2015-12-16

Highlights of the IMPACTS Project
- Ambition, Scope and Key Findings

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CO-FUNDED BY THE EUROPEAN UNION
SEVENTH FRAMEWORK PROGRAMME

Photo: Shutterstock

IMPACTS at a glance

Collaborative project under the EU's 7th Framework Programme for research

- Duration: 2013-2015 (3 years)
- Budget: 5,6 M EUR
- EU contribution: 4 M EUR
- Coordinator: SINTEF Energy Research
- Research performing partners: 12
- Funding parties (industry): 5
- Industry participation fee: 60 kEUR/year

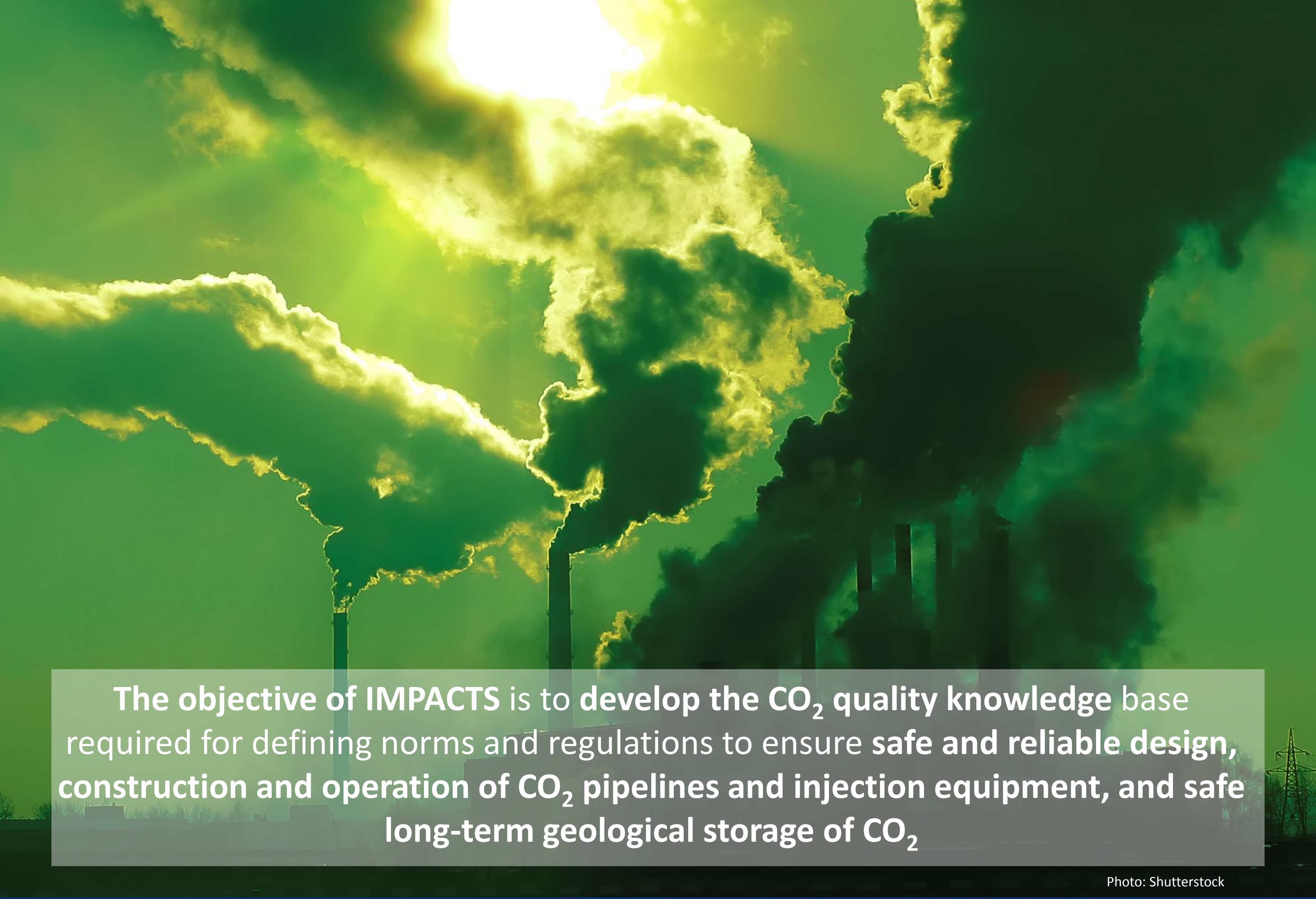
Research performing partners:

1. SINTEF Energy Research, Norway
2. Ruhr University Bochum, Germany
3. CIUDEN, Spain
4. TNO, The Netherlands
5. GFZ German Research Centre for Geosciences, Germany
6. Tsinghua University, China
7. Progressive Energy Limited, UK
8. Centro Sviluppo Materiali (CSM), Italy
9. ISPE, Romania
10. Det Norske Veritas (DNV), Norway
11. ALSTOM, Germany
12. Statoil Petroleum, Norway

IMPACTS partners (2/2)

Funding parties:

1. Statoil Petroleum, Norway
2. Lundin, Norway
3. Gas Natural Fenosa, Spain
4. MAN Diesel and Turbo, Germany
5. Vattenfall, Sweden

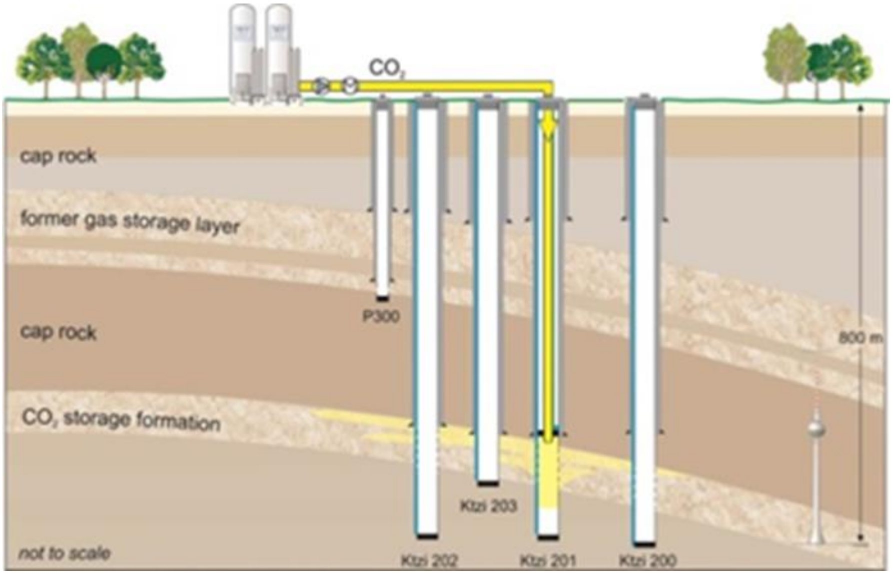


The objective of IMPACTS is to **develop the CO_2 quality knowledge** base required for defining norms and regulations to ensure **safe and reliable design, construction and operation of CO_2 pipelines and injection equipment, and safe long-term geological storage of CO_2**

Photo: Shutterstock

Specific Objectives:

1. Quantify the fundamental properties of relevant CO_2 mixtures
2. Reveal the impacts of relevant impurities in the CO_2 stream
3. Derive CO_2 quality issues considering integrity of the whole chain
4. Provide recommendations for optimized CO_2 quality
5. Build knowledge critical for implementation of safe and cost efficient transport and storage of CO_2
6. Arrange annual IMPACTS seminars to share knowledge across subprojects
7. Publish results in scientific journals with peer review and establish a plan for results exploitation



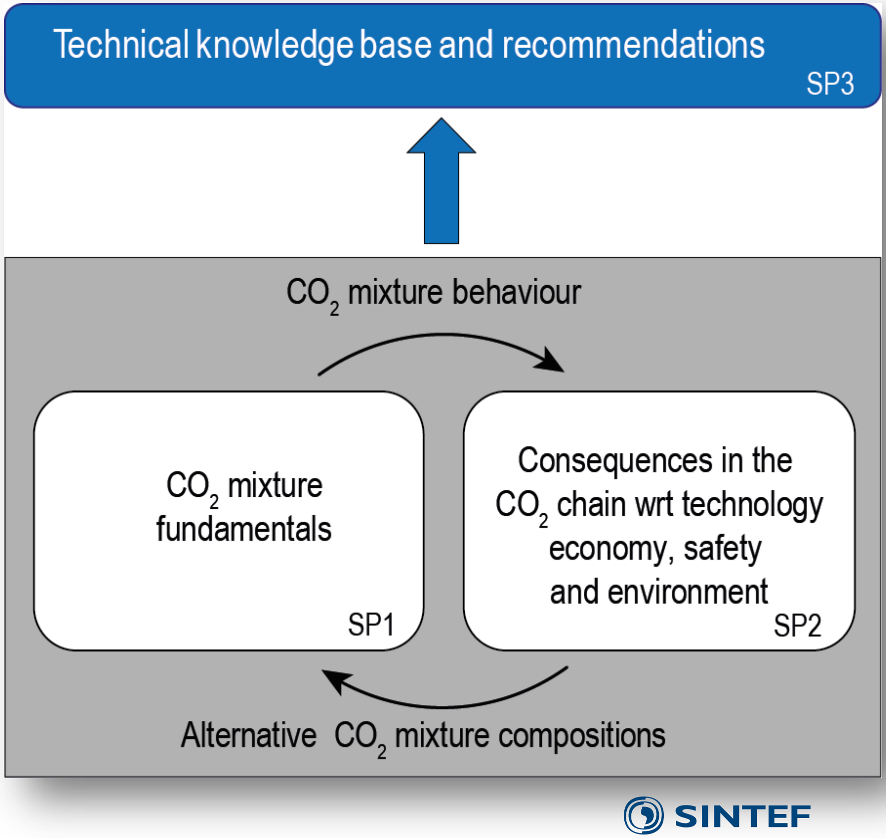
Ketzin site: Co-injection of CO_2 with N_2 (GFZ)

IMPACTS Concept

- SP1: Investigation of fundamental properties of relevant CO_2 mixtures. This will give new insights on the effects of impurities in CO_2 on thermodynamics, fluid dynamics, corrosion potentials

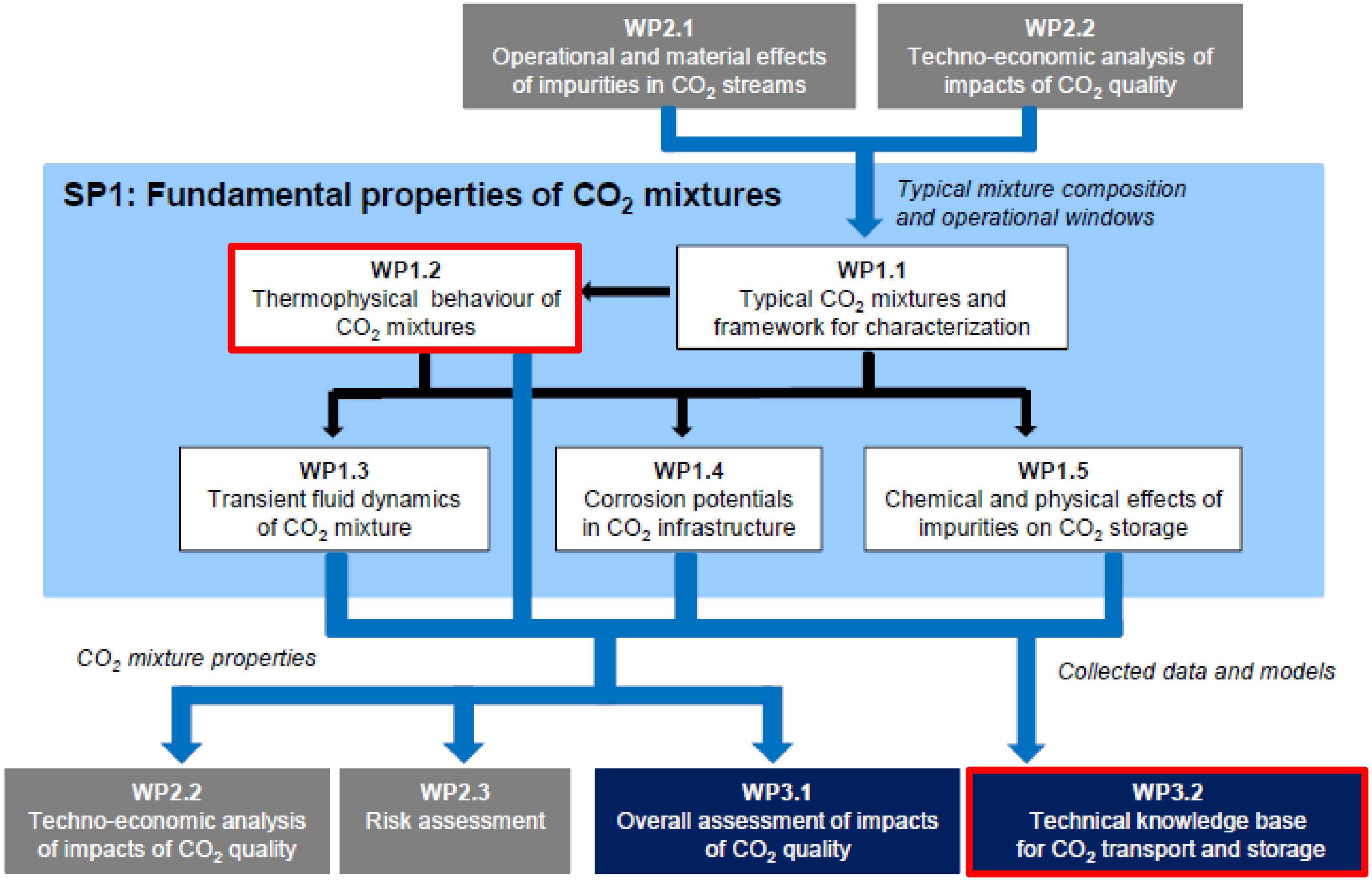
- SP2: Large-scale experiments will produce data on the effect of impurities. The techno-economic impacts of CO_2 mixture composition and possible HSE consequences will be assessed.

- SP3: The results will constitute a technical knowledge base for developing practices for design and operation of CO_2 pipeline and storage site infrastructures.



IMPACTS Project Layout

IMPACTS
The impact of the quality of CO_2 on transport and storage behaviour



Alexandre Morin, 2013

Contact: filip.neele@tno.nl

Classification of impurities Transport

- H_2
  - Largest impact on pipe flow
- NH_3
  - Polar fluid, complex impact, usually low levels
- CO, O_2, N_2, Ar, CH_4
  - All have similar impact
  - Increase critical p, increase bubble point, decrease mixture density, increase enthalpy in supercritical region
- SO_2, H_2S
  - Similar effects, opposite to those of previous group

Make handling of mixture more difficult, energy consuming, etc.

Friendly impurities – less energy required, lower volumes, etc.

Impurity Ranges studied in IMPACTS

Values in ppmm if not %

Impurity	H_2O	N_2	O_2	Ar	NOx	SOx	CO	H_2S	H_2	CH_4	C2+	Cl	NH_3
General limits (some only applicable in specific cases):													
Max	1000	5%	300	600	250	250	200	200	5000	1000	2000	20	300
Benchmark	100	2000	100	20	100	100	20	100	50	500	1000	5	50
Min	0.001	100	2	1	20	20	10	20	20	20	100	1	10
Adjusted For Oxyfuel:													
Max		5%	5%	5%			1500						
Benchmark		2%	3%	2%			50						
Min		1%	2	100			10						
Adjusted For Pre-combustion:													
Max		5%	300	600	250	250	1500		2%	100			
Benchmark		2%	10	200	10	10	400		1%	50			
Min		1%	2	100	10	10	50		20	20			
Adjusted for Gas Processing													
Max										5%			
Benchmark										4%			
Min										20			

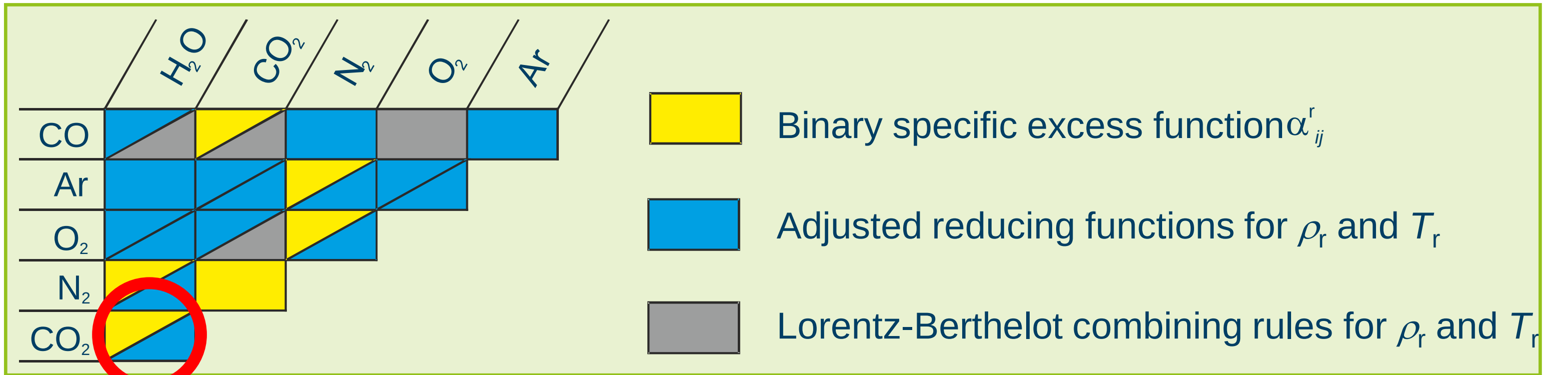
The benchmark levels given are intended to reflect the typical levels which would currently be achieved using standard capture equipment

IMPACTS has Generated: Improved Understanding of Fundamental Properties of CO_2 Mixtures

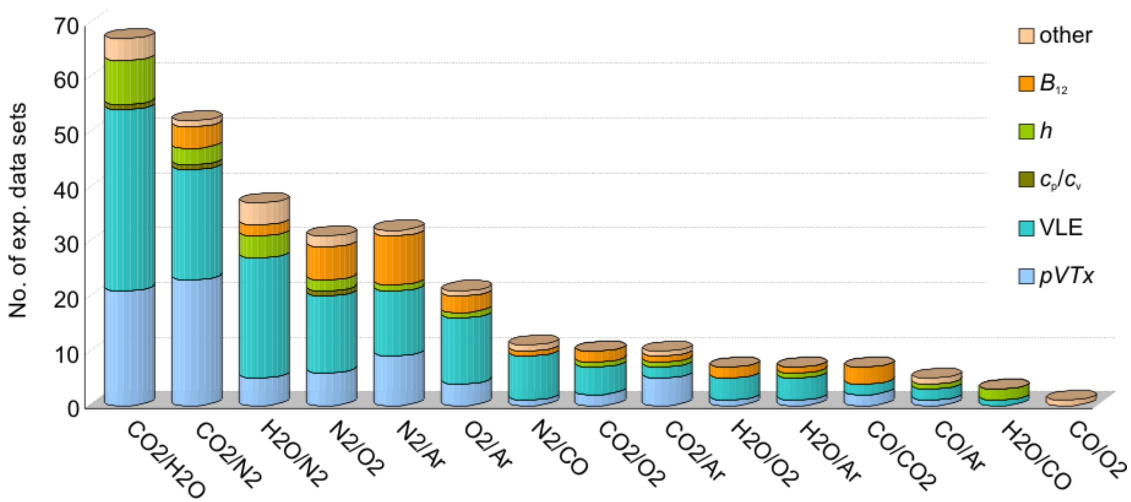
- **A better equation of state for CO_2 mixed with all the potential contaminants expected in captured CO_2**

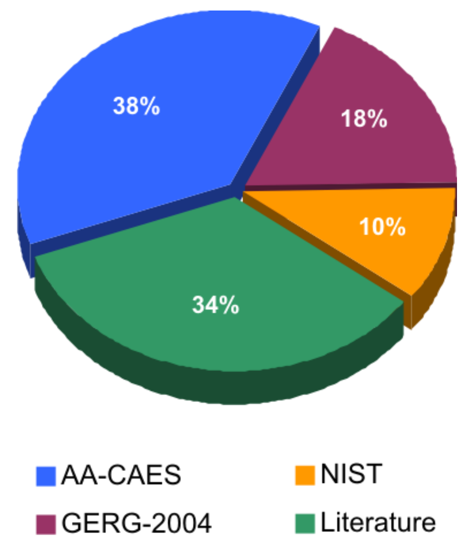
- The EOS-CG model
  - Reference equation of state for combustion gases
  - State-of-the-art CO_2 mixture thermophysical properties model verified against high quality data
  - TREND Software Publicly available at the RUB website by contacting Dr. Roland Span
  - Available for IMPACTS members on the E-room

EOS-CG – Improving GERG-2008 for CO_2-Rich Mixtures



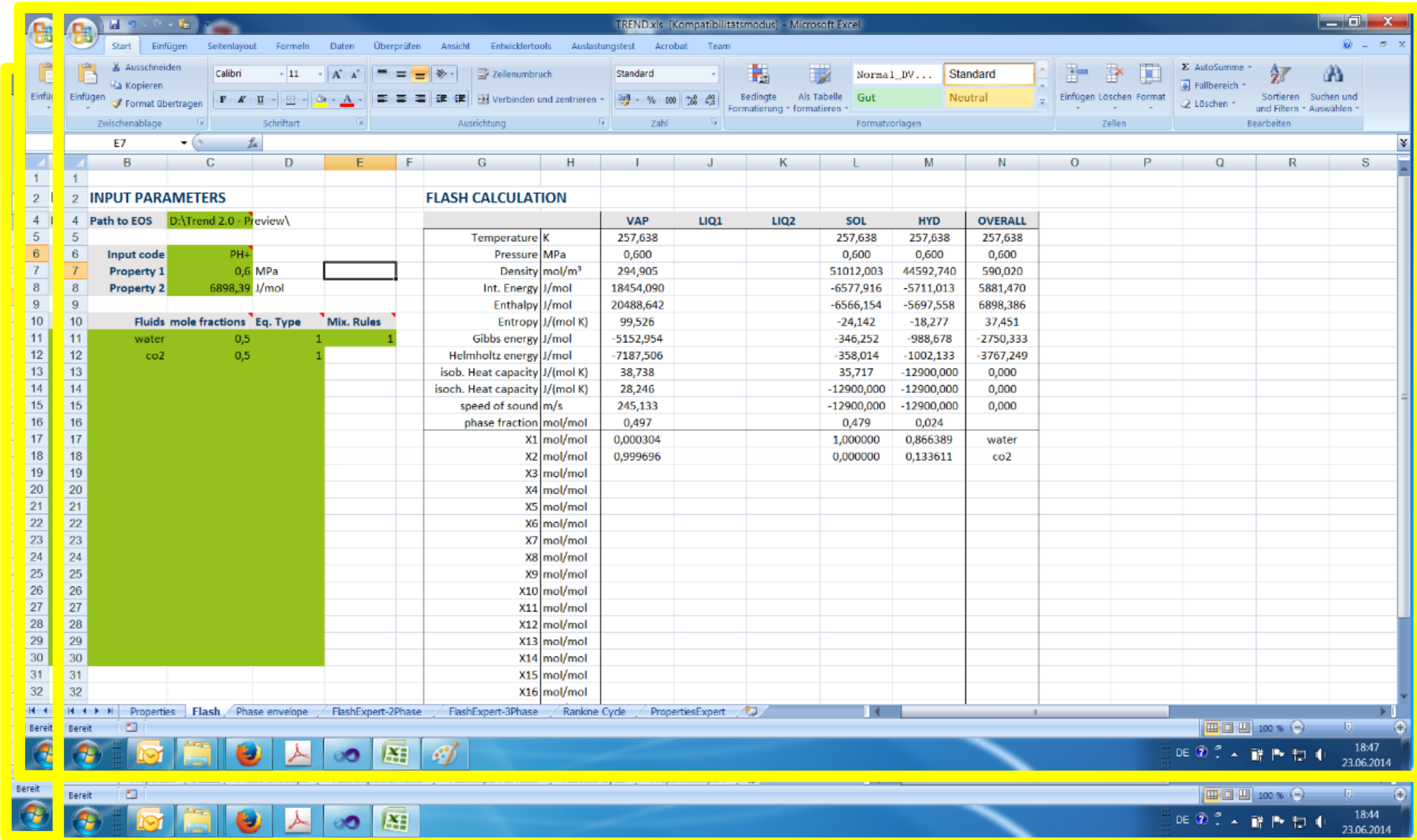
- **5 mixtures:** new excess functions
- **5 mixtures:** new reducing parameters





Key Output from IMPACTS: TREND Software

- Estimates phase transitions at given T, P (based on Fortran, Excel interface)

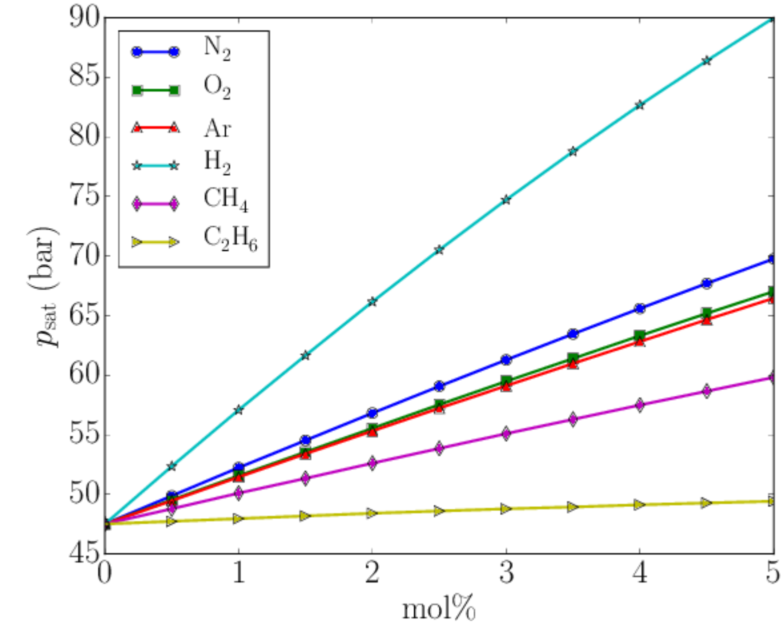


Fundamental Properties of CO_2 Mixtures Cont.

- New experimental data on Properties of CO_2 Mixtures
  - VLE, Density, Corrosion (uniform and stress)
  - Chemical reaction kinetics for CO_2-mixtures-rock

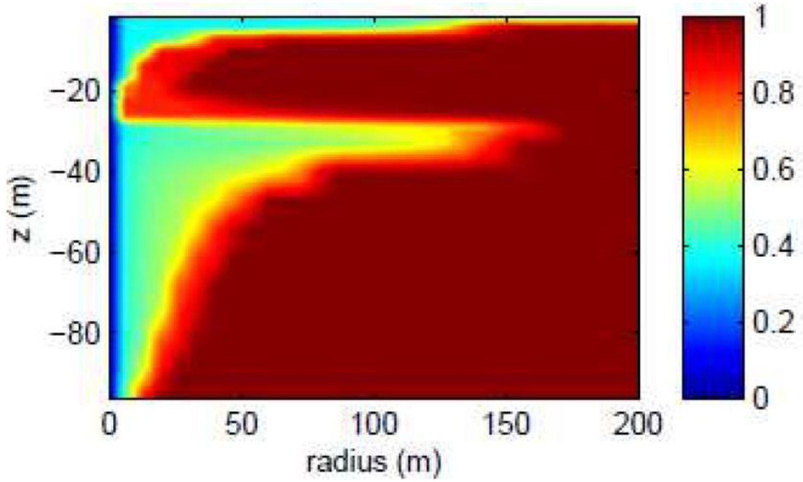
WP1.3

- Saturation (bubble) pressure increases with impurities
- Higher saturation pressure implies thicker pipeline to avoid running fractures



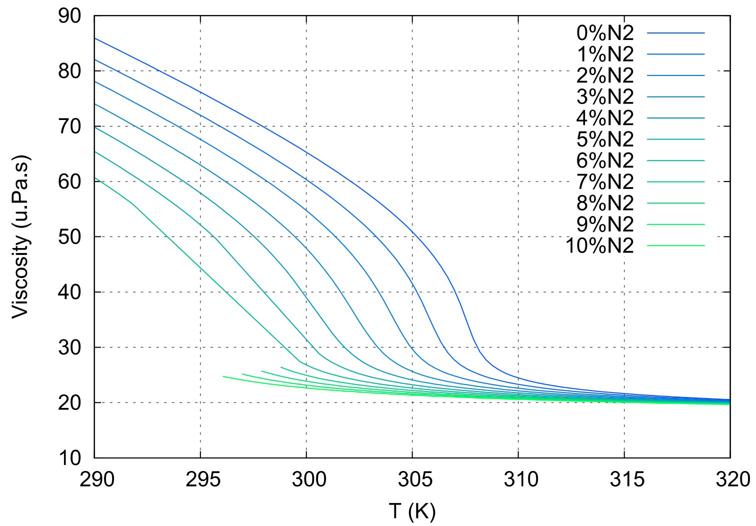
Fundamental Properties of CO_2 Mixtures Cont. (SP1)

- Unique numerical experiments
  - Impurity and model sensitivity for pipeline operations
  - Reservoir modelling and simulations, accounting for chemistry, fluid mechanics and thermodynamics.

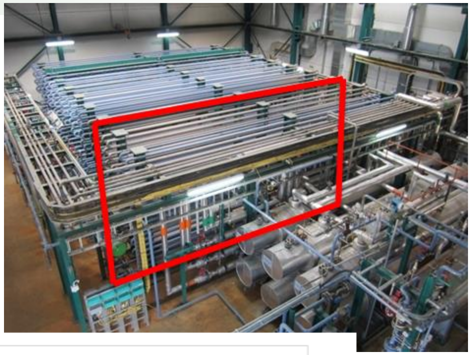


- Thermophyical models for CO_2 mixtures
  - Best models identified and tuned to experimental data
  - Implemented and made available (Excel)

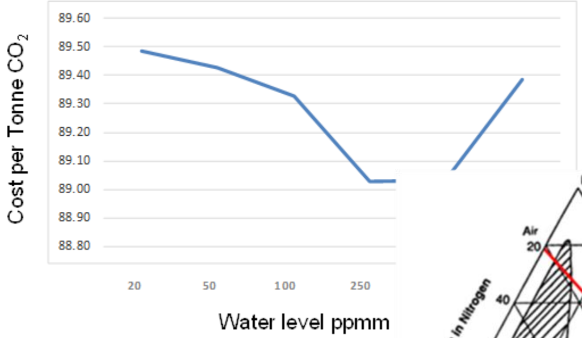
- And much more..



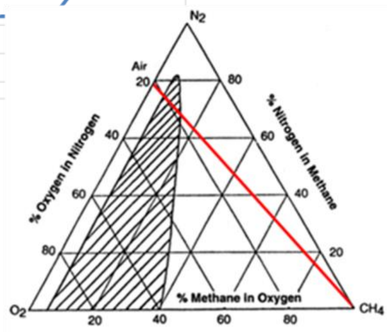
IMPACTS has Generated: Technoechonomic Model for Impact of Impurites on Transport & Storage (SP2)



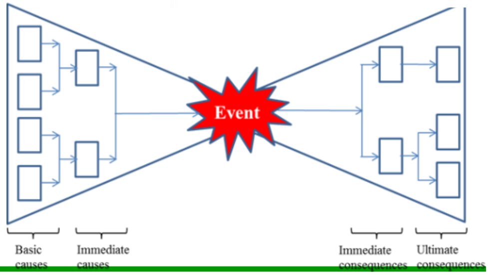
- Insights into initial injection behaviour at Hontomin
- Comparison of impurity impacts on storage materials
- Preliminary studies on transport corrosion and depressurisation



- The IMPACTS T-E model
  - Flexible CCS chain economic model
  - Written in Excel to make it readily useable
  - Available to partners in eRoom
- Insight into trade-offs in various circumstances



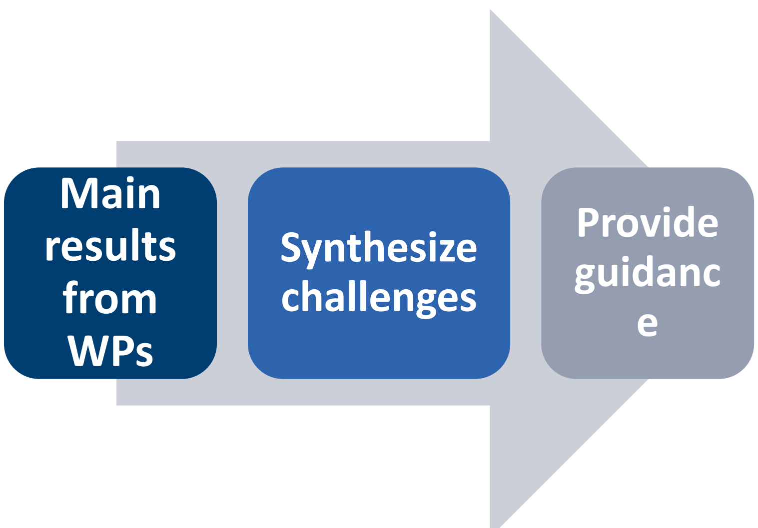
- CCS Impurity Risk Assessment Framework
  - No such framework existed for CCS
  - Detailed interaction with ISO Transport Committee



IMPACTS has Generated: Recommendations Regarding: Impact of CO_2 Quality on entire CCS Value Chain

Synthesize results from WPs

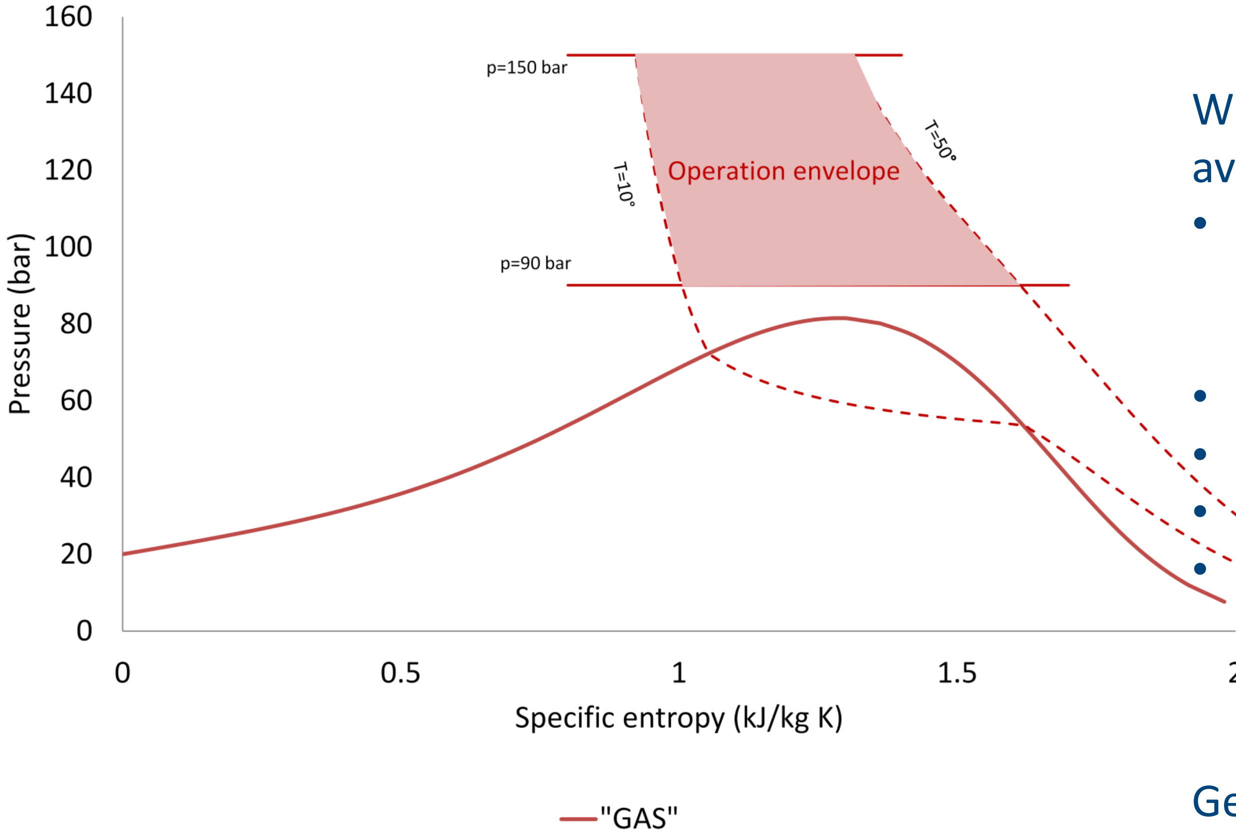
→ Provide guidelines for safe and efficient handling of CCS streams



- Guidelines on the need for upstream conditioning of CO_2 streams (WP1.2)
- Guidelines on the transient operation of pipelines (WP1.3)
- Guidelines on the need for anti-corrosion measures in the CCS chain (WP 1.4)
- Guidelines on the operation and integrity of injection wells (WP1.5 and WP 2.1)
- Guidelines on the choice of storage site and on assurance of reservoir integrity and stability (WP1.5 and WP 2.1)
- Guidelines on the trade-offs between CO_2 composition, CCS system performance targets and the design and cost of the CCS chain (WP2.2)
- Rules of thumb for mixing different of CO_2 qualities in a multi-user transportation system (WP 2.2)
- Framework for risk assessment of CCS considering CO_2 stream with impurities (WP 2.3)

IMPACTS has Improved Design Recommendations for CO_2 Pipelines (SP3)

CO_2 Phase Behaviour with Presence of Impurities, Skaugen et. al (WP3.1)



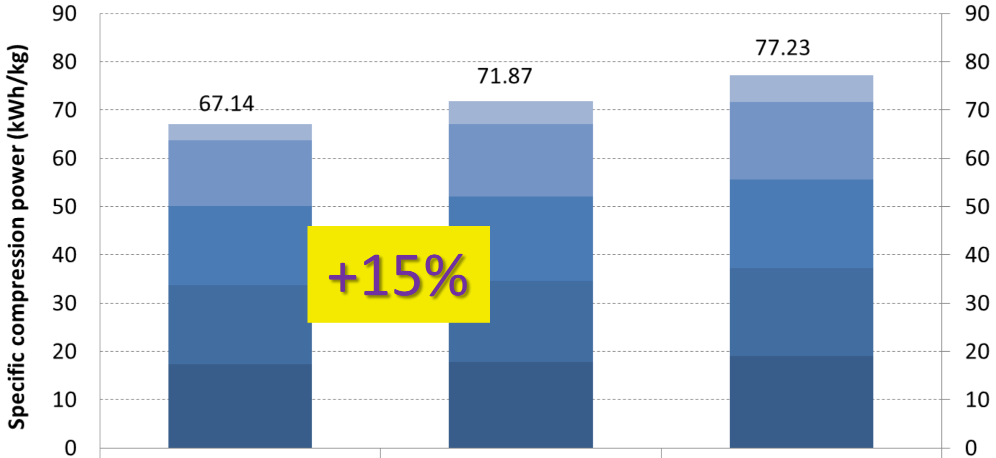
When Dimensioning pipeline to avoid running ductile fracture:

- Cricondenbar pressure is worst case scenario and should be used for dimensioning
- Onshore pipeline 150 bar
- Max ΔP 60 bar before compr
- Assume isentropic expansion
- Crikondenbar pressure is the highest saturation P achieved after exp

Geir Skaugen et.al WP 3.1

IMPACTS has Elucidated Impact of Impurities on Pipeline Operational Conditions

- **Power consumption for conditioning for export**
  Geir Skaugen, et.al (WP3.1)

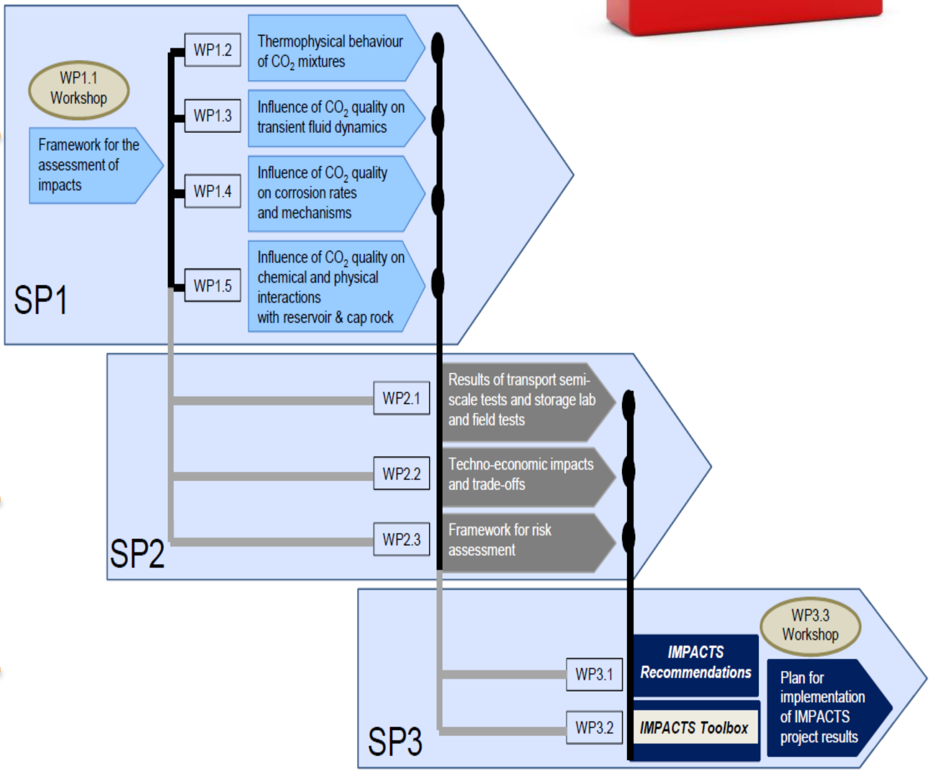


	PURE	BASE	OXY
Export pump	3.39	4.79	5.57
Stage 4	13.66	15.07	16.07
Stage 3	16.33	17.31	18.36
Stage 2	16.44	16.94	18.19
Stage 1	17.31	17.76	19.04
Total	67.14	71.87	77.23

CASE	CO_2	H_2O	N_2	O_2	Methane
«BASE»	93	7			
«OXY»	88	7	3	2	
«GAS»	83	7	1		9

IMPACTS TOOLBOX

- Objective
  - Provide results, tools, models from IMPA
    project to public
  - Cover all areas of IMPACTS research
    - Mixture properties
    - Fluid flow, transport
    - Corrosion
    - Storage
    - Techno-economic assessment of CO
      mixtures in the CCS chain
    - Risk analysis
  - Include recommendations from IMPACTS



IMPACTS has transferred knowledge to the ISO Standard Committee on CO_2 Transportation (WG2)

IMPACTS presented key project results to ISO WG2 on CO_2 Transportation at it's final meeting at Kjeller, Norway on Dec 1st, 2015

- The ISO standard on CO_2 Capture, transportation and geological storage – section on Transport is already in its final stages of issuance.
- IMPACTS has been in continued contact with the ISO Standards committee

NOTICE OF MEETING / REGISTRATION FORM
CONVOCATION / PROJET D'ORDRE DU JOUR

Date 2015-05-26

Reference
ISO/TC 265/WG 2 **N0047**

Title of / Titre du TC/SC
CARBON DIOXIDE, CAPTURE, TRANSPORTATION AND GEOLOGICAL STORAGE - TRANSPORTATION

Secretariat / Secrétariat
DVGW for DIN

Host / Invitant
Institute for Energy Technology (IFE)

MEETING / RÉUNION

Meeting dates		
	2015-12-01	09:00 am – 05:00 pm
	2015-12-02	09:00 am – 05:00 pm
	2015-12-03	09:00 am – 05:00 pm
	2015-12-04	09:00 am – 03:00 pm

Place / Lieu
Institute for Energy Technology (IFE)
Instituttveien 18
NO-2007 Kjeller, Norway

The IMPACTS Network

- Networking and knowledge transfer between research groups and industry is essential for innovation
- 8 workshops and 17 meetings have been held since the start of IMPACTS
- 30 people from 9 different nations have attended workshops

The IMPACTS team at the Hontomin site, March 2014

Karl Erik Karlsen from Gassnova speaking at the IMPACTS workshop on CO2 specifications in current CCS Projects (Photo: SINTEF)

IMPACTS TCCS8 Workshop, June 2015

IMPACTS Dissemination

- Public Dissemination Event at GHGT-12, Austin, TX
- CCS Summer School in Romania, Oct 2015
- Public Final Dissemination Event, Athens, 2015 joint with CO2QUEST
- Special Issue of Papers from Final Event in IJGHGC
- IMPACTS/CO2QUEST Panel at GHGT-13

ghgt-13

IMPACTS CO_2QUEST

2ND INTERNATIONAL FORUM ON RECENT DEVELOPMENTS OF CCS IMPLEMENTATION

LEADING THE WAY TO A LOW-CARBON FUTURE

16TH - 17TH DECEMBER, 2015

ATHENS, GREECE

ST. GEORGE LYCABETTUS HOTEL

IMPACTS Blogs

Blog: Why is Mr. Petrov so engag

Posted on 17. oktober 2014 by BIGCCS

Blogger: Mona J. Mølnvik

In a small room "hidden" in a laboratory at Gløshaugen in the c
Trondheim, Norway, a meeting took place this week between
student Snorre Foss Westman from NTNU, Researcher Sigmu
Størset from SINTEF Energy Research and Scientific Officer N
from the European Commission.

Mr. Petrov was visiting to discuss the mid-term evaluation of the EU project IMPACTS unde
Framework Programme. One objective of IMPACTS is to develop the CO_2 quality knowledge
for defining norms and regulations to ensure safe and reliable design, construction and ope
pipelines and injection equipment.

The impact of the quality of CO2 on transport and behaviour

Highlights from the IMPACTS project – "The impact of the quality of CO2 on transport and st
– a summary of findings presented at workshop during TCCS8.

Marit Jagtøyen Mazzetti CCS, Energy efficiency, Gas technology, Oil and gas Subsea

September 4, 2015 BIGCCS, CCS, IMPACTS 0 Comment

IMPACTS is a PAN European research project where researchers from academia and ir
nine different countries collaborates on investigating impact of impurities in CO_2 captur
plants and other CO_2-intensive industries on CO_2 transport and storage.

All Bioenergy Energy efficiency Energy systems CCS Wind power Hydropower Gas technology Policy Newsletter

Corrosion potentials in CO2 infrastructure – IMPACTS WP1.4

Sintef CCS, Gas technology, Oil and gas / Subsea, Subsea

October 13, 2015 ·Stress corrosion tests, ·Uniform corrosion tests, Centro Sviluppo Materiali, CO2, CO2 mixtures, IMPACTS 0 Comment

Guest blogger: Elisabetta Mecozzi, Head of Structural integrity department at Centro Sviluppo Material (CSM)

CO2 impurities: What else is there in CO2 except CO2?

Sintef CCS, Energy efficiency, Gas technology, Oil and gas / Subsea, Subsea

September 11, 2015 CCS, CO2, CO2 impurities, IMPACTS, TNO 0 Comment

Guest bloggers: Leen van der Ham, Filip Neele, TNO, The Netherlands

> The researchers take part in the IMPACTS project: IMPACTS is a collaborative project co-funded by the European Commission under the 7th Framework Programme. IMPACTS is run by SINTEF Energy Research. Find out more about IMPACTS. One of the tasks of the project is to address the impact of impurities in captured CO_2.

In the IMPACTS project we study the impact of impurities in captured CO_2 on transport and storage. Questions we would like to answer are like these: what is the relation between the quality (level of impurities) of CO_2 and the cost of safe transport and storage? Suppose we save some money and capture less pure CO_2 (if there is such a relation), would that be offset by higher cost for transport and storage because of, for example, corrosion prevention measures? Can we optimize the cost of the entire CCS chain as a function of the quality of the CO_2?

How we study the effects of CO2 impurities in the Lab?

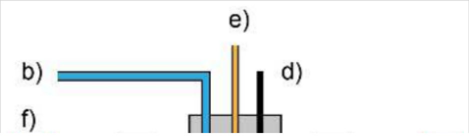
Sintef CCS, Gas technology, Oil and gas / Subsea, Subsea

September 11, 2015 CCS, CO2 impurities, Geochemical, GFZ, IMPACTS, TNO 0 Comment

Guest bloggers: Dr. Michael Hentscher, GFZ German Research Centre for Geosciences and Dr. Svenja Waldmann, TNO

> The researchers take part in the IMPACTS project: IMPACTS is a collaborative project co-funded by the European Commission under the 7th Framework Programme. IMPACTS is run by SINTEF Energy Research. Find out more about IMPACTS.

The first question we have to answer: What does geochemical influence during storage of impure CO_2 mean? The geochemical influence describes chemical reactions of the gas injected in the storage formation and the dissolution of the reaction products into the water phase. This results in increasing water acidity, which furher enhances mineral dissolution reactions? Consequently the formation water chemistry changes over time and additional minerals may precipitate.



IMPACTS has generated:

- **Better equation of state for** CO_2 mixed with all the potential contaminants expected in captured CO_2
- **Inventory of CO_2 mixtures**
  - Defined framework for characterization of impact of impurities on CCS systems
- **Issuance Publicly available TREND software-** Estimates phase transitions at given T, P
- Determined **effect of CO_2 supercritical mixtures on corrosion** of pipeline materials through experimental work
- **Case Study for CO_2 transport with impurities effect on pipeline and shipping**
- **Technoeconomic Analysis**
- **Information to Improve Design Recommendations for CO_2 Pipelines**

Acknowledgements:

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7-ENERGY-20121-1-2STAGE) under grant agreement n° 308809 (The IMPACTS project). The authors acknowledge the project partners and the following funding partners for their contributions: Statoil Petroleum AS, Lundin Norway AS, Gas Natural Fenosa, MAN Diesel & Turbo SE and Vattenfall AB.

Funding partners: