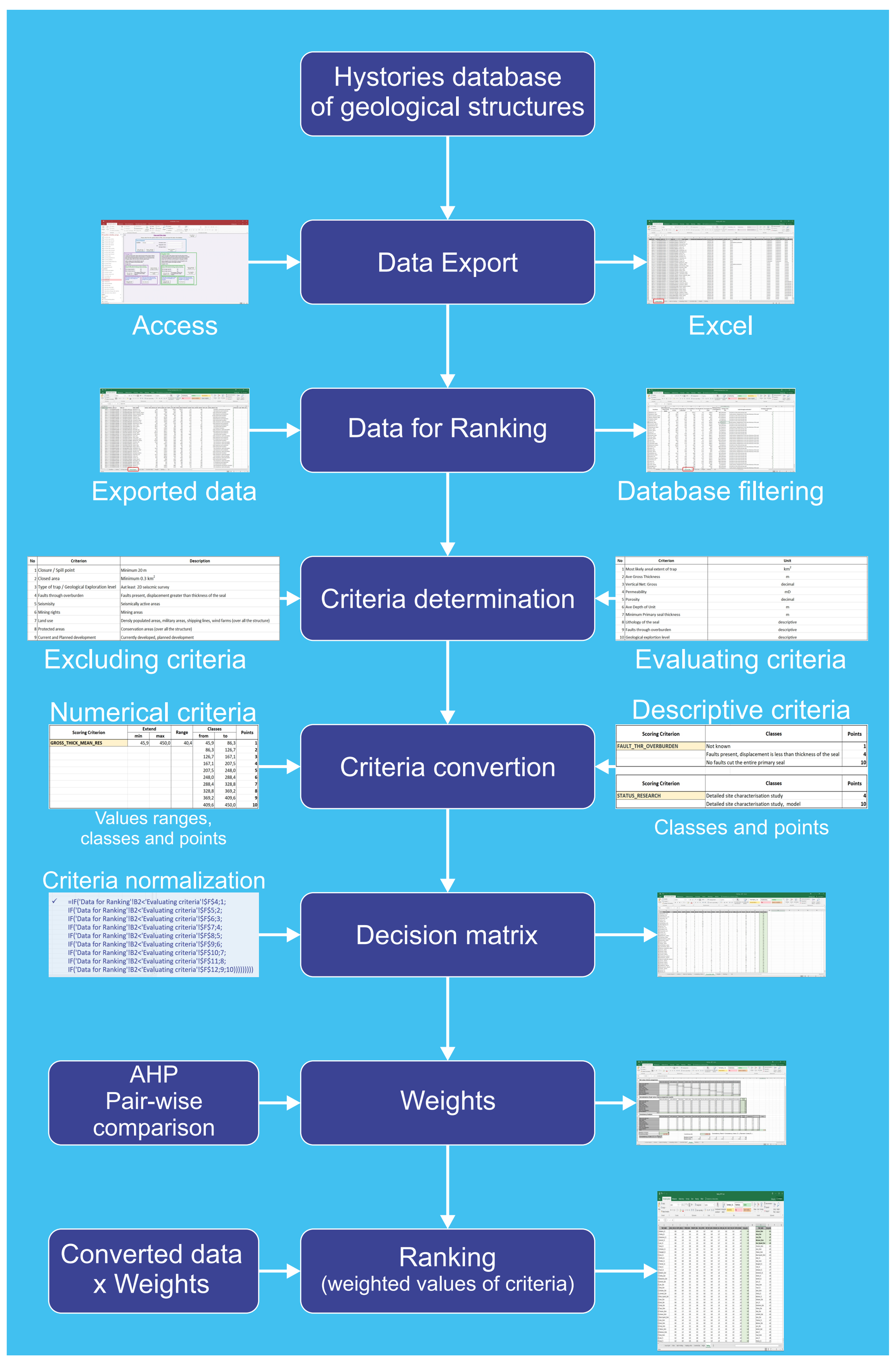
Ranking of geological structures in deep aquifers for UHS

Mineral and Energy Economy Research Institute
Polish Academy of Sciences

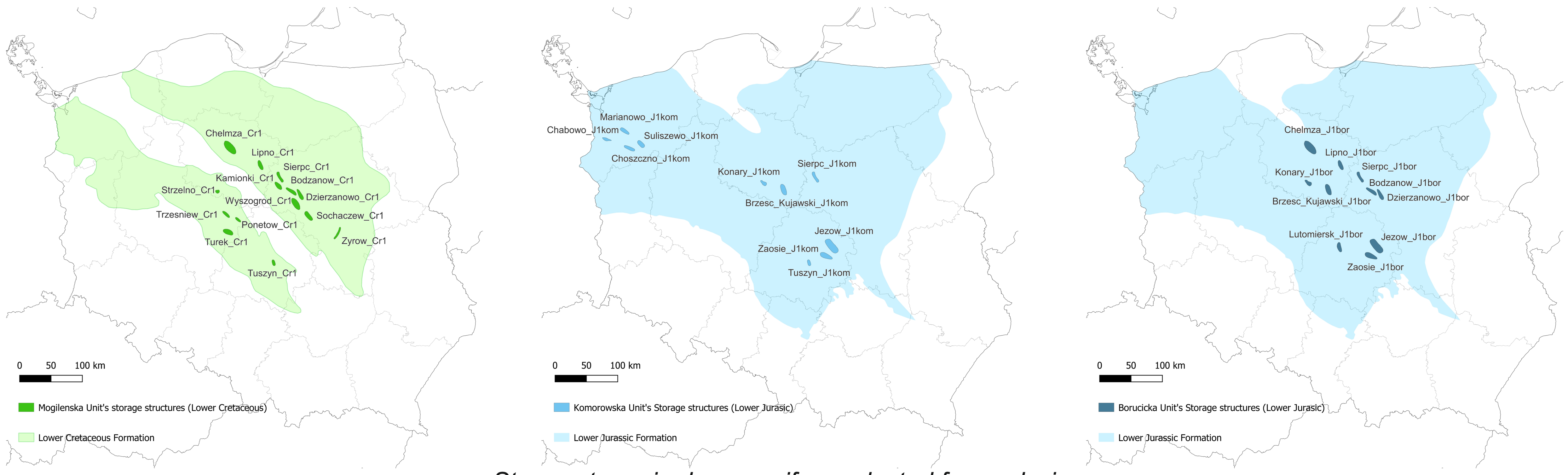
Leszek Lankof, Radoslaw Tarkowski, and Katarzyna Luboń

Context. The use of intermittent renewable energy sources for hydrogen production will require the storage of energy surpluses in periods of increased supply to balance shortages in periods of increased demand. The geological structures in deep aquifers provide the possibility of large-scale underground hydrogen storage. The research aimed to develop the ranking of storage traps in deep aquifers in the Polish Lowland, considering geological and reservoir criteria.



The workflow of the ranking developing

Method. The method applied in the research included the following phases:
1) data export from the Hystories database to choose storage traps in deep aquifers in the Polish Lowlands,
2) determination of exclusion criteria,
3) determination of geological and reservoir criteria for storage traps evaluation,
4) evaluation criteria conversion and normalization,
5) determination of decision matrix,
6) determining the weights of individual criteria,
7) calculations to determine the ranking of storage traps.



Storage traps in deep aquifers selected for analysis

1. Data for ranking. Data on the parameters of analyzed storage traps come from the Hystories database developed based on fundamental data on porous geological structures collected from previous projects, i.e., Energy Storage Mapping and Planning and CO_2 Storage Potential in Europe. The Hystories databases have been significantly updated and expanded by adding newly available data from reports, scientific papers, and other reputable sources. The file exported from the Hystories database included 38 storage traps with all data describing their parameters.

EXCLUSION CRITERIA

Criterion	Condition
Closure/spill point	minimum value 20 m
The surface of the storage trap	minimum value 0.3 km^2
Seismic surveys within the trap	minimum two 2D seismic profiles within the structure
Faults	present faults cutting caprock with a throw greater than the caprock thickness
Seismic areas	occurrence of seismically active areas
Underground restrictions	presence of mining areas within the structure, drinking water reservoirs
Spatial planning	densely populated areas, industrial areas, military areas, transport routes, wind farms
Protected areas	occurrence of national parks and Natura 2000 sites
Mining development	geological structures planned for development

2. Exclusion criteria. Nine exclusion criteria were determined to select storage traps for ranking. The criteria aimed to exclude poorly explored, small traps occurring at great depths, in seismically active areas, and densely populated, intensively developed, and protected areas.

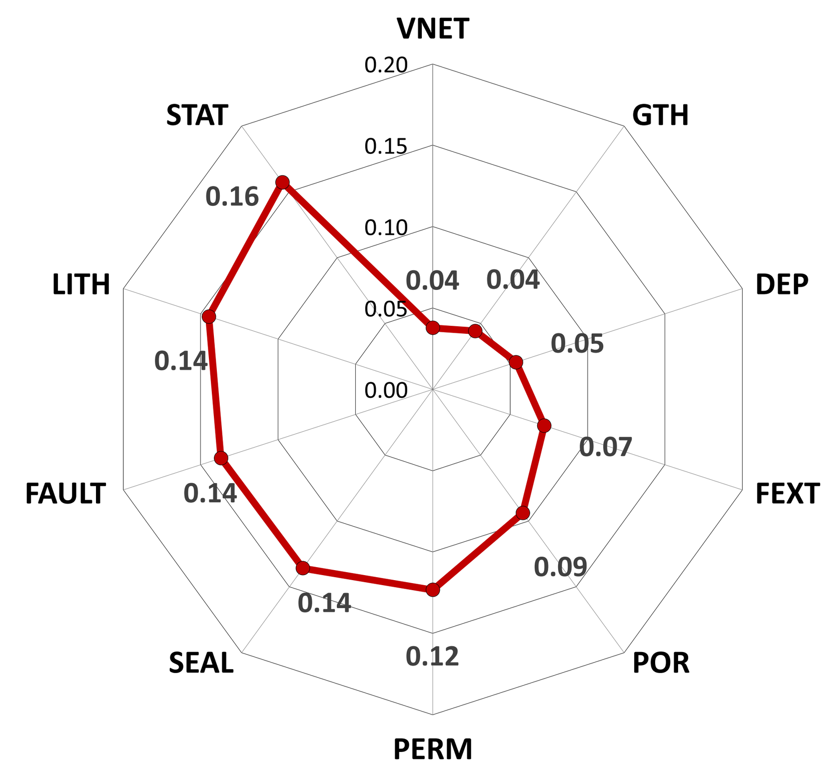
EVALUATION CRITERIA

Criterion	Symbol	Description/value
The average thickness [m]	GTH	The value of the criterion is directly proportional to the structure's thickness.
The average depth [m]	DEP	1100 m is assumed as the optimum depth. Below and above, the number of points decreases proportionally to the change in depth.
Permeability [mD]	PERM	The criterion value is directly proportional to the permeability of the reservoir layer.
Porosity [-]	POR	The criterion value is directly proportional to the porosity of the reservoir layer.
Vertical net gross [-]	VNET	The criterion value is directly proportional to the share of sandstone layers within the structure.
Areal extent [km^2]	FEXT	The criterion value is directly proportional to the structure's surface.
Seal thickness [m]	SEAL	The criterion value is directly proportional to the thickness of the caprock layer.
The lithology of the seal	LITH	Depending on the permeability of individual rocks of sealing overburden, numerical values of 1-10 are assigned from the most to the least permeable.
Faults through overburden	FAULT	Structures where faults do not occur, get the highest number of points. If faults are found, the structure scores fewer points.
Exploration status	STAT	Better explored and characterized structures score a higher number of points in the range of 1-10.

3. Evaluation criteria. Nine criteria were chosen to evaluate storage traps' suitability for UHS, including thickness, depth, permeability, porosity, field extent, thickness and lithology of caprock, faults, and exploration status.

4. Evaluation criteria conversion and normalization. Since the evaluation criteria values are expressed in different units or are dimensionless, they have been normalized for comparison.

5. Decision matrix. Considering the evaluation criteria, a decision matrix was created, including selected traps listed in rows and evaluation criteria set out in subsequent columns.

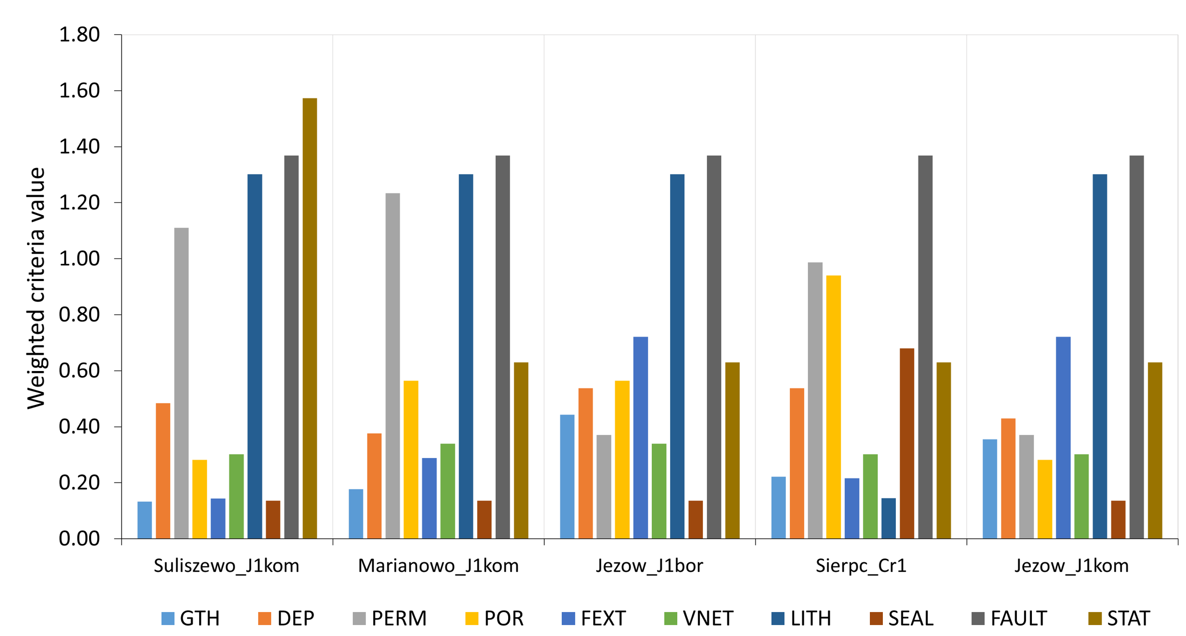


Criteria weights determined by the pairwise comparison method

6. Determination of weights of evaluation criteria. The AHP method based on comparing criteria in pairs using Saaty's scale was used to determine the weights of individual criteria. The most important criterion according to the adopted method is the status of exploration of the structure (0.16) and criteria directly related to the storage trap's tightness, i.e., the sealing layer's lithology and thickness and the presence of faults (0.14). The slight difference between the values of most criteria weights indicates their important role in creating the ranking of storage traps.

STORAGE TRAP	GTH	DEP	PERM	POR	VNET	FEXT	SEAL	LITH	FAULT	STAT	SCORE
WEIGHT	0.04	0.05	0.12	0.09	0.04	0.07	0.14	0.14	0.14	0.16	
Suliszewo_J1kom	0.13	0.48	1.11	0.28	0.14	0.30	1.30	0.14	1.37	1.57	6.84
Marianowo_J1kom	0.18	0.38	1.23	0.56	0.29	0.34	1.30	0.14	1.37	0.63	6.42
Jezow_J1bor	0.44	0.54	0.37	0.56	0.72	0.34	1.30	0.14	1.37	0.63	6.41
Sierpc_Cr1	0.22	0.54	0.99	0.94	0.22	0.30	0.14	0.68	1.37	0.63	6.03
Jezow_J1kom	0.35	0.43	0.37	0.28	0.72	0.30	1.30	0.14	1.37	0.63	5.90
Wyszogrod_Cr1	0.27	0.54	0.49	0.94	0.43	0.30	0.14	0.68	1.37	0.63	5.79
Sochaczew_Cr1	0.22	0.48	0.49	0.94	0.50	0.30	0.14	0.68	1.37	0.63	5.77
Brzesc_Kujawski_J1bor	0.40	0.54	0.25	0.28	0.36	0.30	1.30	0.14	1.37	0.63	5.56
Turek_Cr1	0.13	0.54	0.37	0.75	0.29	0.34	0.14	0.95	1.37	0.63	5.51
Dzierzanowo_Cr1	0.22	0.48	0.99	0.56	0.22	0.30	0.14	0.54	1.37	0.63	5.46
Brest Kujawski_J1kom	0.40	0.43	0.25	0.28	0.36	0.30	1.30	0.14	1.37	0.63	5.46
Chabowo_J1kom	0.18	0.43	0.37	0.47	0.29	0.26	1.30	0.14	1.37	0.63	5.44
Konary_J1bor	0.27	0.54	0.37	0.09	0.22	0.30	1.30	0.14	0.55	1.57	5.34
Choszczno_J1kom	0.09	0.54	0.37	0.28	0.29	0.30	1.30	0.14	1.37	0.63	5.30
Tuszyn_Cr1	0.13	0.32	0.99	0.75	0.14	0.30	0.14	0.41	1.37	0.63	5.19
Trzesniew_Cr1	0.18	0.16	0.12	0.56	0.14	0.30	0.14	1.36	1.37	0.63	4.97
Zyrow_Cr1	0.04	0.54	0.99	0.94	0.07	0.34	0.14	0.68	0.55	0.63	4.92
Strzelno_Cr1	0.22	0.54	0.37	0.56	0.07	0.30	0.14	0.68	1.37	0.63	4.89
Bodzanow_Cr1	0.27	0.54	0.86	0.94	0.29	0.30	0.14	0.68	0.14	0.63	4.79
Kamionki_Cr1	0.27	0.48	0.62	0.56	0.22	0.30	0.14	0.14	1.37	0.63	4.73

7. Ranking calculations.
Using the calculation spreadsheet, the successive values of the decision matrix were multiplied by the criteria weights to determine their weighted value. The sum of the weighted criteria values for individual geological structures shows the suitability of individual structures for UHS. Arranging structures in descending order of the sum of weighted values of individual criteria allowed for determining the final ranking of the analyzed storage traps. The top-ranked storage traps are Suliszewo_J1kom, Marianowo_J1kom, Jezow_J1bor, Sierpc_Cr1, and Jezow_J1kom. Their high position in the ranking is due to the high values of two or three criteria with relatively high weights.



Distribution of the evaluation criteria weighted values for the top-ranked storage traps

Conclusions. Based on the hierarchical analysis of decision problems, the research allowed for the ranking of storage traps in deep aquifers of the Polish Lowlands. The weights of individual criteria play a decisive role in the ranking since the AHP method is based on the subjective assessment of experts. The developed ranking method considers the possibility of modifying the number of criteria and their weights, e.g., by technical, economic, and environmental aspects. The method may support the decision-making process in selecting geological structures in deep aquifers to cover the demand for large-scale UHS.

2nd European Underground Energy Storage Workshop (Paris, 23-24 May 2023)