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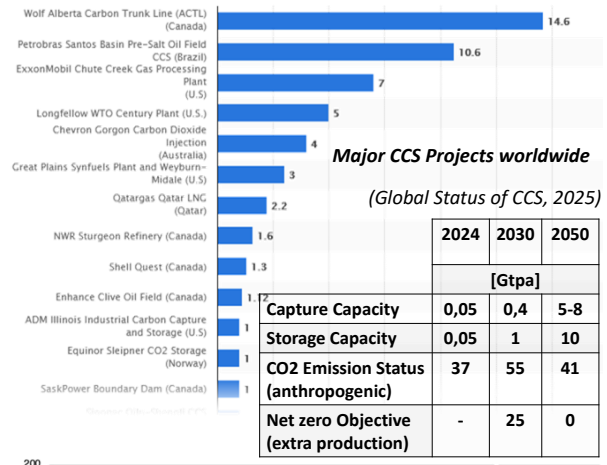
Carbon Capture & Storage (CCS) Data Analytics

i) The Problem

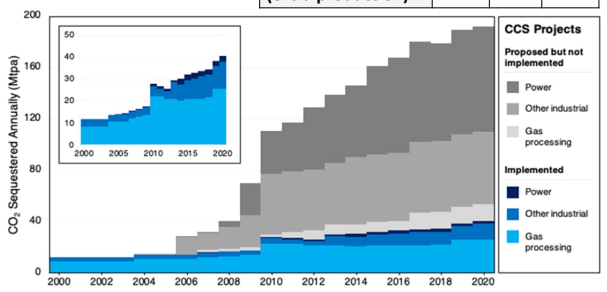
CCS Capacity : reality vs necessity



Major CCS Projects worldwide

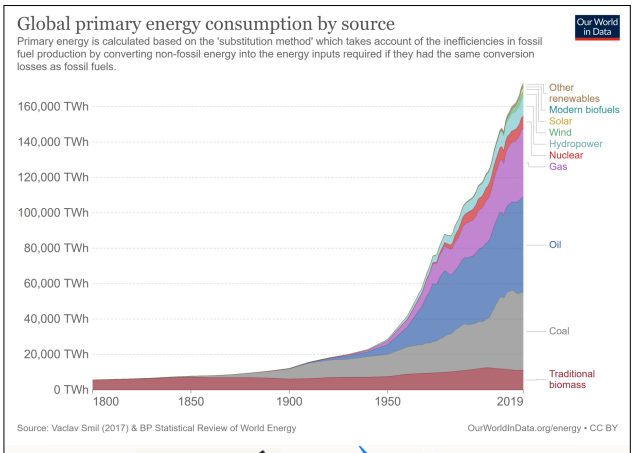
(Global Status of CCS, 2025)

	2024	2030	2050
	[Gtpa]		
Capture Capacity	0,05	0,4	5-8
Storage Capacity	0,05	1	10
CO2 Emission Status (anthropogenic)	37	55	41
Net zero Objective (extra production)	-	25	0



Global proposed vs. implemented annual CO2 sequestration, and global implemented annual CO2 sequestration by type (inset). Most end in failure.

Hydrocarbons as primary source & kings of Energy



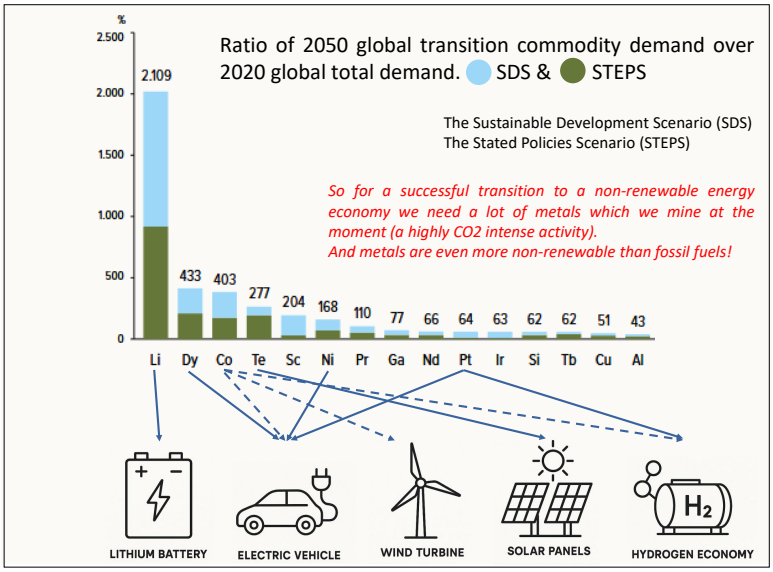
1,6 €/L
0,4 €/kWh
10 kWh of Heat
2-4 kWh Mechanical energy

The energy that **a volume of 1000 m^3 air moving with the speed of 10 $^m/_s$** will produce:

kinetic energy × Performance coefficient × Wind Load factor × Electric efficiency

$7\ MJ \times 0,3 \times 0,25 \times 0,85 \approx 1,23\ Wh$

Equal to 0,4 ml of gasoline



Ratio of 2050 global transition commodity demand over 2020 global total demand. SDS & STEPS

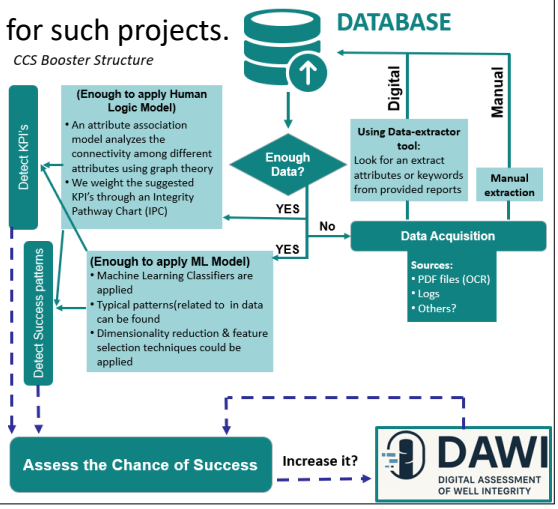
The Sustainable Development Scenario (SDS)
The Stated Policies Scenario (STEPS)

So for a successful transition to a non-renewable energy economy we need a lot of metals which we mine at the moment (a highly CO2 intense activity).
And metals are even more non-renewable than fossil fuels!

ii) Project Description

This work aims to combine and extend all CCS datasheets into one CCS Database and then through ***two different analytical*** and ***data-driven approaches***, recognizes the most important attributes that are relevant in a successful implementation of a CCS Project.

A bot is generated to use this insight to predict the ***chance of success/risk of failure*** of an implementing-CCS-project and different technologies under **DAWI** (Digital Assessment of Well Integrity program) are being developed to simultaneously reduce the time and improve the accuracy and effectiveness for initial assessment and data acquisition for such projects.

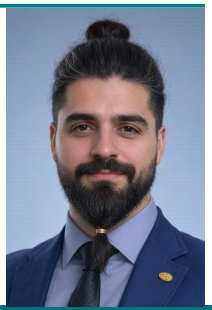


dge DEPARTMENT GEO ENERGY

MSc.Dipl.Ing.-
Arash Nasiri
Drilling & Completion
Department Geoenergy
Arash.nasiri@unileoben.ac.at

Focus:

- **CCS**
- **Digitalization**
- **Well Integrity**
- **Energy Diversification**
- **Mineral topological Analysis**

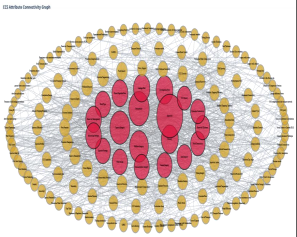


CCS Data Analytics

iii) Methodology

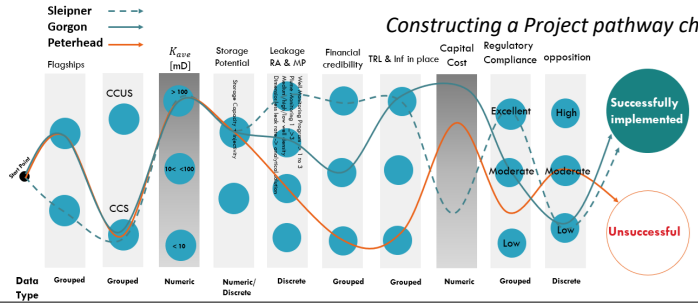
Conceptual Approach

This approach is based on human insight, where the connectivity and relativeness of different attributes define its importance. Number of connections shows the impotence degree of an attribute.



Then through constructing a project pathway chart, the most important variables are weighted and key ones will be recognized. Application of graph theory is useful here. Nodes are representing contributing attributes.

Constructing a Project pathway chart



Related Concepts for Data driven approach

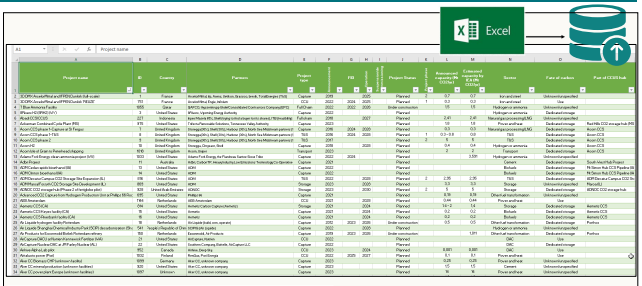
Data analytics is the process of interpreting data to find trends and patterns. It must be mentioned that to do so, we use a set of tools including data mining and data visualization.

A **Data-Driven model for CCS** involves using data-centric approaches, like machine learning, statistical analysis etc to find patterns. And we are particularly interested on the pattern of successful or unsuccessful implementation of a CCS project.

Data Driven Approach- Conducting Approximation

This approach is based on extracting insight from the data after visualization and analysis.

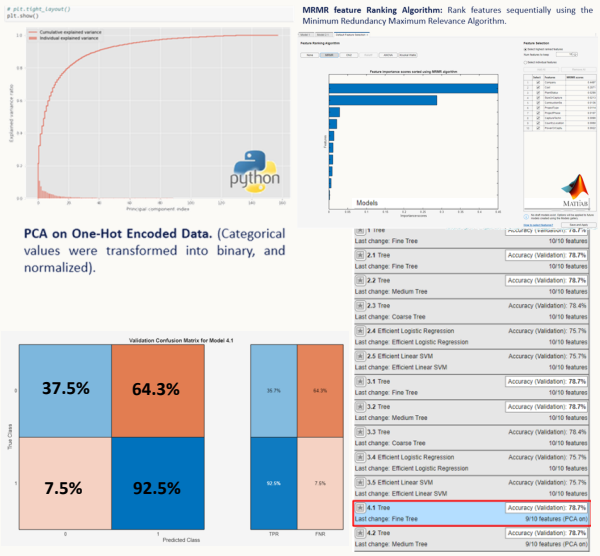
- This was a target-oriented problem.
- An imbalanced categorial data with 12 features with our target variable to be success/failure of a CCS project.
- The initial database was relatively raw hence:
  - ➔Pre-processing(organizing the data, removing NaN, outlier removal) resulted into a 403 x 15 matrix with 12th features.
  - ➔One-Hot Encoding
  - ➔PCA was done (a Dimension-reduction technique which sacrifices the accuracy as it is a linear transformation of the space)
  - ➔ as a RoT, we need 20 features per instance (project)



Classification Model	F1 Score
Naïve bayes	0,176
LDA	0,565
Decision Tree	**0,648**

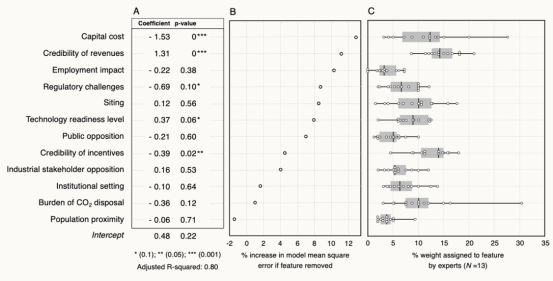
Establishing the back-end Platform for CCS data analytics

Data-driven Approach-PCL implementation



iv) Results & verification

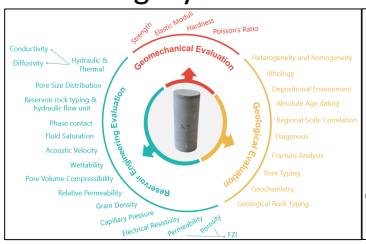
To validate the outcome, both approaches need to detect same key variables as the most influential attributes of a CCS project. Results will also be verified via 'train-validation-test split' approach.



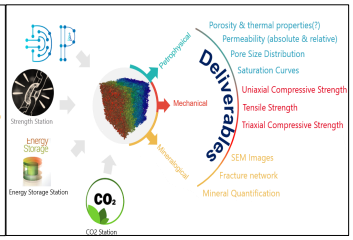
Results will also be compared with the limited literature on the matter. Case in point is the work of (Abdulla et al, 2021. Environ. Res. Lett. 16 014036) The importance of project attributes to project outcome, as determined by (A) a linear regression model; (B) a random forest model; and (C) a multi-criteria decision-making model developed through the elicitation of expert judgment. Box limits give the interquartile range; line, median; whiskers, range; and dots, individual expert responses.

Digital Assessment of Well Integrity (DAWI)

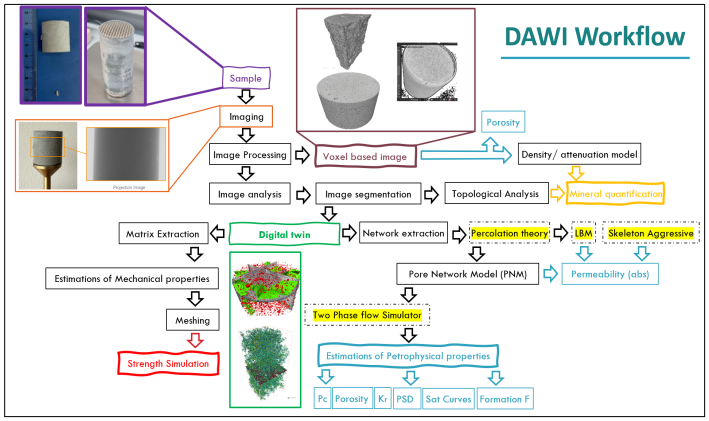
DAWI is an initiative of the Geoenergy department with the objective of reducing the assessment time of samples (in particular cement & rock cuttings). The theme involves the development of a non-destructive & comprehensive; yet fast workflow for the reliable estimation, and simulation of the petrophysical, geomechanical, and mineralogical characteristics of cement, rock and eventually other elements of well integrity.



Traditional core analysis deliverables.
Time: 6 -12 months and works only with cores



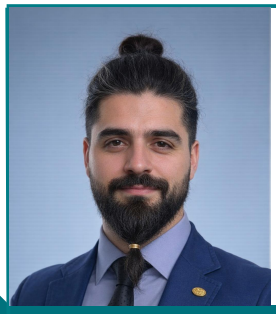
DAWI main deliverables. Time: less than a week and works with cores & cuttings



Mineral detection as a sub-technique to DAWI

Traditional mineral investigation techniques are normally destructive, time-consuming and although providing very useful information, they come with disadvantages some of which cannot be ignored.

Hence, a digital approach is conducted to reduce the time & effort considerably. This approach relies on computer tomography and image analysis techniques. In that regard, two feasibility studies has been successfully conducted.



MSc.Dipl.Ing.-
Arash Nasiri

dge DEPARTMENT GEO ENERGY

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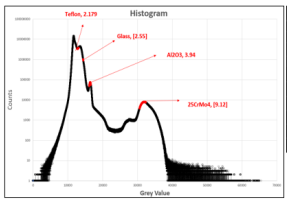
The histogram and values for the reference materials. This figure highlights that mineral phase identification using single-energy µCT is inherently range-based rather than point-based.



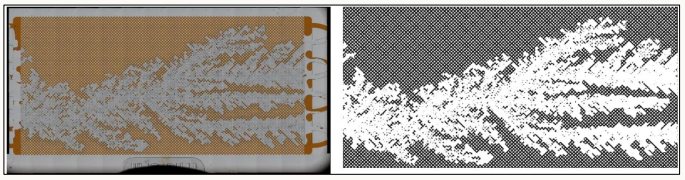
Ref Material	Grey value	Std. deviation	Density [g/cm³]
Teflon	12943.88	192.01	2.179
Glass	14648.46	214.91	2.55
Al2O3	16441.85	244.09	3.94
25CrMo4	31557.09	892.04	9.12

% Weight		
Minerals	**By µCT**	**Traditional Method**
Tectosilicates	48.40	74.8
Carbonate	9.96	9.4
Clay Mineral	32.52	14.1
Rest	9.11	1.7

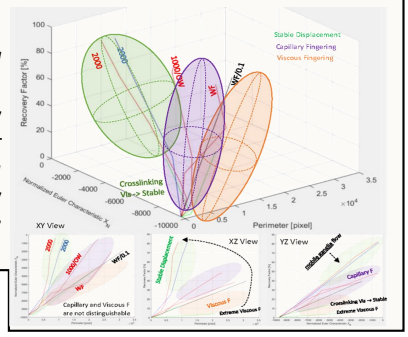
UP>The calculated gray value and its standard deviation for the reference materials.

DOWN> The comparison of mineral phase calculations between µCT calculation and X-ray diffraction measurements

Feasibility study I: 2D µ-Fluidics (2020)



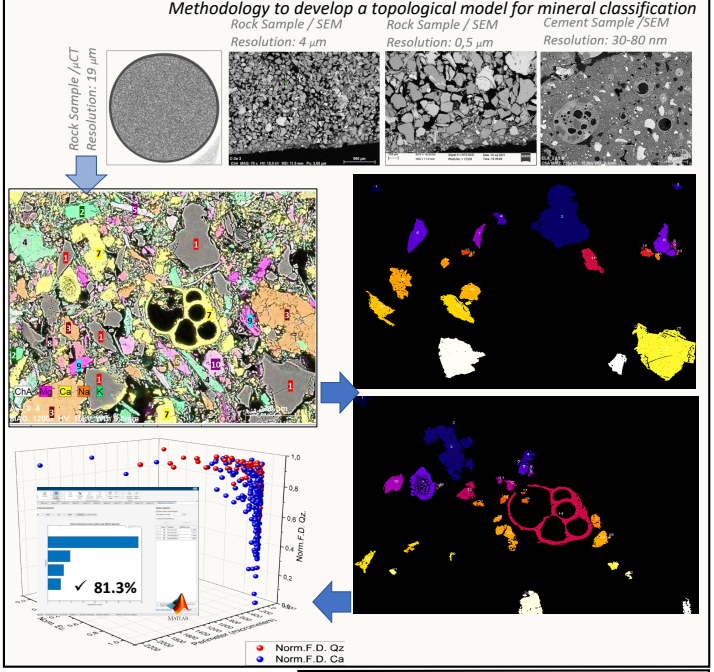
The three-D topological description of the flooding. Note that the XZ view distinguishes the zone better than the other two, showing the sensitivity of both 'recovery factor' and Perimeter to the types of displacement.



Feasibility study II: 2D SEM images (2024)

The combination of geometrical & topological parameters can unequivocally describe a shape. Here we are exercising similar investigation on mineral masses (carbonates vs quartz) which can be found in 2D SEM images.

Methodology to develop a topological model for mineral classification



Strength Simulation