CO_2 ROUTES ACROSS EUROPE

COREu

COREu is one of the largest Horizon funded Carbon Capture and Storage (CCS) projects

More than 40 partners aim at the development of hub concepts for CO_2 transport and storage

From fundamental research to demonstration

Coordinated by SINTEF Energy, Norway

Main Objectives

- **Accelerate CCS deployment by demonstrating safe and effective CO_2 transport and storage.**
- Increase the TRL of the CCS technologies developed.
- **Define economically viable, societal-and environmentally-aware business models** for a sustainable upscaling of the deployment of CCS.
- **Develop improved CO_2 stream specifications** for the demo, facilitating open-access transport, by targeted analysis and experiments.
- Provide experimental data, new methods and tools for safe design and risk assessment of CO_2 transport.
- Provide experimental data and develop tools to de-risk and optimize CO_2 storage.
- **Support the deployment of multimodal, open-access CO_2 transport** by experimental data, validated models and engineering design.
- Facilitate the safe operations of, and enable revenues and credits allocation in, CO_2 transportation networks by advancing metering and analysis technologies.
- Develop a standard methodology for strengthening social acceptance of CCS technologies.
- Monitor, prevent and reduce the environmental impact of transport and storage deployment.
- Contribute to create a positive momentum for CCS across EU, by mobilizing impacting stakeholders (beyond consortium) & offering an innovative setting for collaborative engagement, resulting in accelerated deployment of safe, sustainable and resilient CCS routes in Europe.

COREu

Accelerated route development across Europe

Baltic sea

Western Ukraine

Eastern Czech Republic

Central-East Europe:

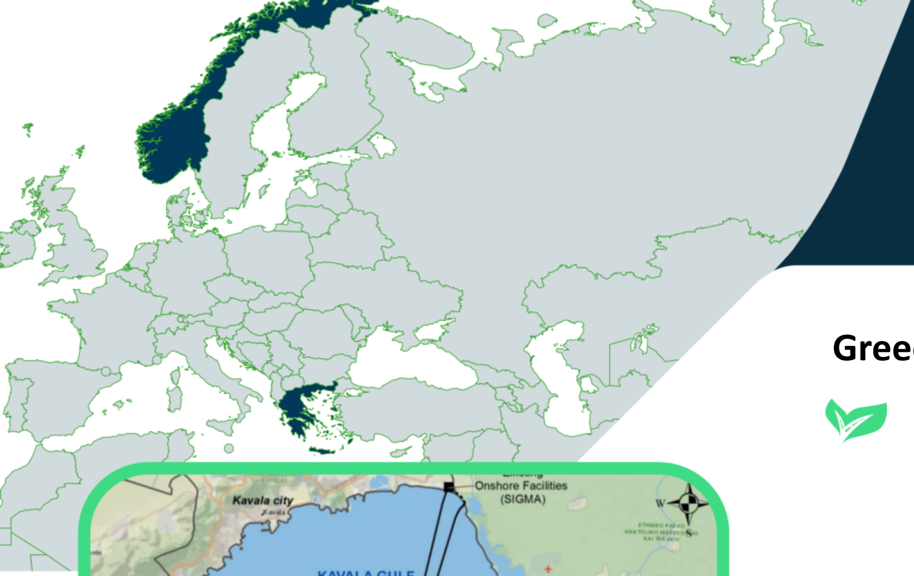
- **Czech Republic**: MND’s storage structures and hub development.
- **Poland**: LPB*’s offshore reservoir exploitation in the Baltic Sea.
- **Ukraine**: UGV*’s CO_2 capture and transportation routes.

Long-term Assessments:

- Carbon intensity, LCA, environmental impact, and risks.
- Scenarios for cross-border CO_2 transport infrastructures.

* LPB-Lotos Petrobaltic SA
* UGV-UKRGASVYDOBUVANNYA JOINT STOCK COMPANY

Demonstrations

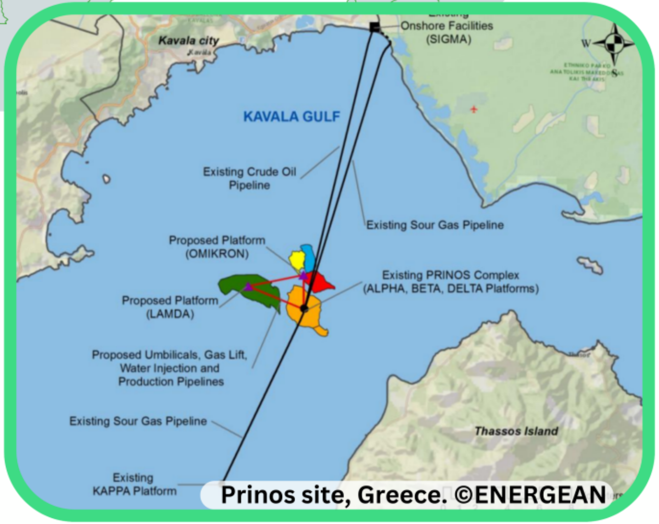


Greece :

- CO_2 delivery to Prinos offshore storage site (using GVP* transport vessels).
- AUV*-based leakage monitoring system.
- Monitoring induced seismicity with subsea sensors.

Norway:

- Onshore test of innovative offloading solution by MacGregor.
- Storage suitability assessment.
- CO_2 pilot operations and leakage monitoring.
- Monitoring induced seismicity with subsea nodes.
- Upscaling to full-field development.



Prinos site, Greece. ©ENERGEAN

- GVP- GAS VESSEL PRODUCTION PROIZVODNJA IN INZENIRSKE DEJAVNOSTI DOO
- AUV- Autonomous underwater vehicle

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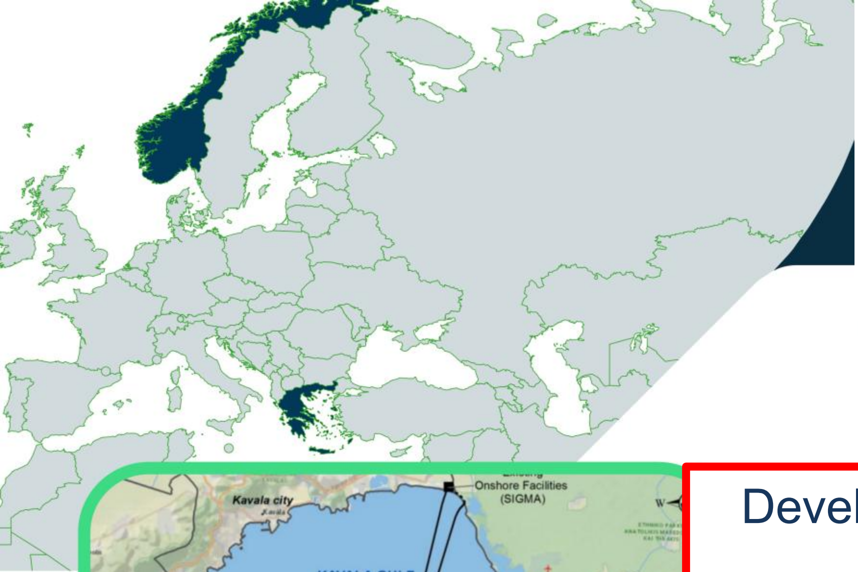
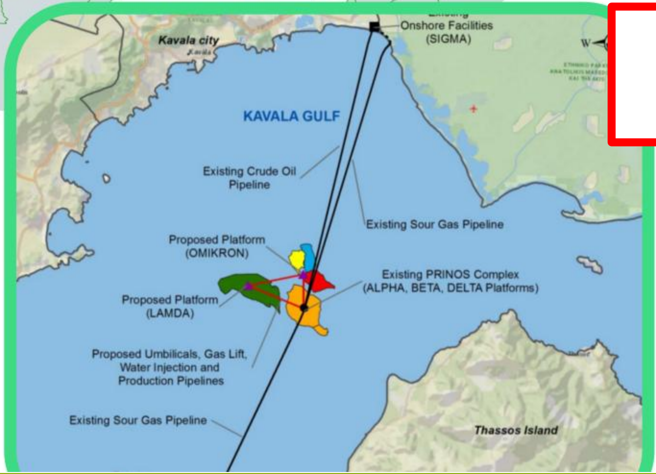


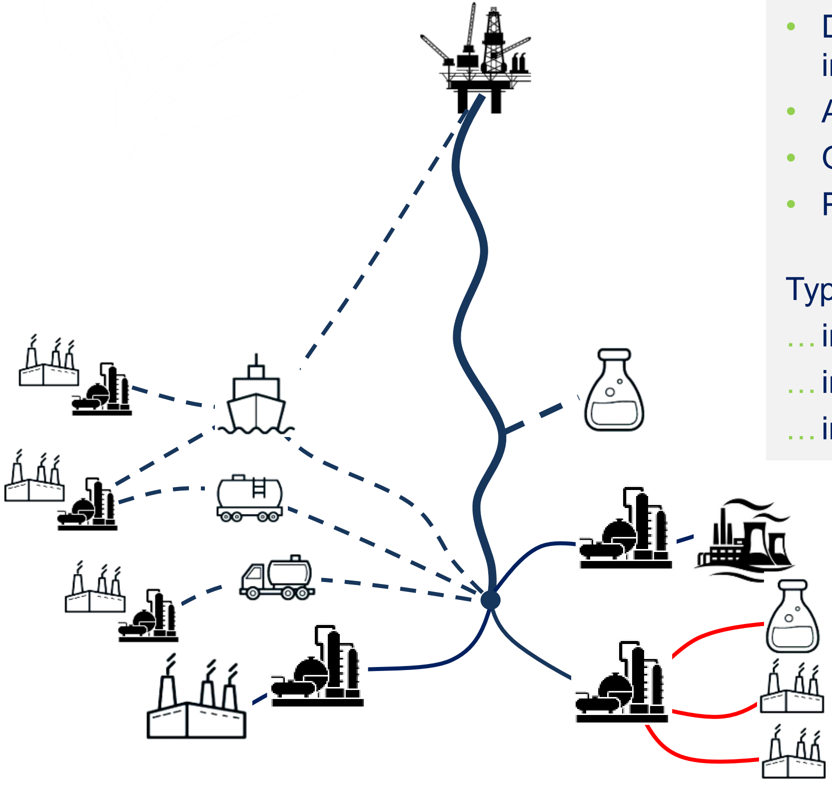


Develop **CO_2-stream specifications** for open-access transport

Project innovations

1. Use of **GVP Carbon Fibre Cylinders** to transport captured and compressed CO_2 by truck to the storage site.
2. Onshore demonstration of four system architectures to **transfer CO_2** from transport vessels in ships to the injection well.
3. **Induced seismicity monitoring system**: a wireless, battery-powered set of offshore sensors that can stay on the seabed for up to six months without recharging.
4. **CO_2-sniffing AUV**: this technology will be used to ... near the injection wells and ... e route.
5. ... ign and assessment of ... avoid running ductile
6. Enabling the assessment of the economic and **safe reuse of existing assets** such as pipelines, wells, and platforms.
7. **Well-reservoir flow coupling.**
8. **Metering and analysis of CO_2 streams** including the customisation and demonstration of a tool to monitor the whole CCS value chain.

In a Multimodal Network CO_2 is not Pure



- Different origins and capture mechanisms result in different typical impurities (list is for sure not complete!)
- Amine scrubbing: water, traces of amines and air components
- Oxyfuel: water, air components, SO_x, NO_x
- Pre combustion: water, H_2, H_2S

Typical impurities are ...

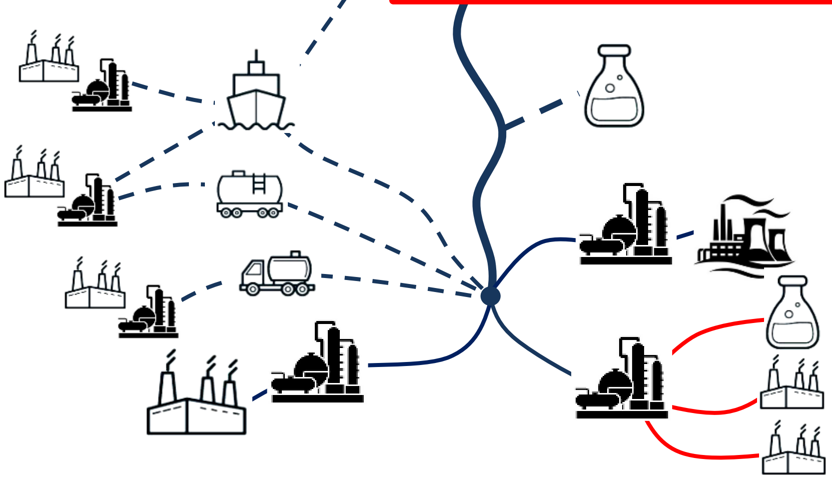
... in the % range: nitrogen, oxygen, argon, methane, hydrogen

... in the ‰ range: water

... in the ppm range: SO_x, NO_x, H_2S, amines ...

In a Multimodal Network CO_2 is not Pure

Impurities in the ppm range become cost drivers, keep us busy in modelling properties of CO_2 streams



Northern Lights

Liquid CO_2 (LCO2) Quality Specifications

Component	Unit	Limit for CO_2 Cargo within Reference Conditions
Carbon Dioxide (CO_2)	mol-%	Balance (Minimum 99.81%)
Water (H_2O)	ppm-mol	≤ 30
Oxygen (O_2)	ppm-mol	≤ 10
Sulphur Oxides (SO_x)	ppm-mol	≤ 10
Nitrogen Oxides (NOx)	ppm-mol	≤ 1.5
Hydrogen Sulfide (H_2S)	ppm-mol	≤ 9
Amine	ppm-mol	≤ 10
Ammonia (NH_3)	ppm-mol	≤ 10
Formaldehyde (CH_2O)	ppm-mol	≤ 20
Acetaldehyde (CH_3CHO)	ppm-mol	≤ 20
Mercury (Hg)	ppm-mol	≤ 0.0003
Carbon Monoxide (CO)	ppm-mol	≤ 100
Hydrogen (H_2)	ppm-mol	≤ 50
Methane (CH_4)	ppm-mol	≤ 100
Nitrogen (N_2)	ppm-mol	≤ 50
Argon (Ar)	ppm-mol	≤ 100
Methanol (CH_3OH)	ppm-mol	≤ 30
Ethanol (C_2H_5OH)	ppm-mol	≤ 1
Total Volatile Organic Compounds (VOC)	ppm-mol	≤ 10
Mono-Ethylene Glycol (MEG)	ppm-mol	≤ 0.005
Tri-Ethylene Glycol (TEG)	ppm-mol	Not allowed
BTEX	ppm-mol	≤ 0.5

If Impurities Keep us Busy, the Bulk is Well Described?

Int J Thermophys (2023)44:178
https://doi.org/10.1007/s10765-023-03263-6

EOS-CG-2021: A Mixture Model for the Calculation of Thermodynamic Properties of CCS Mixtures

Tobias Neumann[1,2] · Stefan Herrig[1] · Ian H. Bell[3] · Robin Beckmüller[1] · Eric W. Lemmon[3] · Monika Thol[1] · Roland Span[1]

$$\frac{a(\rho, T, \vec{x})}{RT} = \alpha(\delta, \tau, \vec{x}) = \alpha^{\mathrm{o}}(\rho, T, \vec{x}) + \alpha^{\mathrm{r}}(\delta, \tau, \vec{x})$$

$$\alpha^{\mathrm{o}}(\rho, T, \vec{x}) = \sum_{i=1}^{N} x_i \left[\alpha_i^{\mathrm{o}}(\rho, T) + \ln x_i\right]$$

$$\alpha^{\mathrm{r}}(\delta, \tau, \vec{x}) = \sum_{i=1}^{N} x_i \alpha_i^{\mathrm{r}}(\delta, \tau) + \Delta\alpha^{\mathrm{r}}(\delta, \tau, \vec{x})$$

$$\frac{1}{\rho_{\mathrm{r}}(\vec{x})} = \sum_{i=1}^{N} \frac{x_i^2}{\rho_{\mathrm{c},i}} + \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} 2 x_i x_j \beta_{v,ij} \gamma_{v,ij} \frac{x_i + x_j}{\beta_{v,ij}^2 x_i + x_j} \frac{1}{8} \left(\frac{1}{\rho_{\mathrm{c},i}^{1/3}} + \frac{1}{\rho_{\mathrm{c},j}^{1/3}}\right)^3$$

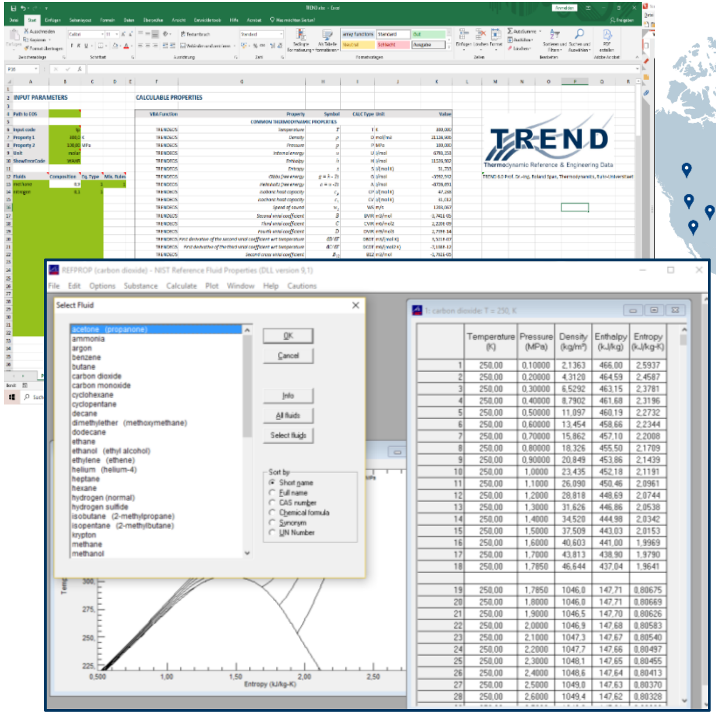
$$T_{\mathrm{r}}(\vec{x}) = \sum_{i=1}^{N} x_i^2 T_{\mathrm{c},i} + \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} 2 x_i x_j \beta_{T,ij} \gamma_{T,ij} \frac{x_i + x_j}{\beta_{T,ij}^2 x_i + x_j} \left(T_{\mathrm{c},i} T_{\mathrm{c},j}\right)^{0.5}$$

$$\delta = \frac{\rho}{\rho_{\mathrm{r}}(\vec{x})} \text{ and } \tau = \frac{T_{\mathrm{r}}(\vec{x})}{T}$$

- An accurate property model covering 15 CCS components is available
- Ared Cezairliyan Award 2024
- **Software** required for broad application

TREND and REFPROP – Two Software Packages Defining Property Standards in Energy Technologies

- Accurate property models are available for about **160 pure fluids**
- Working fluids in energy technologies (power, refrigeration, heat pumps, air conditioning) & bulk chemicals
- **Relevant mixtures** covered (incl. natural gas, LNG, CCS, cryogenic engineering)



TREND ~ 190 user
REFPROP ~ 10 000 user
the models are the same!

TREND and REFPROP – Two Software Packages Defining Property Standards in Energy Technologies

TOP Authors
for multiparameter reference equations of state:

Eric W. Lemmon, NIST
(EOS for 104 fluids)

Roland Span, RUB
(EOS for 48 fluids)

Monika Thol, RUB
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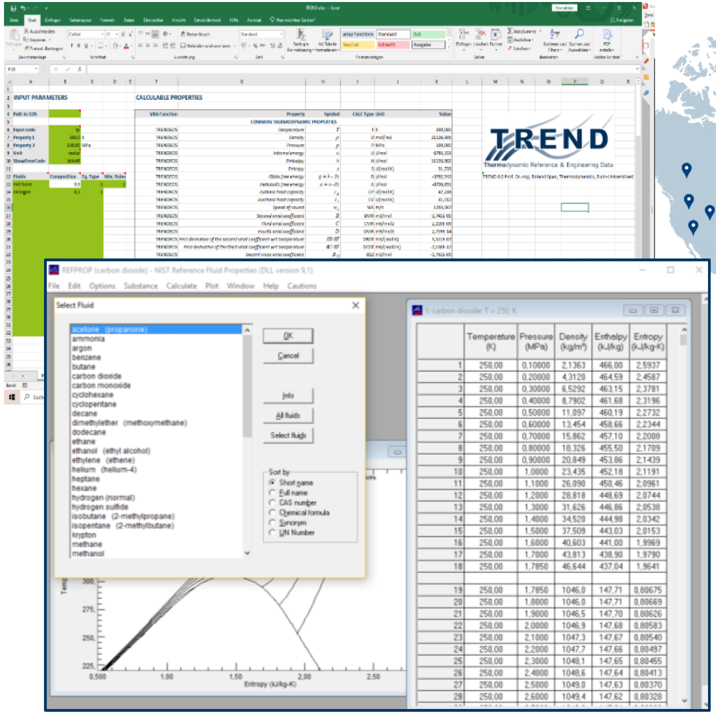
Wolfgang Wagner, RUB✝
(EOS for 17 fluids)



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