited for EOR/EGR only (the last case not in the proposal);
- CO2 storage of over 100 kt will be governed by the geological and mining law (same as, for example, hydrocarbon production) where Ministry of Environment is the authority; only demo projects are permitted – till 2024-2026;
- Storage fee of 1.25 €/t CO2 injected – 60% goes to the commune/municipality where injection is located.

The Programme

„Assessment of formations and structures for safe CO2 geological storage including monitoring plans";

- Ordered by Ministry of Environment (=the permiting authority of Directive on geological storage of CO2).
- Conducted by 6 national institutions (PGI-NRI – leader, AGH-UST, CMI, MEERI, O&GI, PBG).
- Timeframe: 10.2008-09.2012; ~80 persons involved;
- Goals:
- Supporting Polish demo projects,
- Providing the permitting authority with information necessary for implementing storage,
- Cooperation with other stakeholders, R&D organizations.

The scope of the programme (geology)



It covers entire territory of Poland and the Baltic economic zone, but is focused on*:

- regional studies for 8 areas with saline aquifers,
- hydrocarbon fields and coal beds in general,
- case studies for saline aquifer structures (4),
- case studies for hydrocarbon fields (2) and coal beds (1).

reinterpretation of archive data, laboratory analyzes

The regional studies

The following geological formations are perspective for the regional study areas of saline aquifers:

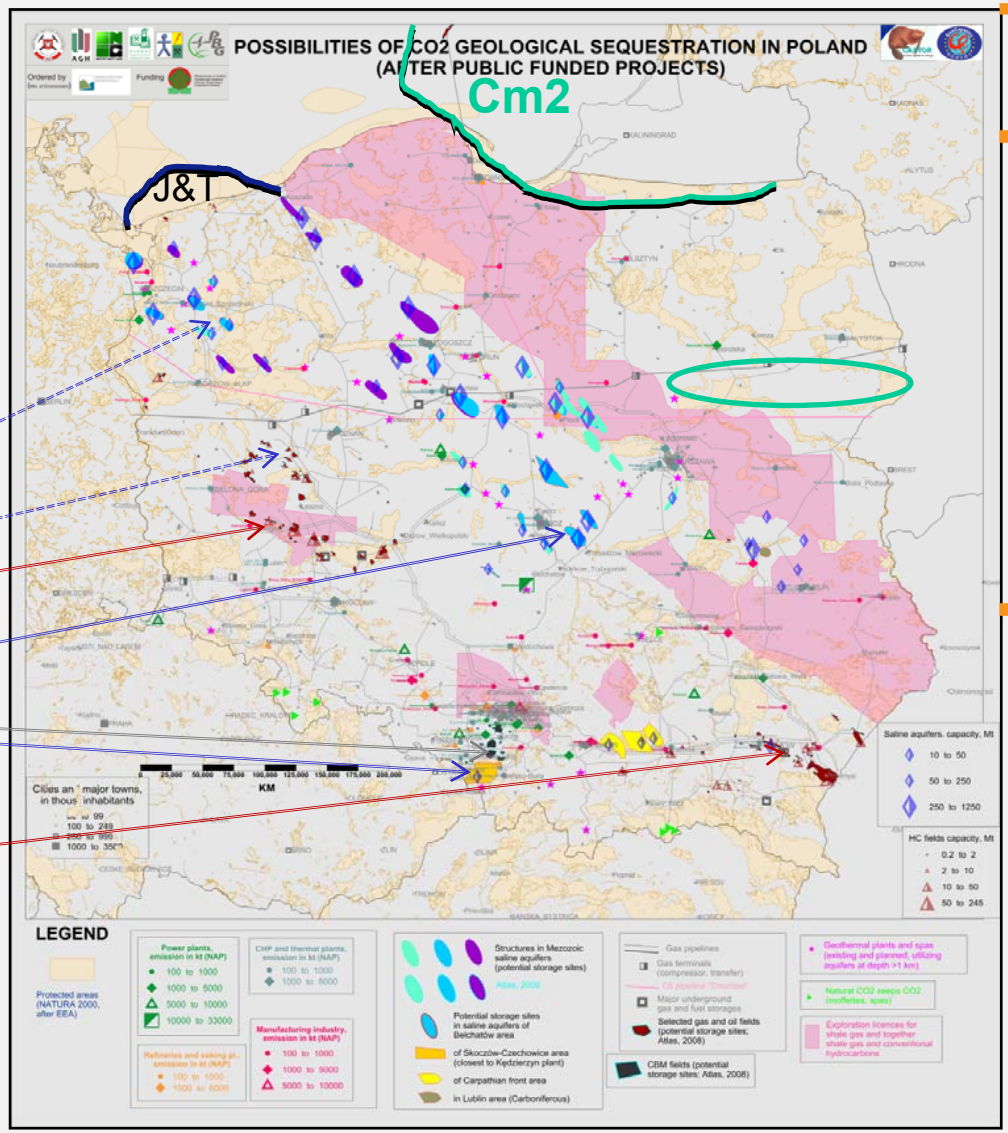
- I (central) – Jurassic (J1, J2 sandstones);
- II (S) – Miocene;
- III (central-NE) - Jurassic (J1, J2 sandstones), T, Cr1;
- IV (SE) – Carpathian front foredeep (Cr to Cm);
- V (E) – Carboniferous (C3 sandstones), J, Cm;
- VI (W) – Permian (P1), T, J;
- VII (NW) – Jurassic (J1 sandstones), T3, T1 – a small part offshore;
- VIII (N, incl. offshore area – E part of Polish Baltic economic zone) – Cm2, T.

Site screening/selection criteria (based on CO2STORE guidelines)

- **Seal thickness:** minimum **50 m,** seal integrity is essential
- **Aquifer depth:** from **800 m** to **2500+ m**
- **Aquifer net thickness:** minimum **20-30 m** (~a single layer)
- **Porosity of the reservoir:** minimum **10%,** preferably **20%**
- **Permeability of the reservoir:** minimum **50-100 mD**
- **Salinity:** minimum **30 g/l**, in case of relic, isolated fluids it might be lower
- **Capillary entry pressure** – is the caprock good enough, impermeable (if K<0.0005-0.005 mD it is likely safe)?
- **<u>Information</u> necessary to evaluate the structure against criteria mentioned above**

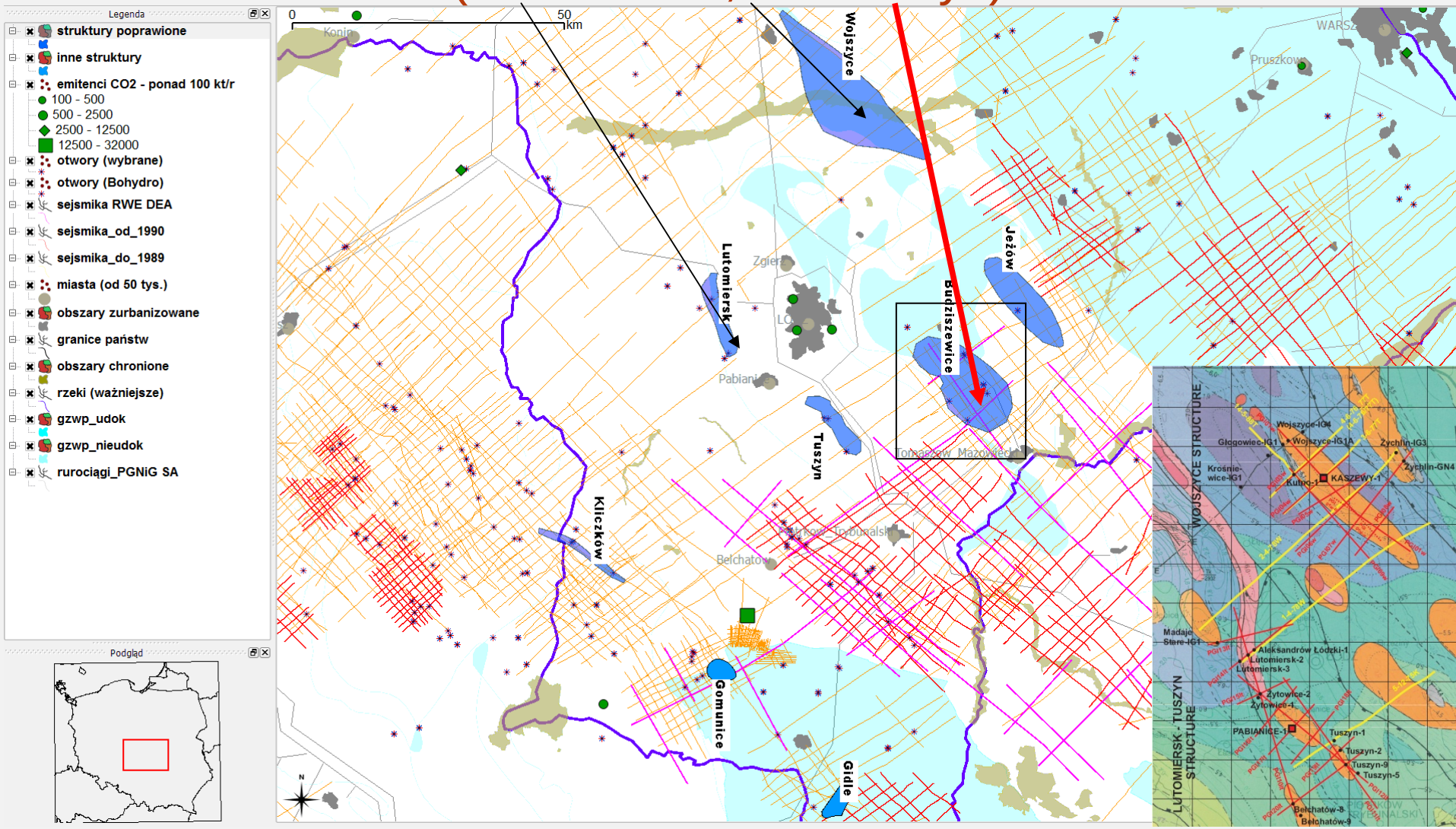
The outcome of the programme

Case studies in saline, aquifers, hydrocarbon fields and coal beds.



- Regional studies being completed;
- Case studies (4 structures in saline aquifers, one oil, one gas field, one CBM area; one saline aquifer structure being completed).
- Estimated realistic/effective storage capacity for Poland is about 10 Gt (saline aquifers 89%, hydrocarbon fields 10%, coal beds 1%); over 90% onshore

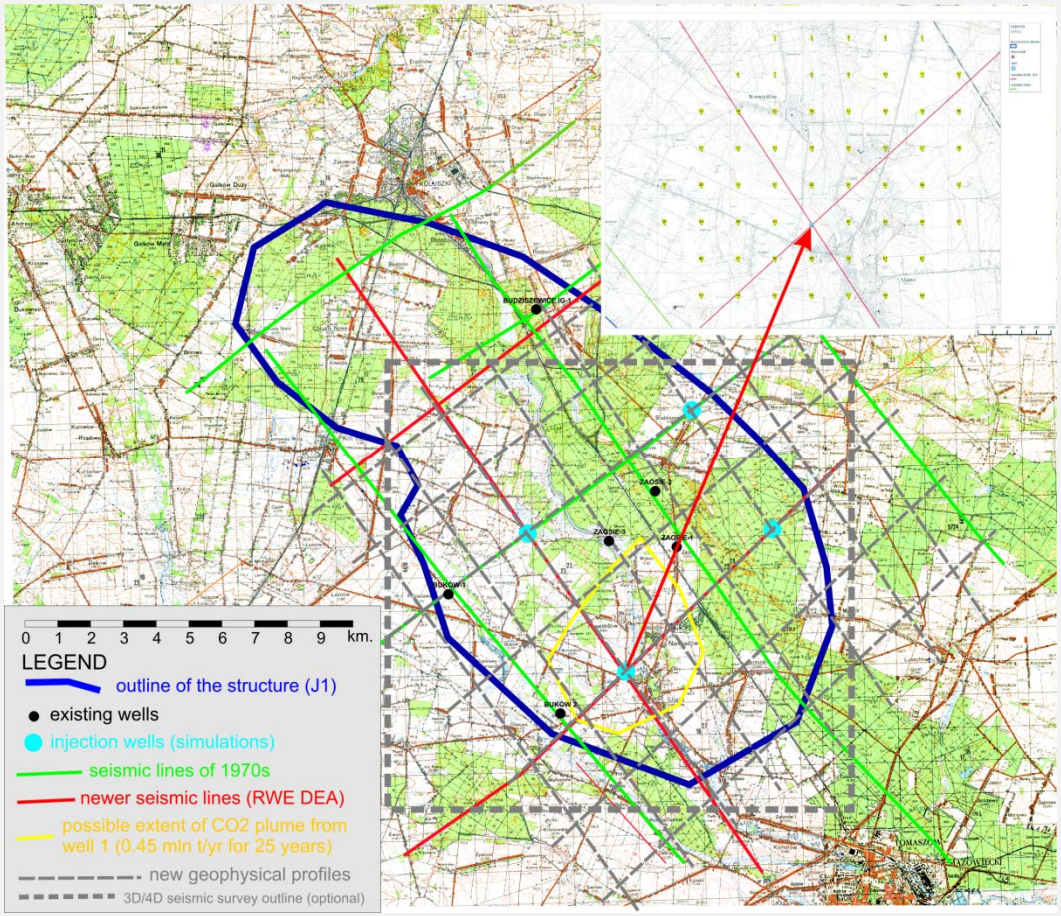
Works for area I - 1st Polish demo project (Bełchatów, 1.8 Mt/yr)

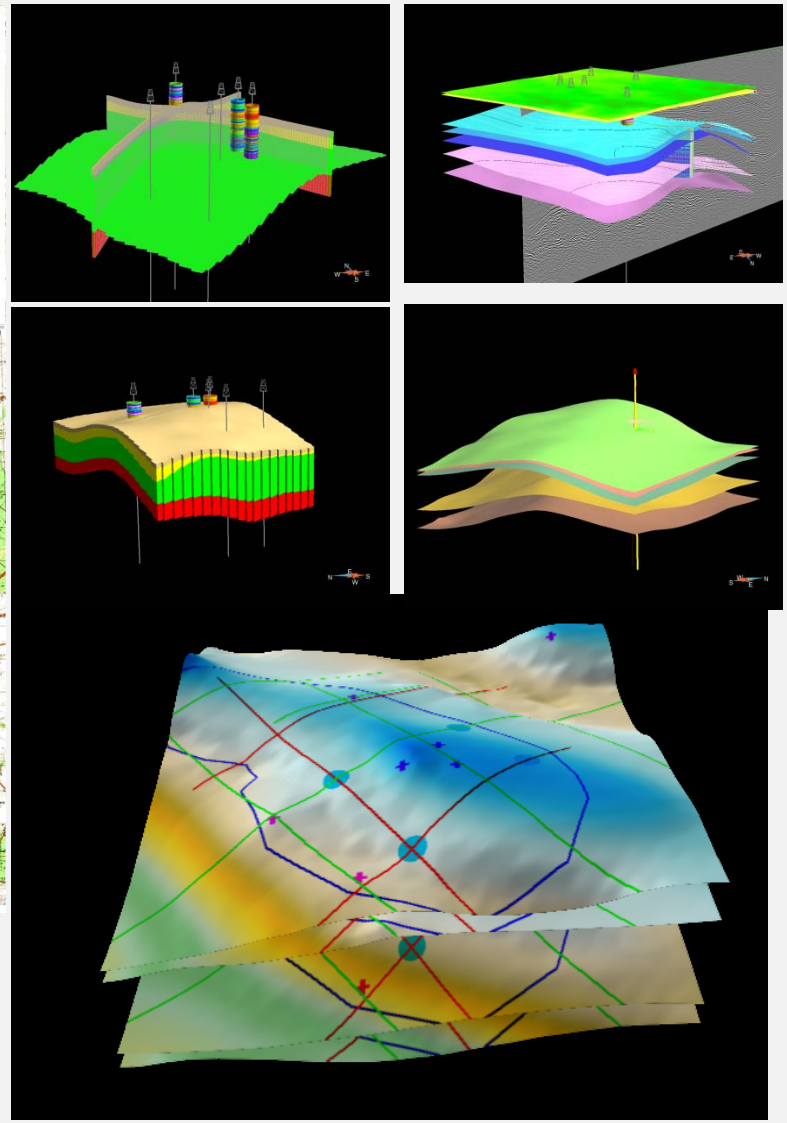


B-Z structure was selected (of sufficient data coverage, though not ideal) and two backup sites/areas were proposed to the investor (PGE).

The site model and proposed surveys

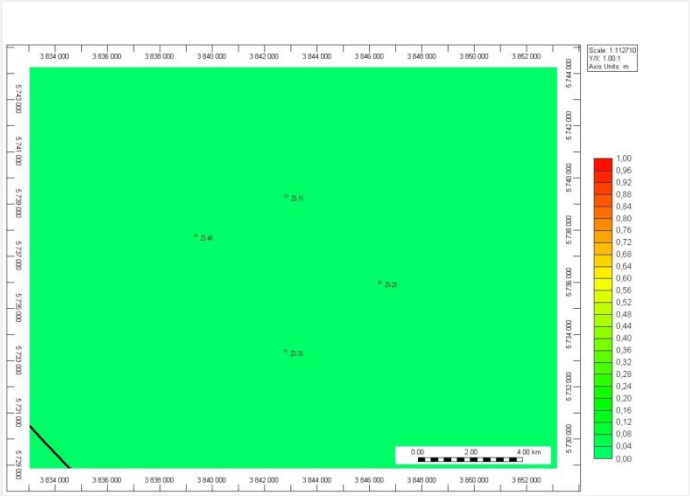
(site characterization and baseline monitoring)

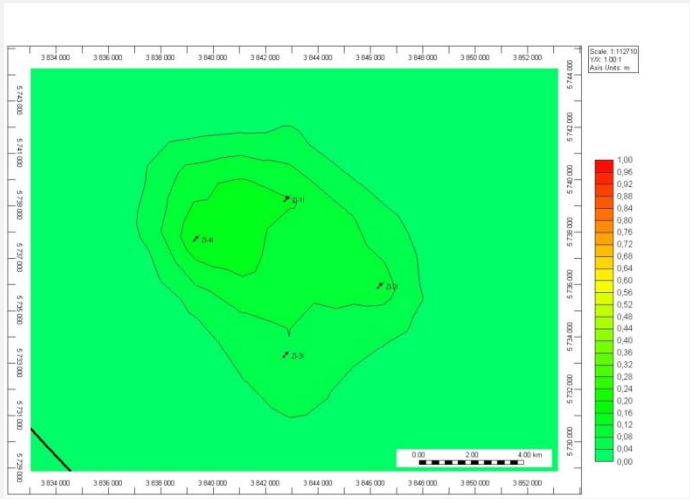




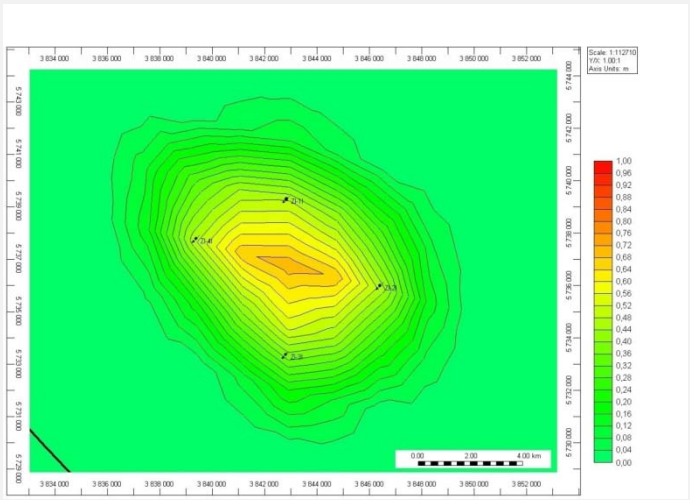
Injection simulations (AGH-UST) of J1

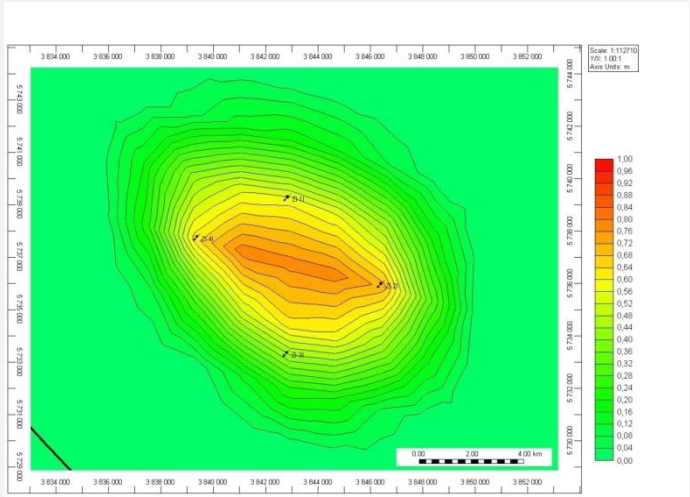
(0, 5, 20 y. of injection; 25 y. after; storage capacity 56-121 Mt)





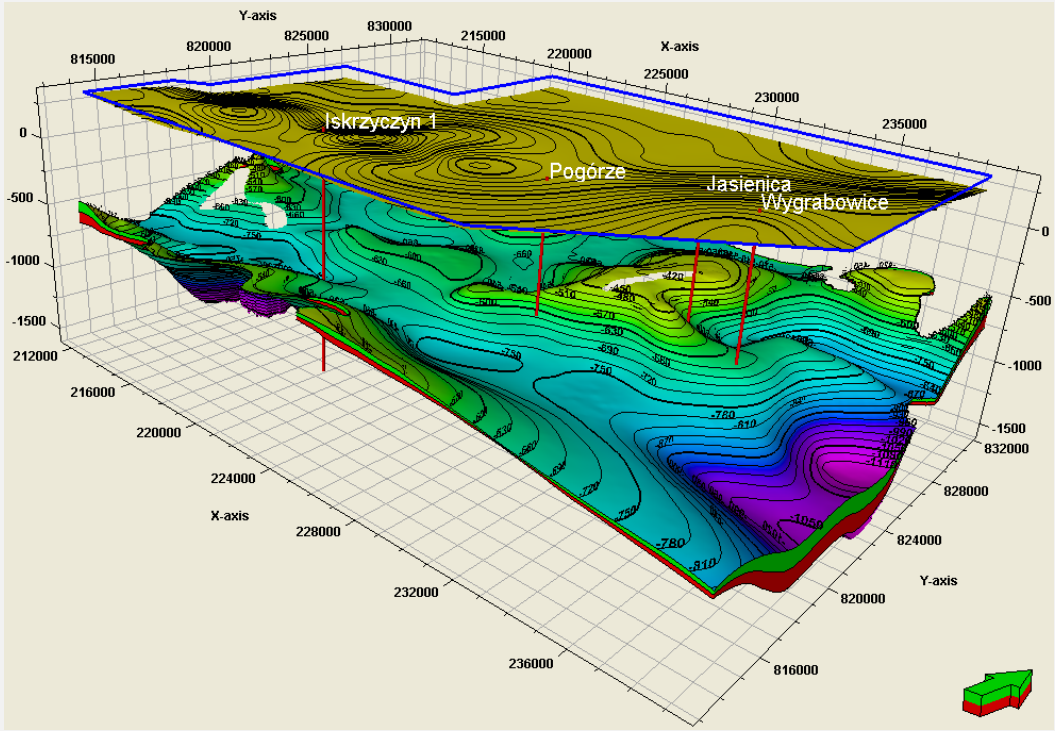
CO2 na plume area ~14 x 14 km (max.)

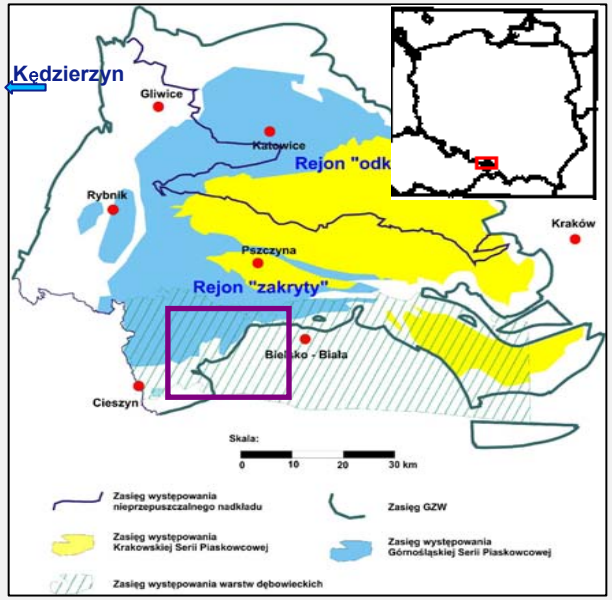




Works for area II – 2nd Polish demo project

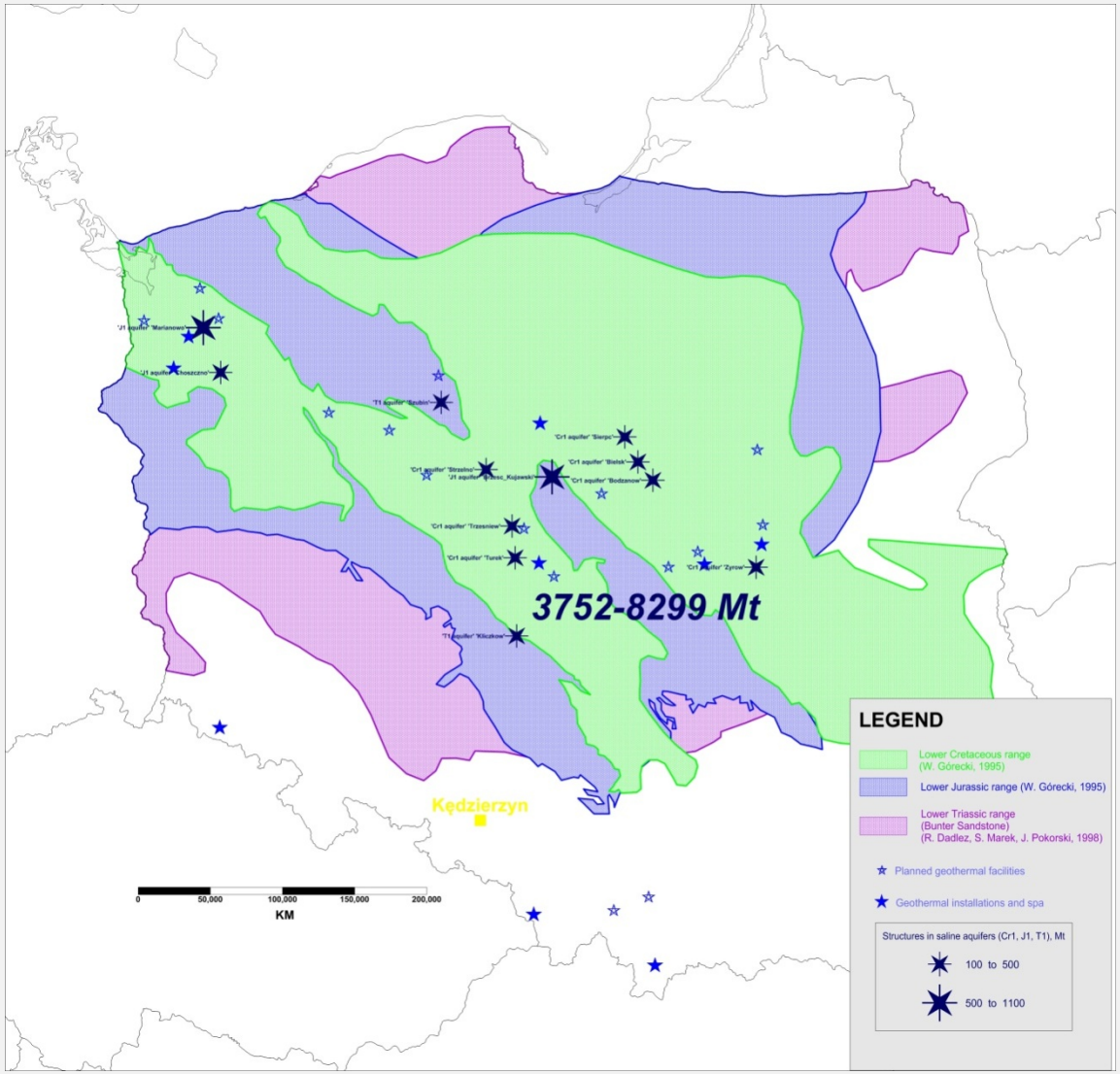
(Kędzierzyn, 1.4 Mt/yr; PGI Upp.Sil. & CMI)





- Principal aquifer – dębowieckie beds of Lower Miocene + basement (zamarskie beds, Upper Carboniferous),
- Insufficient storage capacity – 25 Mt after injection simulations (at least 35 Mt required),
- Other options considered – gas fields NW of Wrocław and saline aquifers in central Poland (200 km distance).

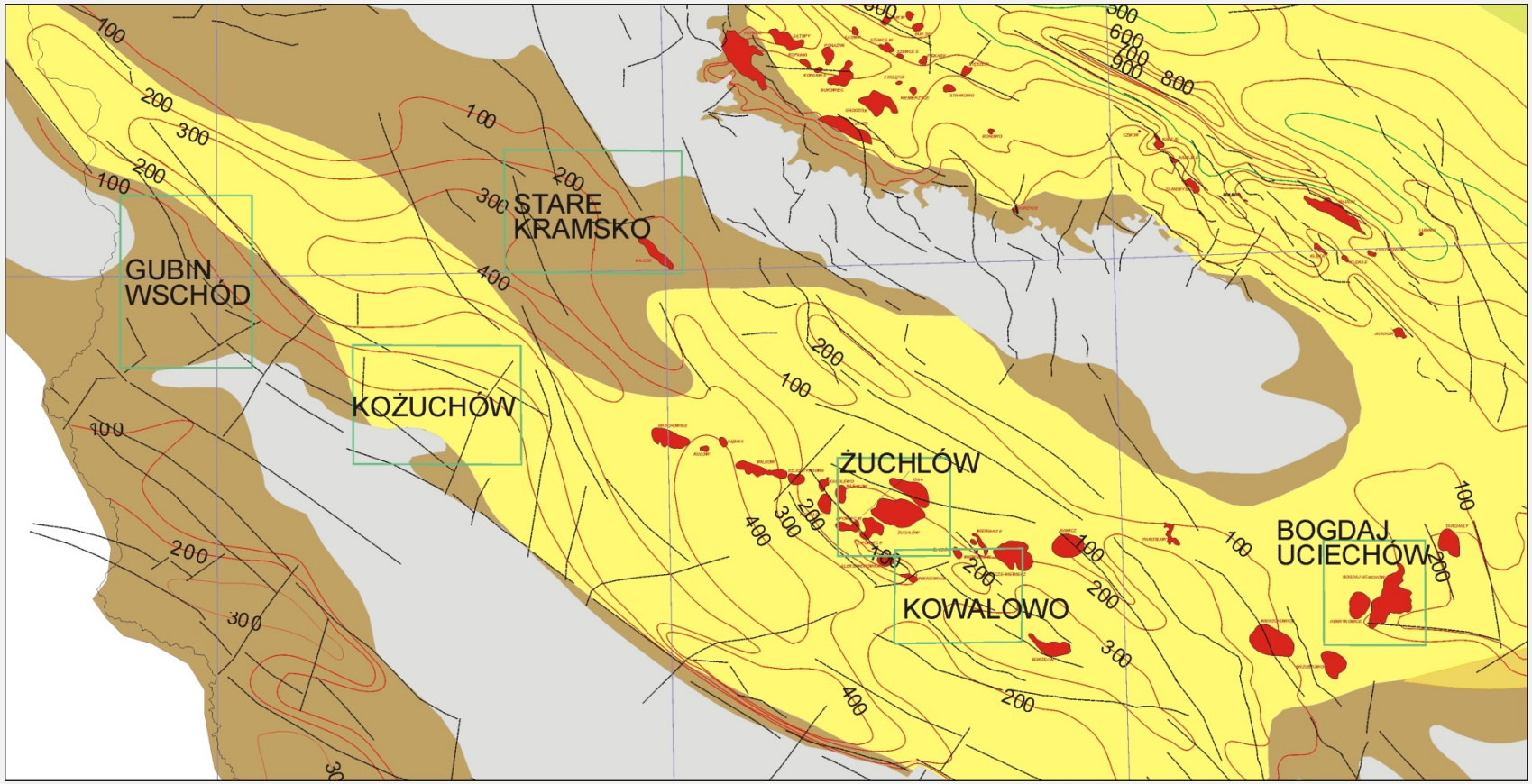
Mezozoic saline aquifers



Saline aquifers of Jurassic, Triassic and Lower Cretaceous are assumed to make the most of Poland's CO2 storage capacity.

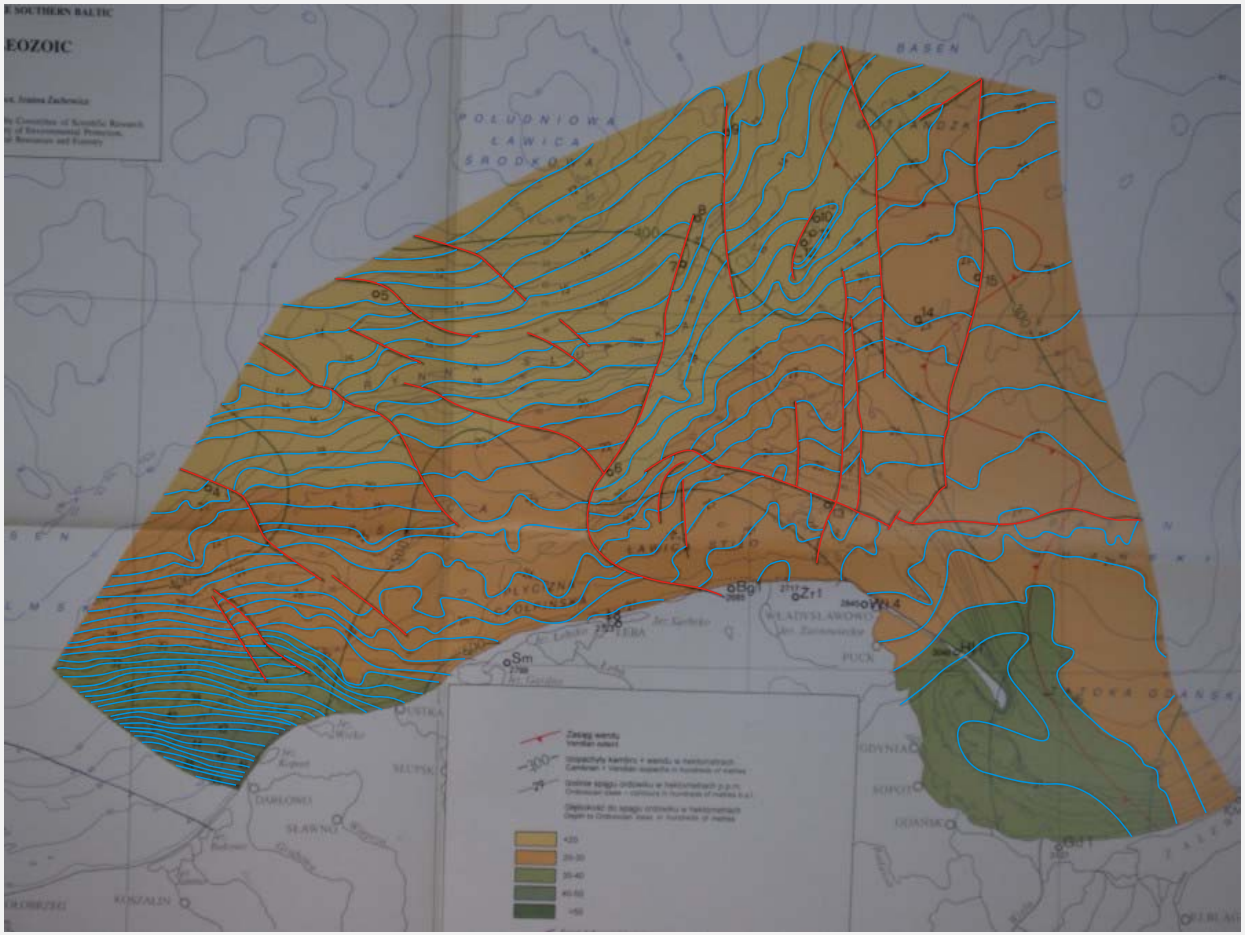
Realistic storage capacity assessed now is close to the upper limit of previous studies (**8 Gt**) because more ‚new' structures were added, compensating those rejected or downsized.

W Poland – Permian basin (area VI)



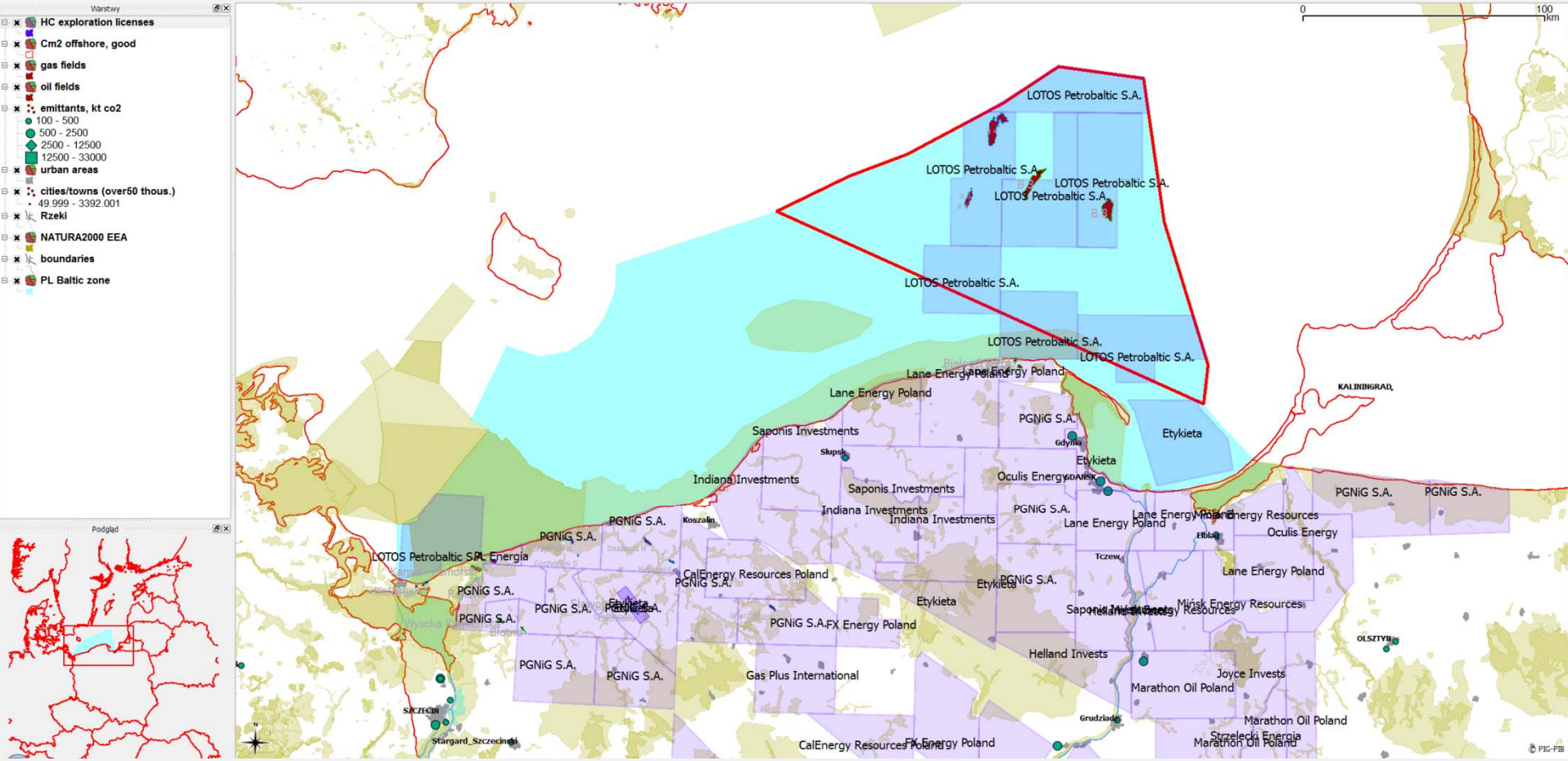
Many gas fields in Rotliegend and also oil and gas fields in Zechstein were discovered and are exploited there. Rotliegend is also a perspective saline aquifer (though of high salinity; porosity 10-20%, permeability 10-100 mD) and several structures (some of them have gas fields on top) were assessed. Storage capacity of saline structures in this aquifer is likely **1 Gt.**

The offshore area (VIII)



Map of the top of Cambrian/floor of Ordovician. The Cambrian aquifer is secondary to Jurassic onshore, but not so bad within 1,3-2 km depth range (in oil fields in eastern part porosity is up to 10% and permeability 60-100 mD) but with compartments. Realistic storage capacity – **0.4 – 0.8 Gt** (sweep efficiency 1-2%).

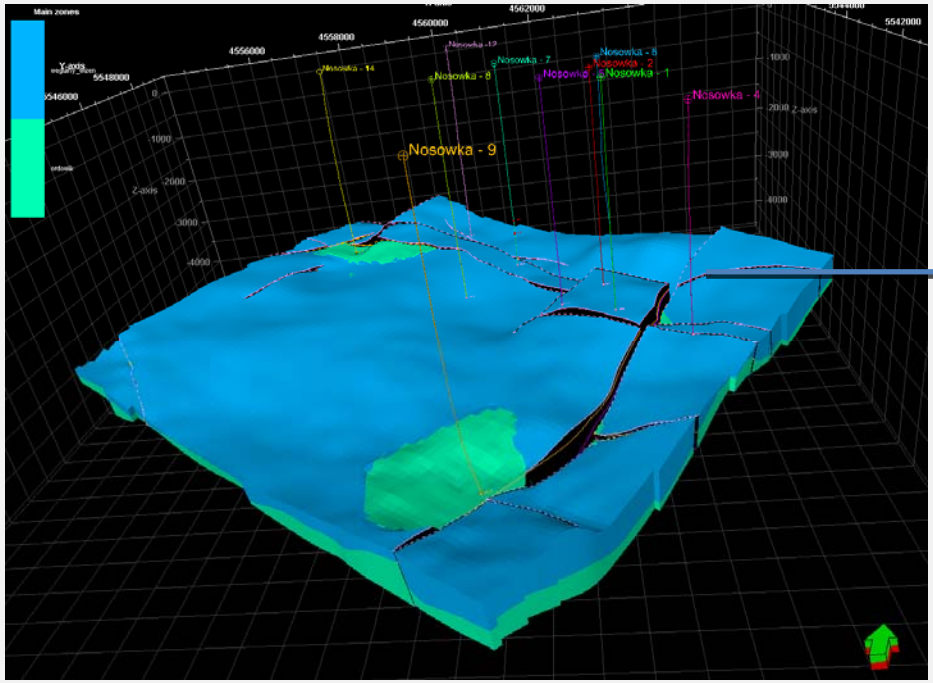
The offshore area (VIII)

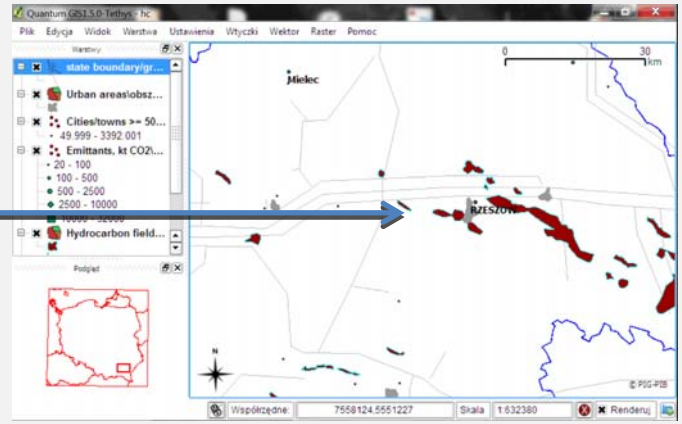


There is a great interest in exploration for unconventional hydrocarbons in Poland (even offshore). However, recent reports of PGI and USGS rather point out no real conflict with CO_2 storage. The red polygon denotes perspective area of Cambrian aquifer offshore.

Hydrocarbon fields

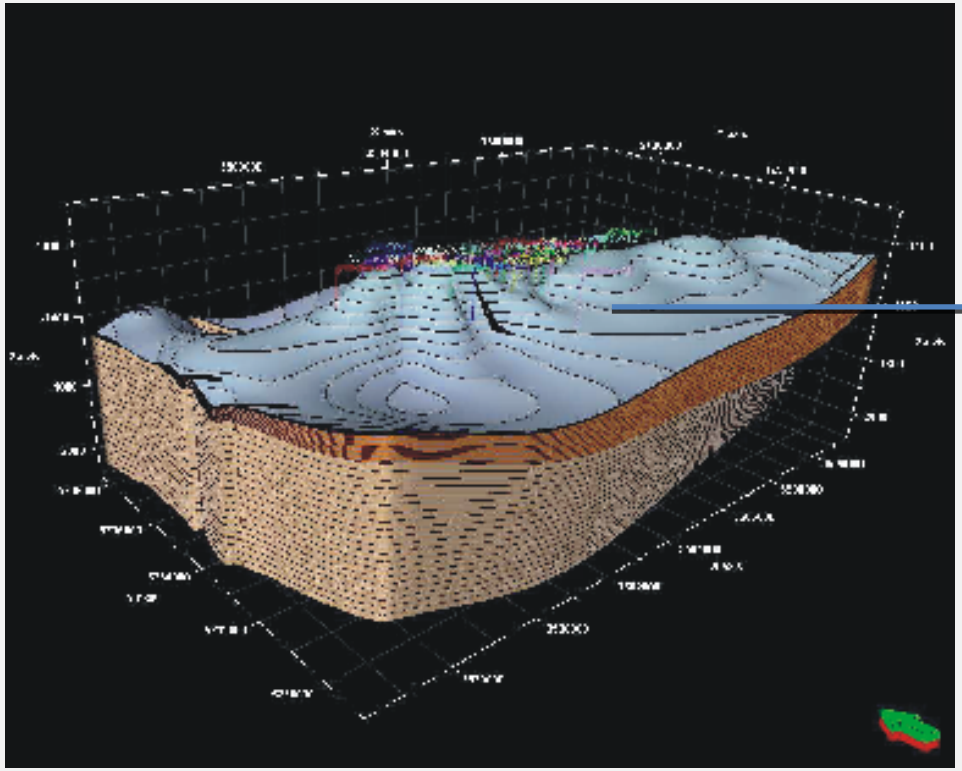
(Nosówka oil field in SE Poland; O&GI/INiG)

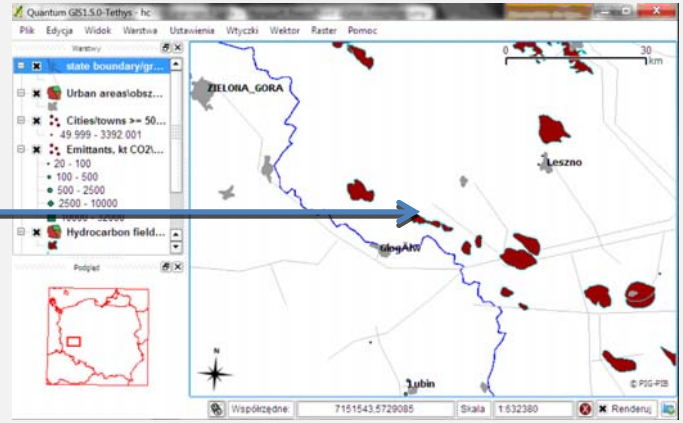




- Reservoir – C1 (Visean)
- Caprock – Lower Miocene
- OOiP 4.5 mln t (only a small part exploited); OGiP 0.585 bln m3
- UR of oil 0.9 mln t, gas 0.117 bln m3
- EOR simulated – 0,55 Mt CO2, 0,42 Mt of oil production

Hydrocarbon fields
(Wilków gas field in W Poland; AGH-UST)

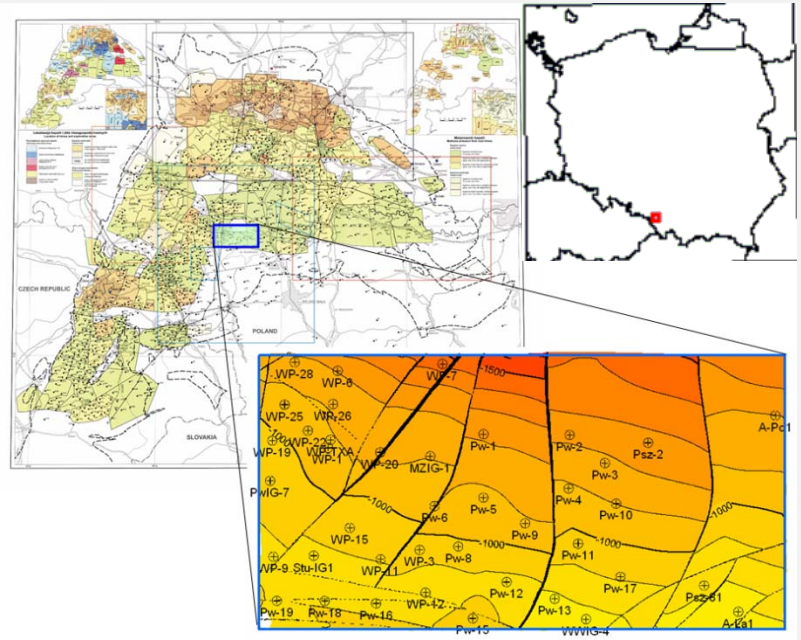


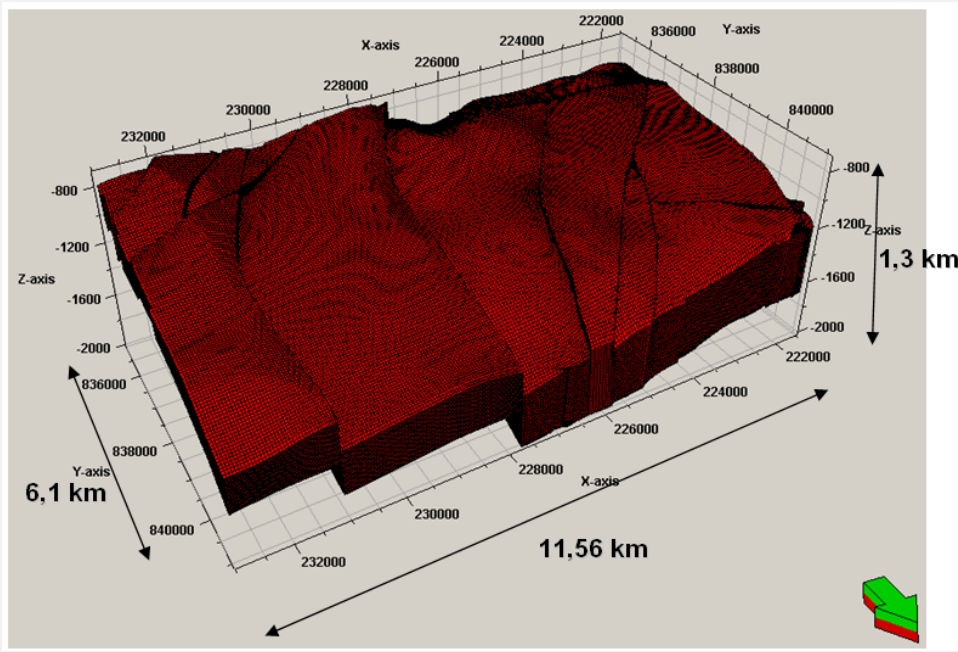


- Reservoir – P1 (Rotliegend)
- Caprock – Zechstein
- OGiP 5.5 bln m3; UR 4.4 bln m3
- Storage capacity 14-20 Mt

Coal beds

(W-P CBM field; CMI & PGI Upp. Sil.)

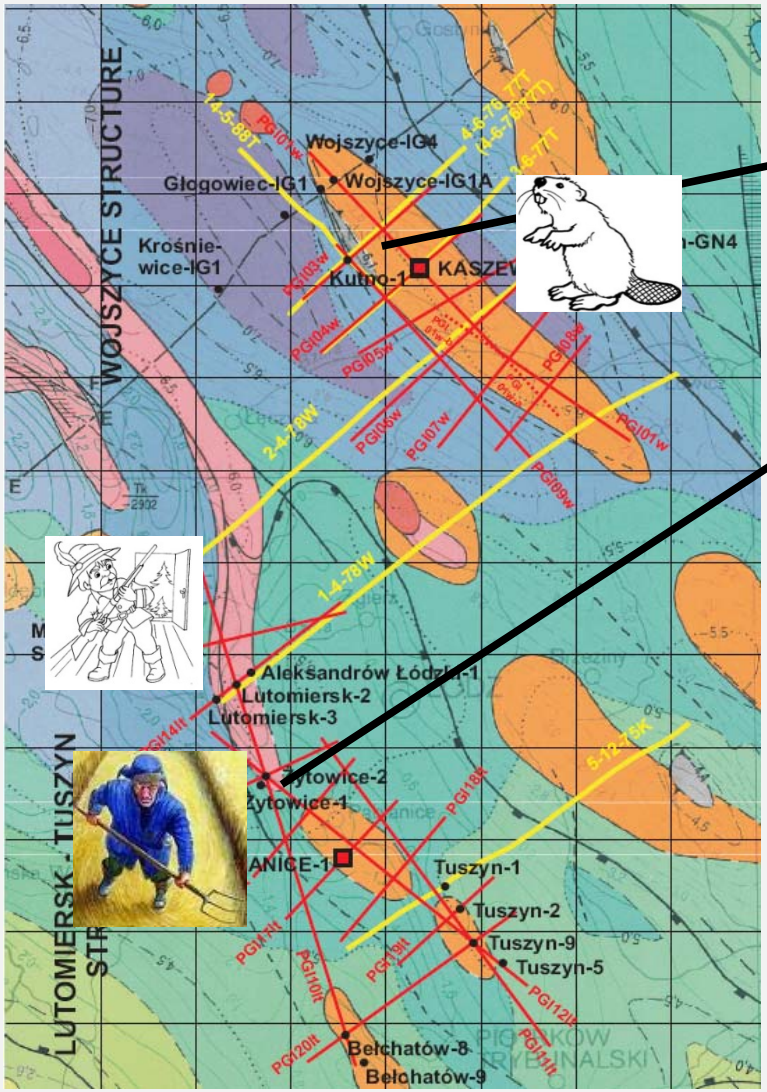


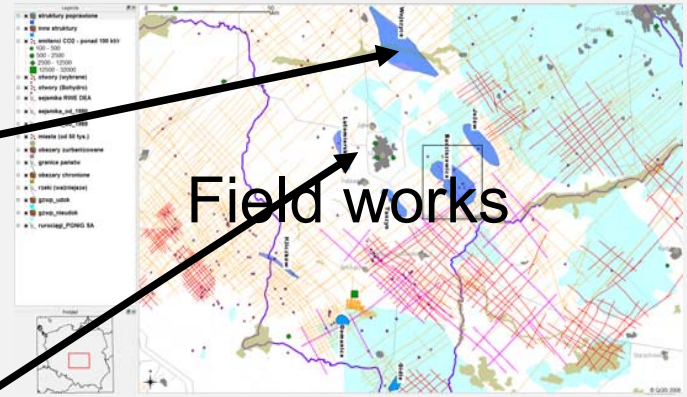


- Reservoir – 2 coal beds of thickness 1.3-5.6 and 2,5-10,5 m respectively; depth ~1-2 km
- Caprock – C3 siltstones, Miocene claystones (good)
- Methane content 2,5-10 m3/t, permeability 2-3 mD
- Realistic storage capacity 20 Mt (a few similar fields)

Field works of PGE Bełchatów

(the backup structures; not a part of the programme)



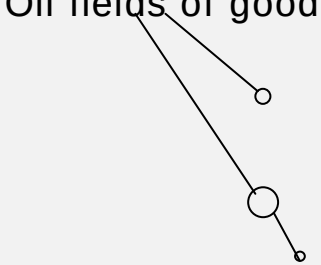


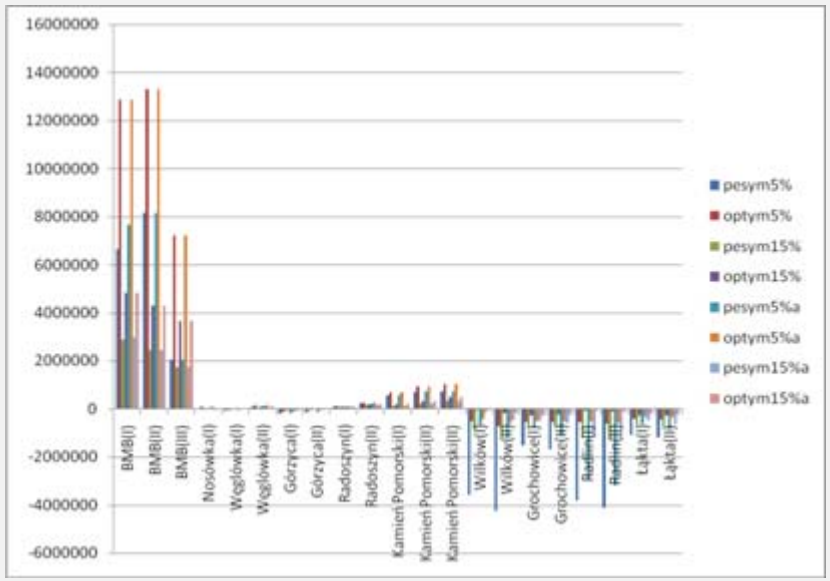
- Two sites were explored (2D seismic, 2 wells),
- In NE there is nature protected area – longer approval procedures,
- In SW public opposition encountered (an NGO), a few seismic lines relocated.
- The northernost site selects, site characterization pending

EOR/EGR economic evaluations

(project for Ministry of Environment, led by Oil and Gas Institite, PGI as a partner)

Oil fields of good outcome





NPV of oil and gas fields

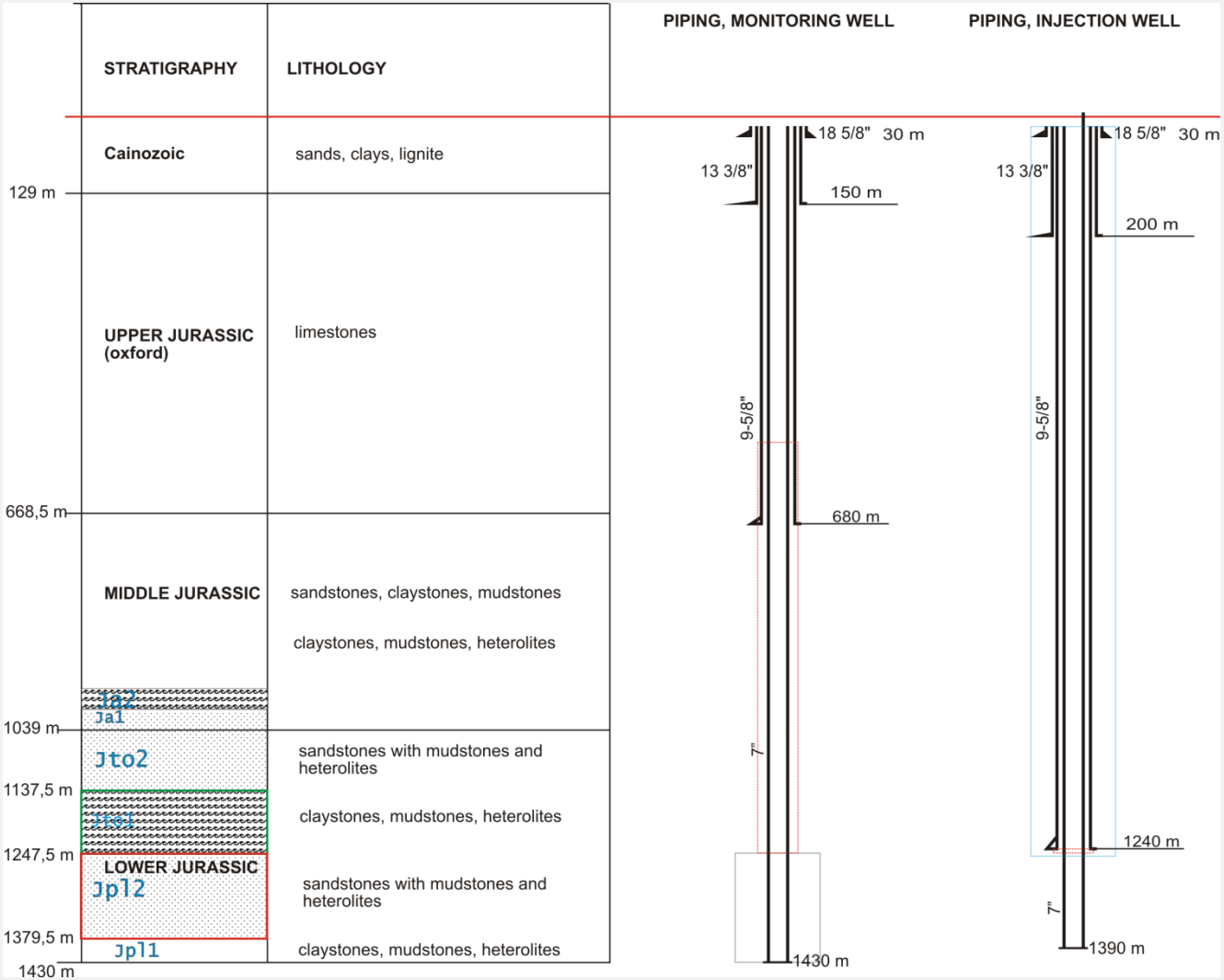
Obvious conclusions drawn – when using CO2 to enhanced hydrocarbon recovery it seems it might be a good business for relatively big oil fields, problematic in case small oil fields and no business at all in case of gas fields.

Pilot injection project
(another initiative; not a part of the programme)

Research/injection permit by Ministry of Environment (research partners: PGI-NRI & AGH-UST).

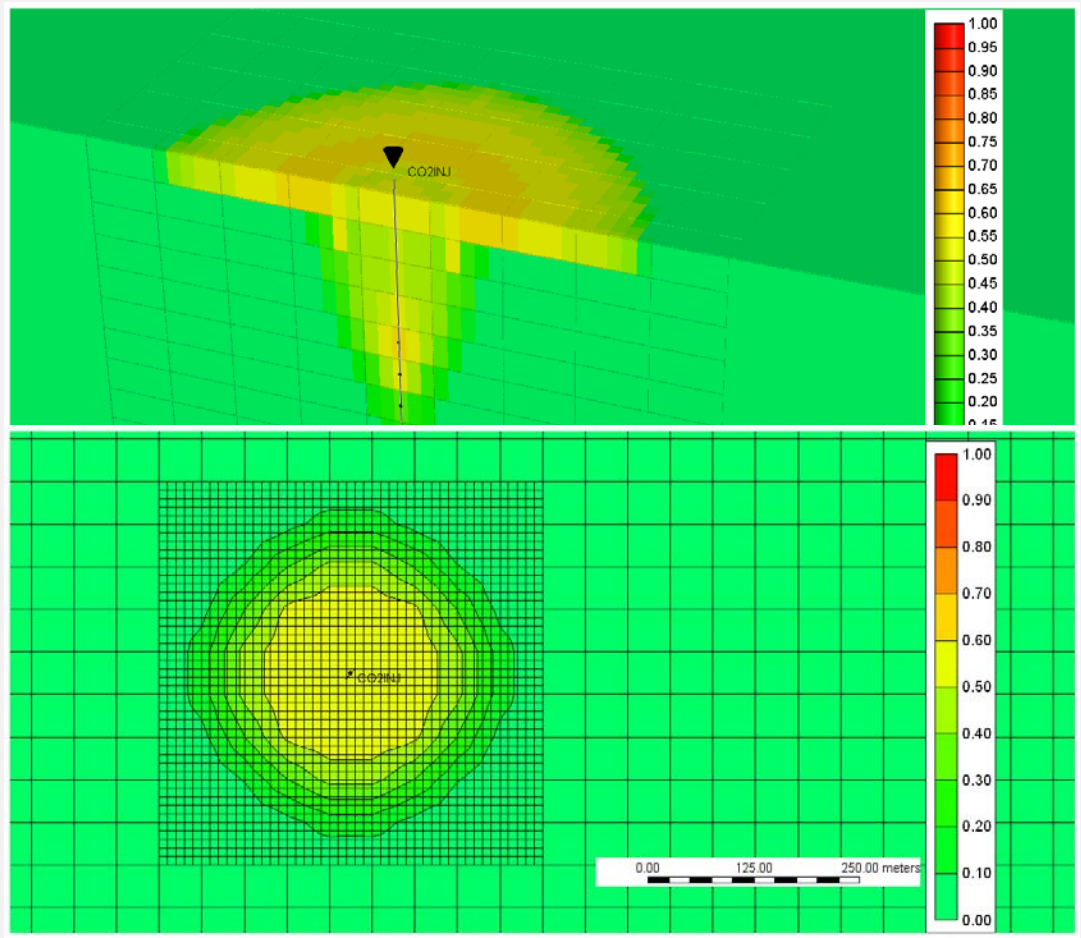
- Location in central Poland, not far from the demo site(s)
- J1 (Jpl) aquifer as for demo site(s)
- Duration – 3 years
- One injection well, one observation well (~1400 m)
- Reservoir properties – effective porosity likely 20%; permeability 200-500 mD; temperature 45 C; pressure ~12.5 MPa
- Goal – to evaluate injectivity of J1 aquifer
- Amount of CO2 injected – 27 kt within 2 years
- Project status – contract ready for signing, land purchased, research permit granted by Ministry of Environment, mining plan ready

Pilot injection project
profile and design of the wells



Pilot injection project

injection simulations (AGH-UST) – the CO2 plume range practically stabilizes after two year injection stops (~200 m radius)



Conclusions

Studies of the National Programme and other projects can provide the following conclusions:

- CO2 storage capacity of Poland is sufficient in terms of realistic capacity (equals 50-70 years of ETS emissions); the matched (‚exploitable') capacity is being explored;
- The most of storage potential is located onshore (>90%), a small part offshore - mostly in E Baltic area;
- Hydrocarbon fields and (especially) coal beds are of rather limited storage capacity, same in case of EHR potential.
- Saline aquifers make about 89% of total storage capacity, of them the best are Mezozoic formations (especially J1, to lesser extent T3&T1; Cr3 is not always safe) then regional aquifers of Rotliegend, Cambrian and Upper Carboniferous follow.
- Several case studies prove feasibility and safety of CO2 storage.

Thank you for your attention:

www.pgi.gov.pl