Project no.:
271495

Establishing CO_2 enhanced oil recovery Business advantages in South Eastern Europe

Joint collaboration between NORCE (prev. IRIS), TNO, GeoEcoMar, PicOil Infoconsult, CO_2Club Romania

13. November 2018

Niederaussen, Germany

Technologies are ready – CCS is just (!?) a decision away!

The large scale roll out in (SE) Europe lacks. Why?

- Who are the decision makers and how do they think?
- How to support the decision making process?
- Which hurdles and uncertainties apply from an economic, environmental, safety, social, legal/political, and engineering perspective?

A decision is to be judged upon the quality of the decision process and how knowledge is used at the time ***– not its outcome****!*

Decision makers that have to say YES to CCS: Local and national governmental bodies; CO2 emitters; (oil-)field / storage operators; transportation operators; etc…

Business case development for decision makers is key

…given that prior obstacles are met:

- Legal issues
- Social acceptance of CCS

…and that incentives are clarified:

- CO_2 emission cost, taxation, etc.
- Additional revenue created (e.g. increased oil recovery, products)

…and that risks are acceptable (risk aversion?):

- Reduced via the flexibility obtained in a sink-source cluster network

→Then, CCS may occur. CCS needs a boost!

Opportunities and need for CCS

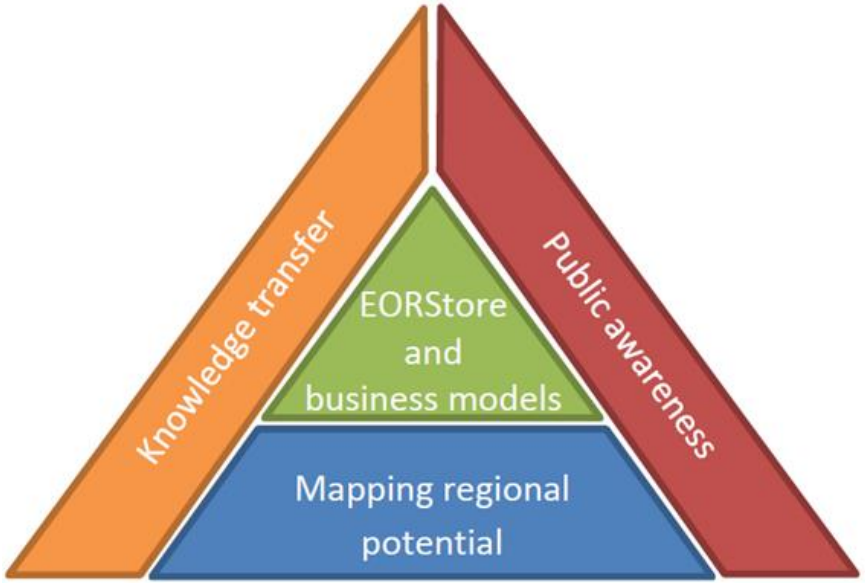
- CO2 emissions needs to be reduced now. Speed is essential.
- *Clustering* of emission points and CO2 storage sites, e.g. in Netherlands:
  - Half of the industrial CO2 emission occur in the port of Rotterdam
  - Storage in depleted gas fields in NS are available now (SPEED)!
  - Extensive experience with natural gas technology

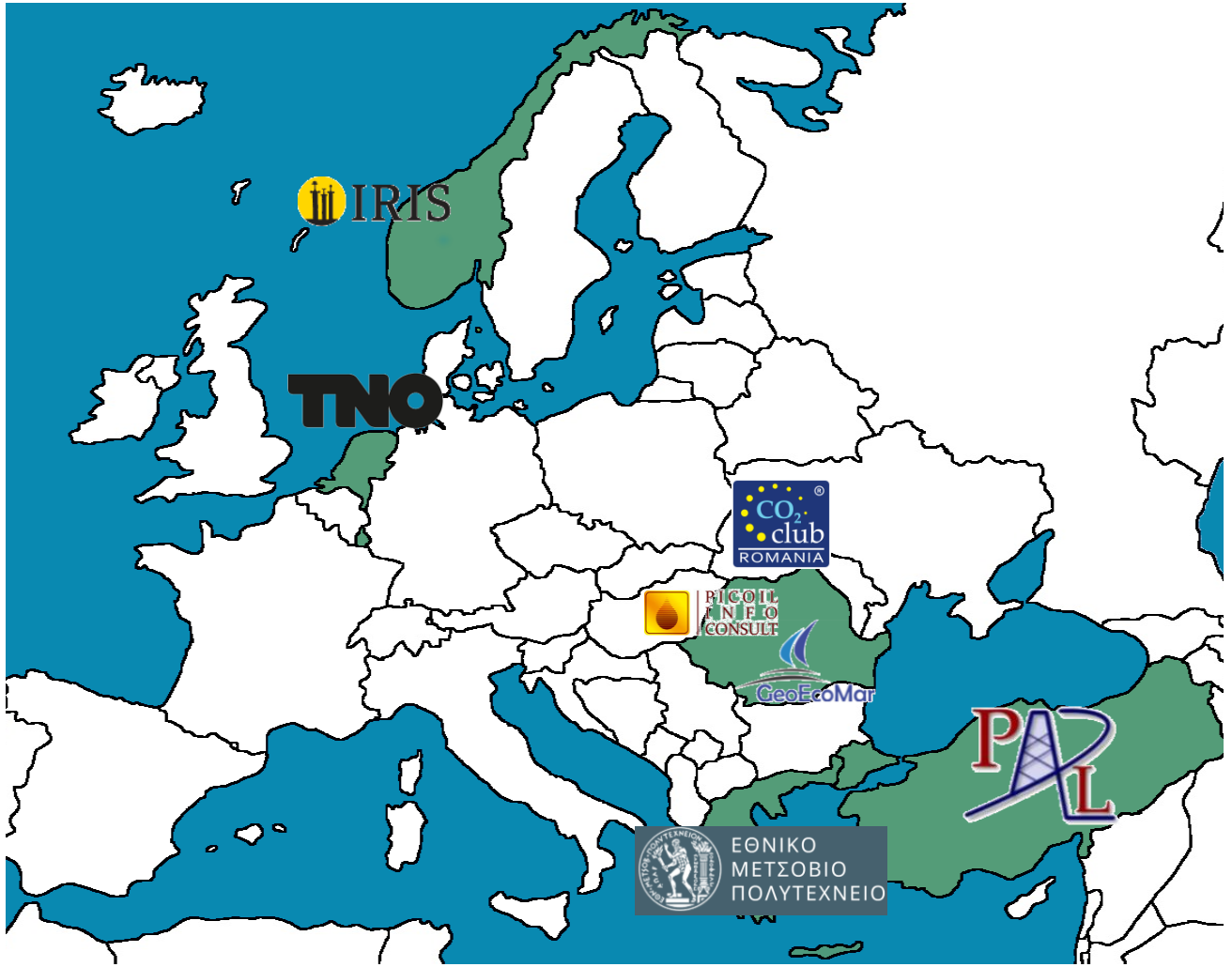
Sink/source clustering and storage network development will:

- Reduce cost to generate earning
- Safe store at varying CO2 production rates (geomech, near well issues) to maximize store
- Have sufficient CO2 available at varying rate for maximal EOR value creation
- Co-optimization of both EOR and storage, time

ECO-BASE

Establishing CO_2 enhanced Oil recovery
Business Advantages in South Eastern Europe





Project performed in Turkey (PAL) and Romania (GEOECOMAR),
supported by The Netherlands (TNO) and Norway (NORCE , prev. IRIS)

Aimed at theme 5 of ACT call:

"the utilization of CO2 by including prospective revenue streams and related business models as a vehicle to render CO2 capture-transport-storage economically feasible".

Project goals

The main goal of the project is to *demonstrate that CO2 used for enhanced oil recovery can economically improve the oil production and to initiate safe and reliable permanent CO2 storage in the **SSE region** (Turkey, Romania, Greece).*

Secondary goals:

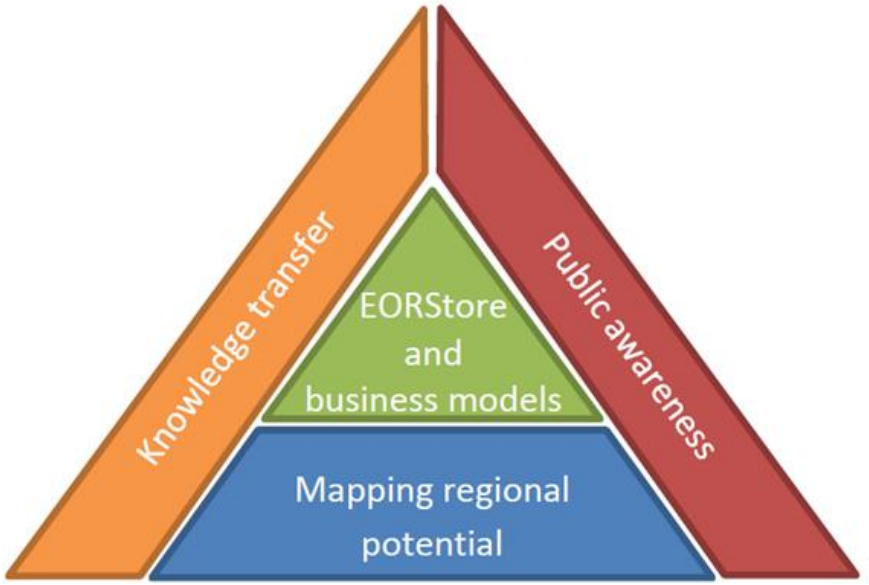
- Prepare Southeast European regional framework of physical and legal conditions for CCUS.
- Input to new regulations and incentive.
- Identify local opportunities for CO2-EOR as a promoter of CCUS – Source/sink clustering.
- Create country specific roadmaps for specific clusters (sources, EOR and storage).
- Site development plans, co-optimize storage and production for clusters.
- Build an investment climate for CO2-EOR (business case development).
- Steps for building public private partnerships.

Project organization

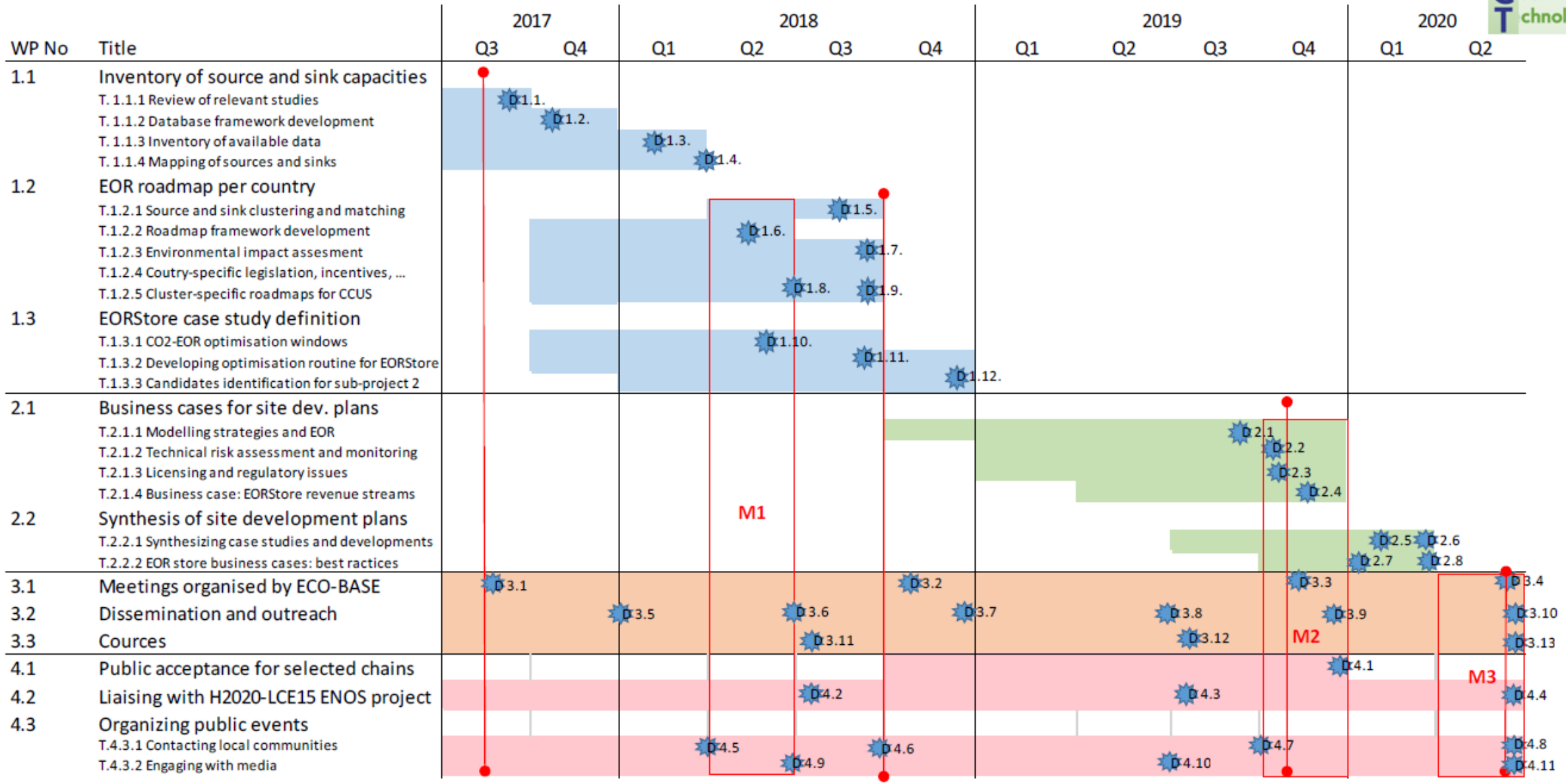
Four sub projects:

1. Map CCUS potential in Turkey and Romania and to establish regional EORStore roadmaps.
2. Create business case for selected EORStore case studies. Optimize for EORStore and address technical, legal and regulatory incentives.
3. Knowledge sharing between participating countries. Courses and knowledge transfer for stakeholders.
4. Public awareness and acceptance to create favorable atmosphere for CCUS.

ECO-BASE cooperate with existing organizations (CO2-GeoNet) and projects (ENOS).



ECO-BASE outline and key milestones

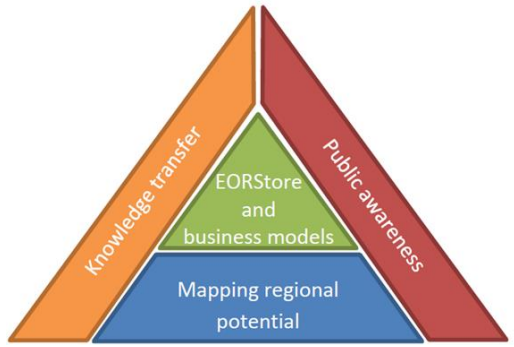


M1 Milestone indicating key deliverable or event crossing several tasks/WPs

ECO-base meeting indicating WPs involved

D1.1. Deliverable and its number

Sub-project1: Mapping potential and roadmaps



Inventory of sources and sinks:

- Use relevant data from previous studies.
- Database framework and database development with source and sink data in SEE. GIS maps.

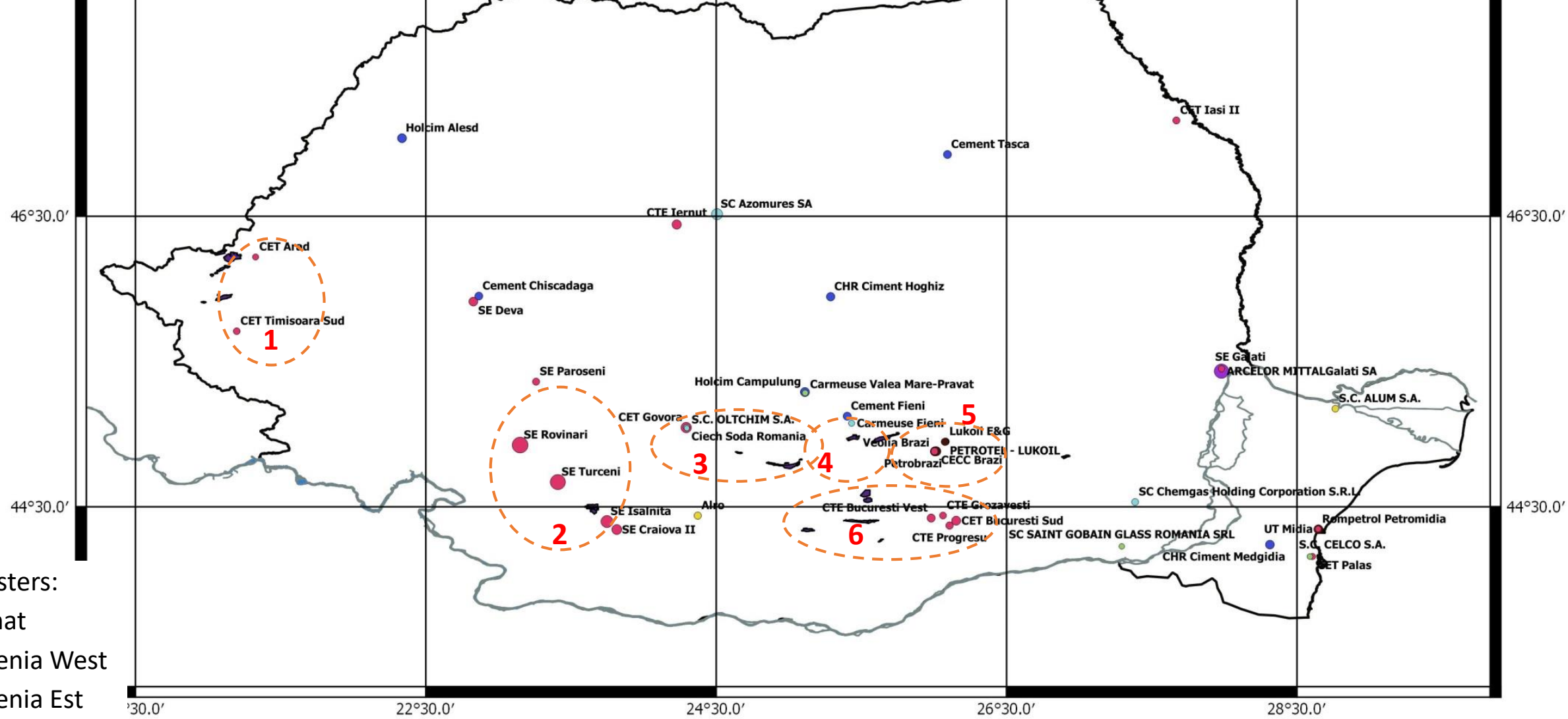
EOR roadmaps:

- Source/sink clustering and matching.
- Description of the roadmap framework.
- Environmental Impact Assessment of CO2-EOR.
- Opportunities and bottle necks per Member State.
- Cluster roadmaps for the development of CCUS.

EORStore case study definition

- Decision tree for ranking CO2-EOR potential.
- Methodology to optimize for CO2-EOR combined with permanent storage.

Milestone 1: Identify the best EORStore cases for SP2



Clusters:

Banat

Oltenia West

Oltenia Est

Arges

Prahova

Bucuresti

Map of sources, sinks and a transportation network

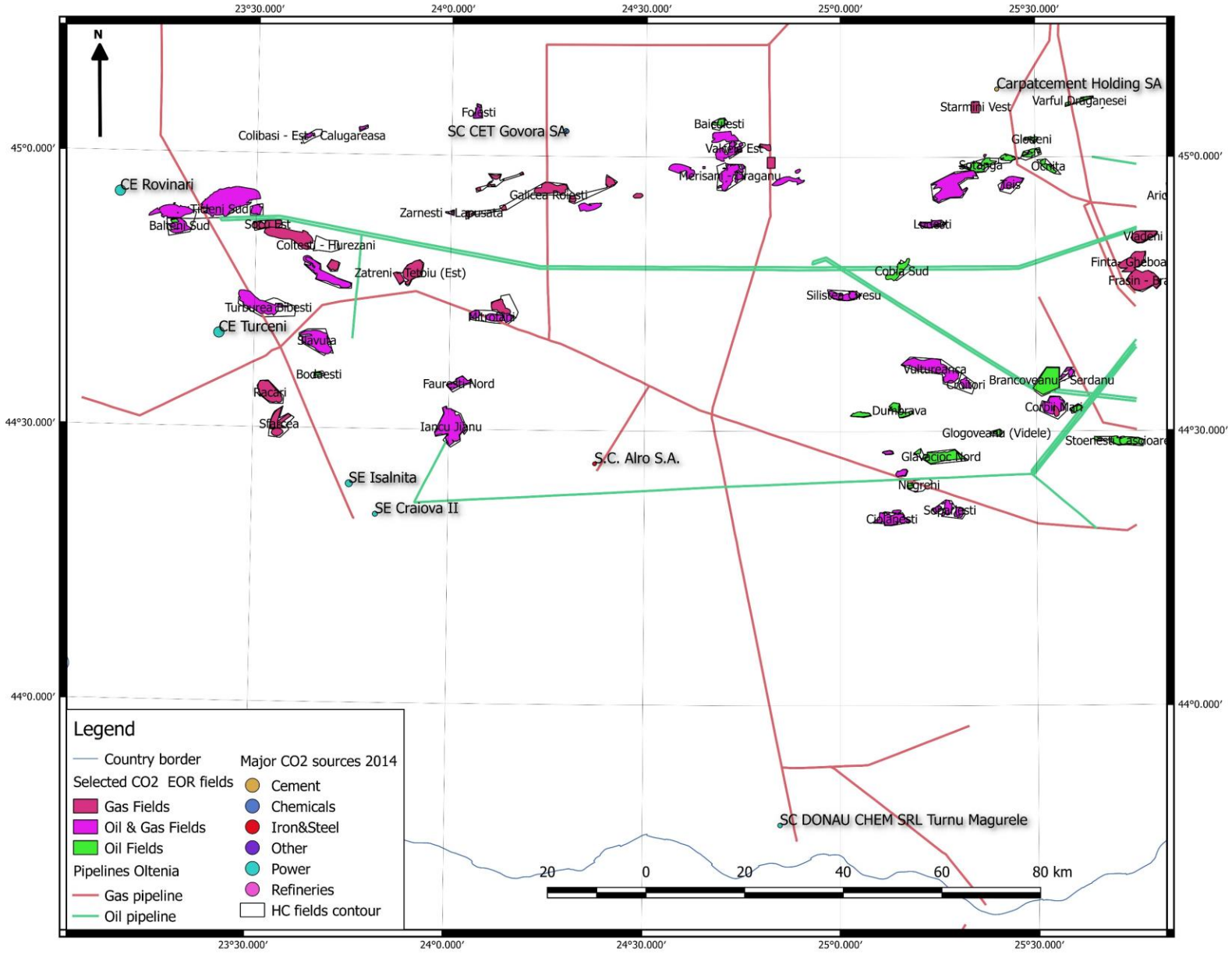
Has implications to:

- Reduced cost of CO2 delivery

Flexibility in the network:

- Handle a varying CO2 **production** rate
- Handle the varying CO2 safe **receiving** rate

→ Important for **business case** development and **risk assessment**.



Screening for CO_2EOR potential

SWORD (by NORCE) to estimate oil recovery given input variables:

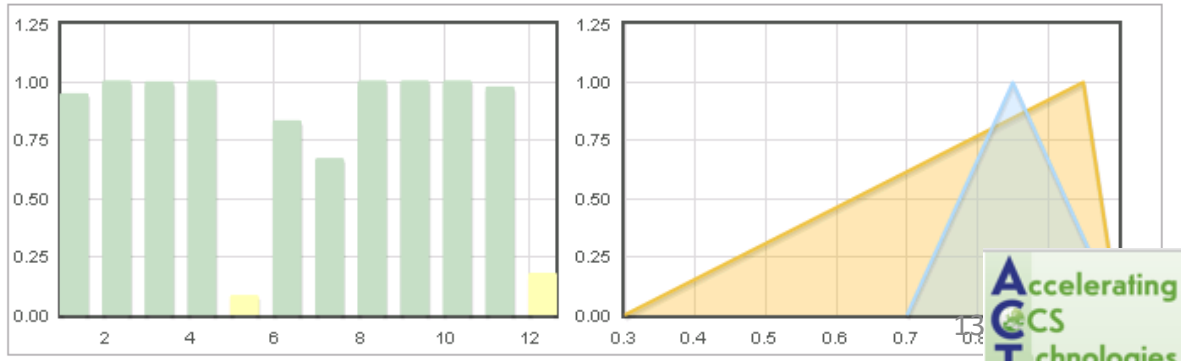
→ Important for business case development as it proveds a tool to estimate the future cash flow for a storage operator.

Do the reservoir properties fit the database parameter range?

Applicability screening → **Applicability evaluation**

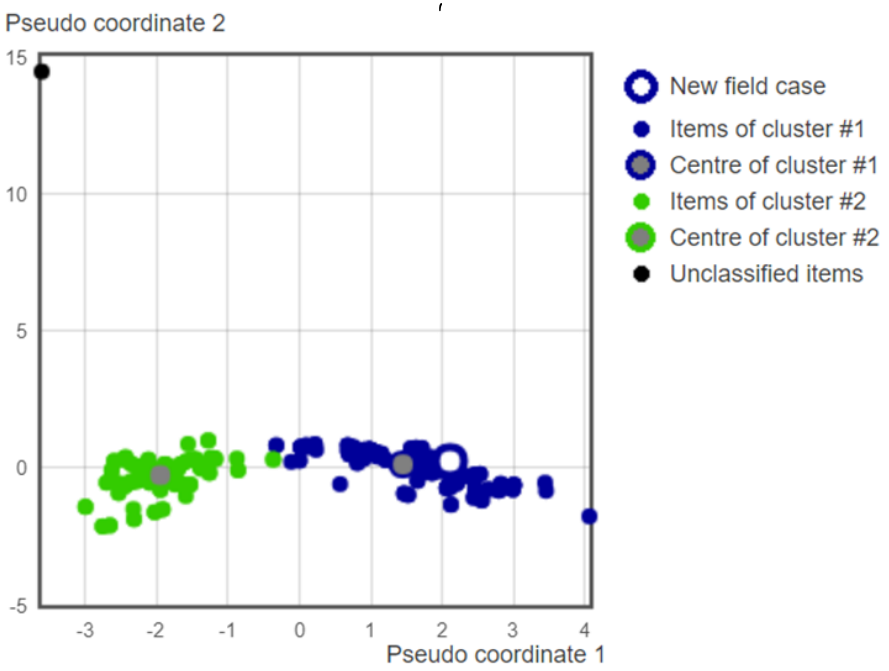
Method	Score	Violations
Chemical methods	0.806	0
Gas injection	0.728	0
Thermal methods	0.635	0
Water flooding	0.545	0

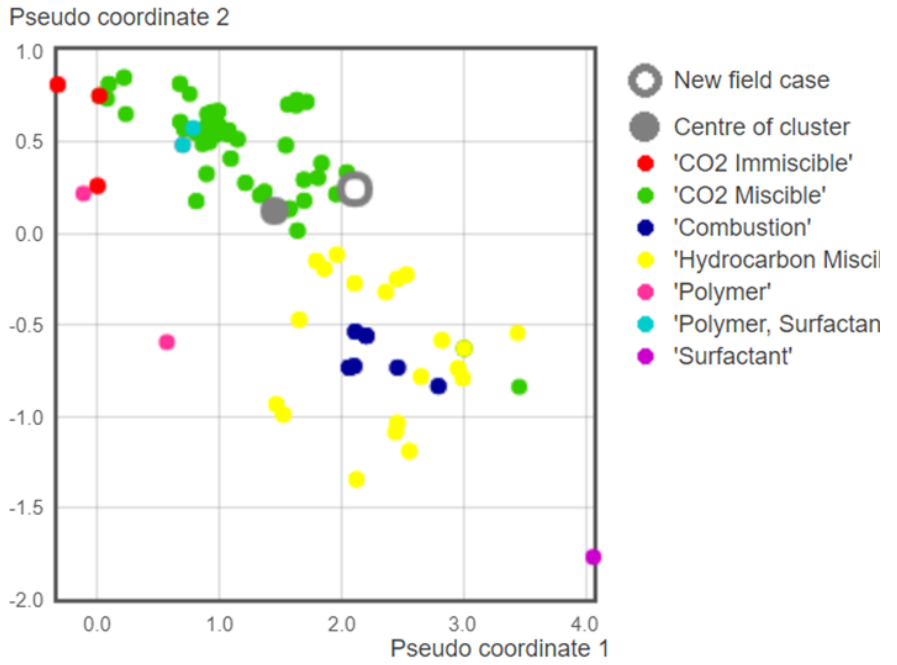
Parameter	Unit	User			Reference intervals			Score
		Min	Max	Comfort center	Min	Max	Comfort center	
Depth	m	150	2000	1075	30	2500	1265	0.946
Permeability	md	100	2000	1050	100	2000	1050	1
Thickness	m	6	20	13	2	25	13.5	0.997
Temperature	Celsius	0	70	35	0	70	35	1
Oil viscosity	cp	1	10	5.5	0.4	250	125.2	0.079
Pressure	bar	80	250	165	10	250	130	0.829
Oil density	kg/m3	750	850	800	650	850	750	0.667
Anisotropy (kv/kh)	(0-1)	0.01	0.1	0.055	0.01	0.1	0.055	1
Clay content	(0-1)	0	0.05	0.025	0	0.05	0.025	1
Salinity	kg/m3	0	20	10	0	20	10	1
Curr/init oil saturation	(0-1)	0.7	1	0.85	0.3	1	0.95	0.975
High/low perm. ratio		1	20	10.5	1	200	100.5	0.174



Screening for CO_2EOR potential

Database look-up: How did similar reservoirs world-wide perform?





Results

IOR/EOR methods (interpolation in automatically chosen cluster)

	Method	Number of cases in interpolation	Interpolated recovery factor (0-1)	Confidence	Confidence index - interpolation cases (0-1)	Confidence index all cases (0-1)
1	CO2 Miscible	8	0.44	Good	0.97	0.

Accelerating CCS Technologies

Screening a field for it's CO_2EOR potential

Simple analytical model

(Buckley Leverett):

Recovery rate and ultimate recovery for revenue creation

Performance prediction → **Advanced process input**

Polymer | Surfactant | Nitrogen (miscible) | CO2 (miscible) | Hydrocarbon (miscible) | Cyclic waterflooding | WAG

Minimum miscibility pressure (MMP)

Use custom MMP

Molecular weight C5+
213.5000 kg/kmol

Oil volatile mole fraction
0.33 (0-1)

Oil intermediate mole fraction
0.28 (0-1)

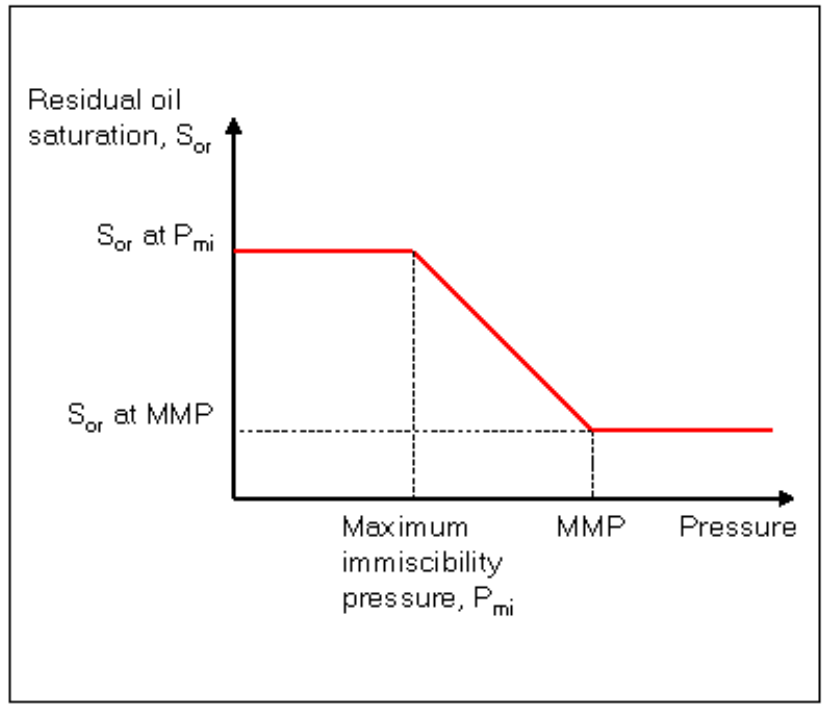
Temperature
60.00 Celsius

MMP
163 bar

Custom MMP
0.0 bar

Residual oil saturation at MMP
0.03 (0-1)

Maximum immiscibility pressure
50.0 bar



Decision tree analysis

- Systematic way of assessing a series of decisions made under *risk* and *uncertainty.* Both qualitative and quantitative.
- Expenses (OPEX, CAPEX) and revenue (quota price minus cost of CO2-injection, and EOR) addressed simultaneously.
- Bayesian statistic, sum of independent events

→ Expected monetary value (EMV) for decisions and likely outcomes

→ Future cash flow (FCF) and net present value (NPV, discount rates). Compared to CAPEX.

→Basis for sensitivity analysis during project development.

Decision tree - Emitters perspective

Company XYZ emits 2 Mtons CO2 per year. *Should they invest in CCS technology and rather store the emitted CO2*?

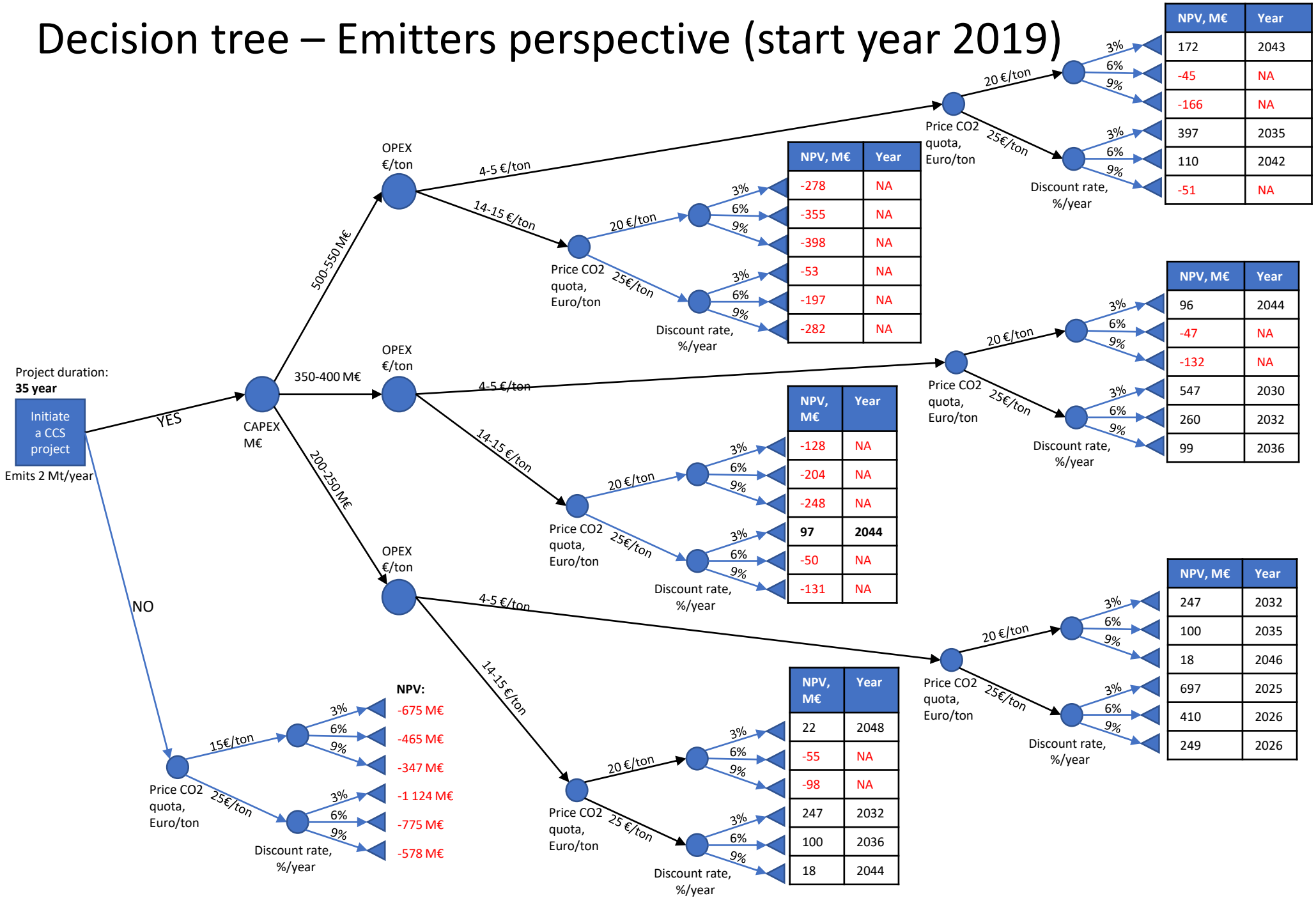
- Discount rate (3, 6, 9%)
- Cost of CO2 release (CO2 quota system; 12 and 22 €/ton)
- CAPEX of the investment (200-250M€, 350-400M€, 500-550M€, drawn from flat distributions)
- OPEX for storage (4-5 and 14-15 €/ton, drawn from a flat distribution)

- No cross-relations between the input variables (e.g. OPEX-CAPEX relations, can be included)
- No time-dependence (can be included).
- Any probability distribution can be included in the tool.

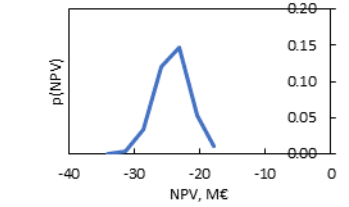
Calculated the future cash flow (release cost - storage cost) & net present value - CAPEX.

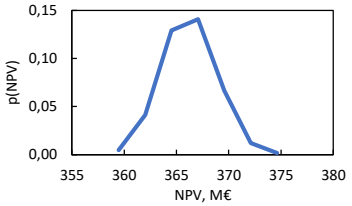
Use Monte Carlo simulations in Excel such that probability distributions in the NPV and time of break even is obtained.

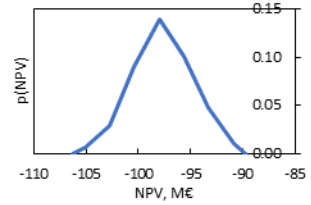
Decision tree – Emitters perspective (start year 2019)



Prob distr. Of likely outcome







Regional CO2-EOR Roadmaps

Data collection and mapping

- Database framework for potential CO2 options (uniform structure)
- Data collection of sources and sinks in Romania and Turkey
- Mapping sources and sinks in GIS
- Clustering and matching sources and sinks
- Select candidate clusters for roadmap development

Regional roadmaps

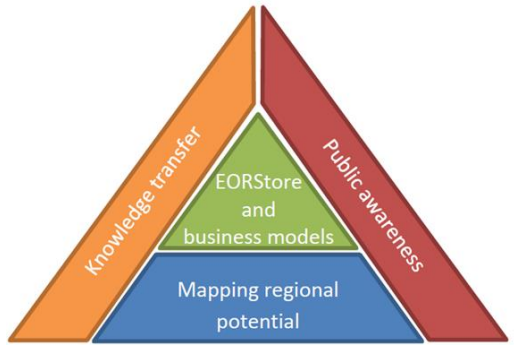
- Develop a practical roadmap framework
- Use the framework for regional cluster-specific roadmaps

Regional conidtions

- Country-specific overview of current policies, opportunities and bottlenecks (oil production, CCS, climate change, emissions, etc.)
- Impact of CO2-EOR on the environment in relation to current legislation (Environmental Impact Assessment or Statement; EIA or EIS)

CCS

Sub-project2: Optimise EORStore



Site development plans (SDPs) of concrete cases

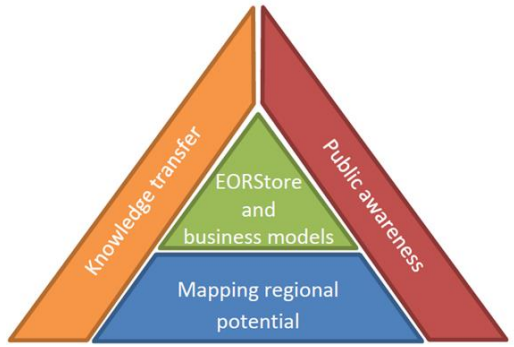
- Dynamic and static modelling. Design optimal recovery and scenario definition.
- Technical risk assessment and preliminary monitoring plan.
- Licensing plan / permitting.
- Business case incentives for CO2 EOR.

Synthesis of several SDPs

- Site specific plans for further action.
- Identify similarities, differences and lessons learned.
- Open workshop on experience sharing for CO2-EOR and necessary steps to be taken.
- Summary report with conclusions and guidance for preparing business cases for CO2-EOR with tail end permanent storage.

Milestone 2: EORStore case development plans

Sub-project3: Knowledge sharing



ECO-Base meetings

Dissemination and outreach

- A website ecobase-project.eu
- Newsletters
- Annual publication report

Courses

- Sulcis summer school EOR workshop 2018-2020
- Course in Romania (combined with project meeting) 2019
- Course in Turkey (combined with project meeting) 2020

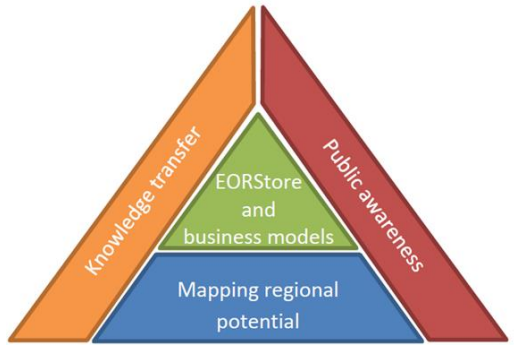
Sulcis CCUS summer school 2018-2020

Our project is co-organizer and provider of EORStore workshop during Sotacarbo's CCUS Summer School (http://www.sulcisccssummerschool.it/

The importance of CO_2 utilisation combined with storage is presented to students with different background

Join us in 2019 and 2020!

Sub-project4: Public awareness and acceptance



Public acceptance for selected chains

- Workflow learning for public involvement and acceptance

Liaising with the ENOS project

- Annual E2 report on joint actions between ENOS and ECO-BASE

Organize public events

- Coordination workshop – engagement program.
- Annual report of local community awareness programs in Turkey, ~~Greece~~ and Romania.
- Media engagement.

On-going collaborations

- Coordinated effort to social sciences (by ALIGN with ACORN, ELEGANCY, ECOBASE)
- CO2-EOR optimisation coordinated with WP4 ENOS H2020
- Learnings from ENOS journalist event on CO2GeoNet OpenForum 2018 (more to follow)
- A number of new proposals that has considerably synergy with ECOBASE (both in ACT, Norway/EEA Grants, H2020)

Thank you!

ECO-BASE

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