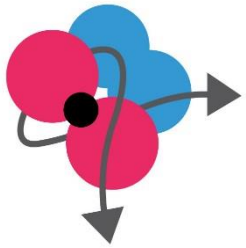
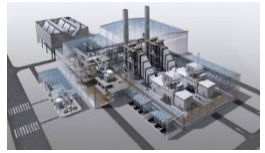
# ELEGANCY
# Enabling a Low-Carbon Economy via Hydrogen and CCS

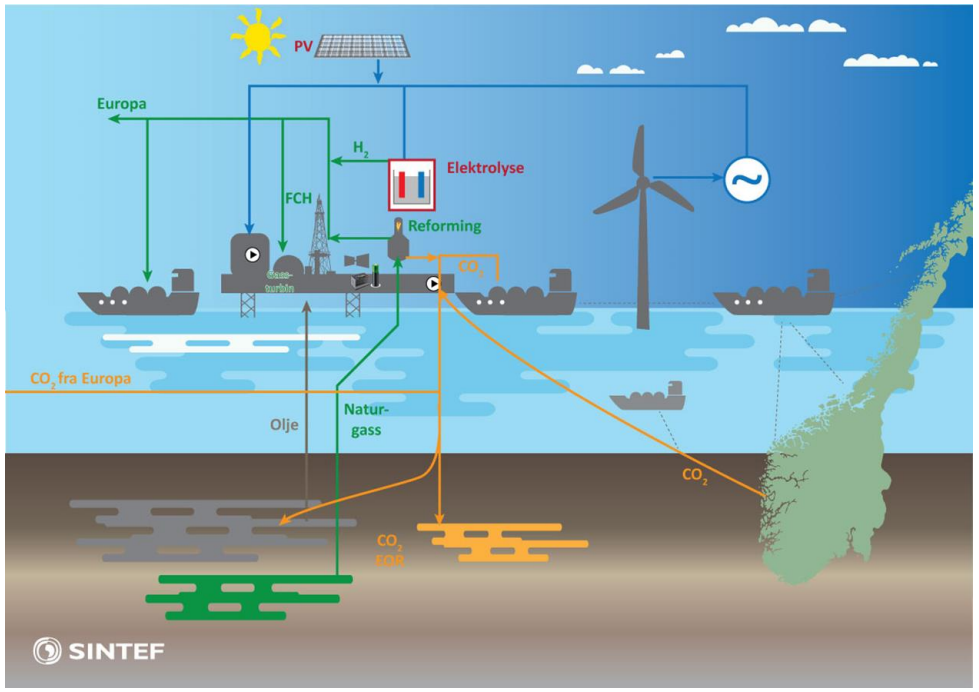


Robert de Kler

2017-11-10

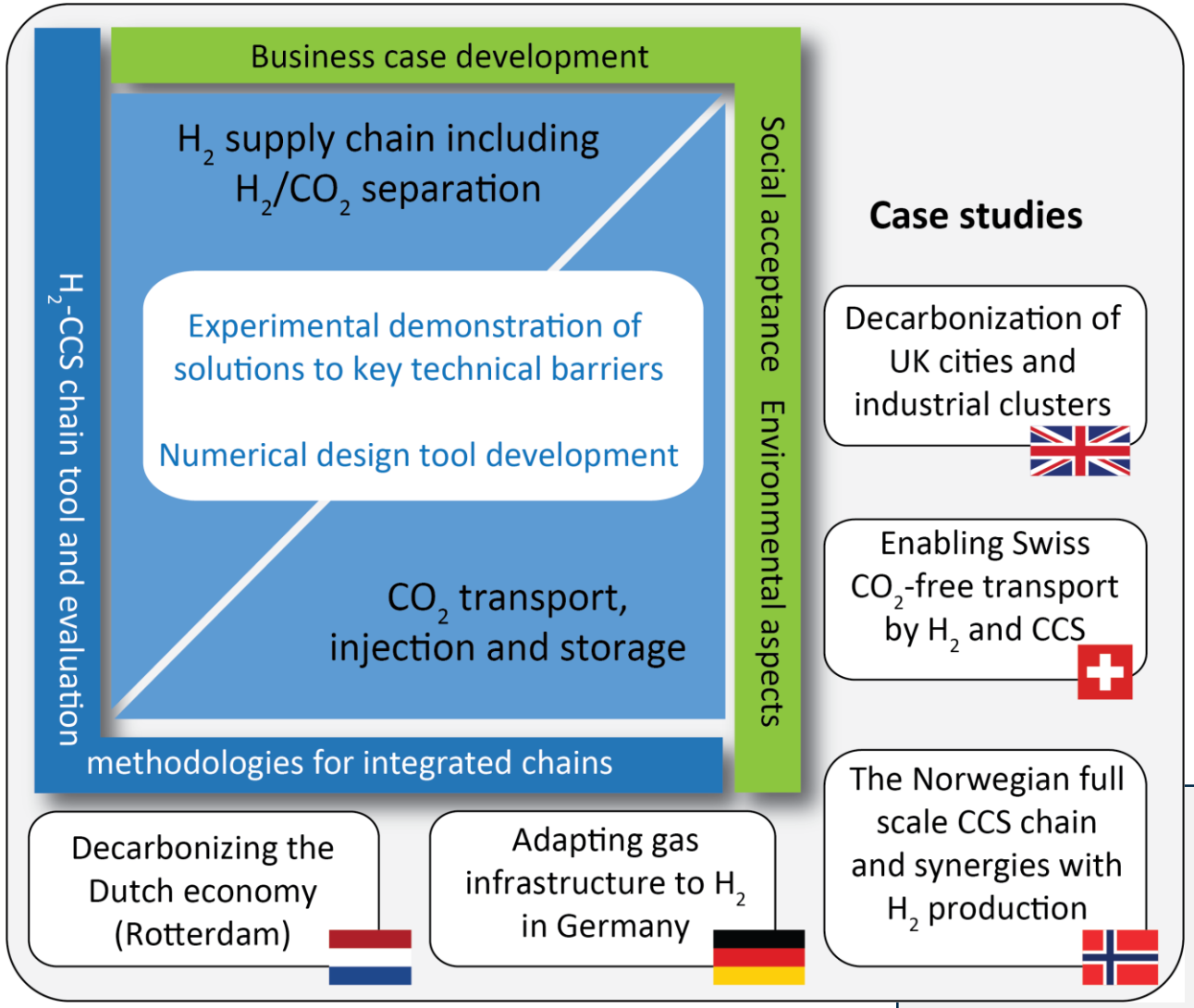
# ELEGANCY – Context






- The low carbon economy needs hydrogen for:
  - Industrial decarbonization
  - Heating and cooling
  - Transport (Marine, Rail, heavy trucks and cars)
- The low carbon economy needs CCS to:
  - Decarbonize industrial emissions
  - Provide a credible carbon negative solution
  - Provide the speed needed in the energy and climate transformation
- Combining hydrogen with CCS offers an exiting opportunity for synergies and value creation
  - Common use of infrastructure and the same offering to the end-user
  - Flexible hydrogen production offering balancing value to the grid
  - Value creation and sustainability from domestic assets on a long term scale
  - Could provide Europe with a unique position in industry, heating and cooling and transport by enabling massive amounts of hydrogen for various uses in society
- ELEGANCY aims at providing stepping stones essential in the realization of the energy system of the future
  - Efficient value chains for large scale hydrogen deployment- the merger of CCS and renewables in the society
  - Solving key technical barriers and providing experimentally validated tools for design of safe and efficient chain elements
  - Enable a credible path for the hydrogen/CCS transition and role in the future low carbon society

# ELEGANCY – key information




**Case studies**

Decarbonization of UK cities and industrial clusters

Enabling Swiss $CO_2$-free transport by $H_2$ and CCS

The Norwegian full scale CCS chain and synergies with $H_2$ production

Decarbonizing the Dutch economy (Rotterdam)

Adapting gas infrastructure to $H_2$ in Germany

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
Sustainable Decisions
Imperial College London
INEOS
Scottish Enterprise

ETH zürich
CLIMEWORKS
firstclimate

Statoil
SINTEF
GASSCO
UiO : University of Oslo
AkerSolutions

ECN
TNO innovation for life

RUHR UNIVERSITÄT BOCHUM
RUB
uni per
Open Grid Europe
The Gas Wheel

- Duration: 2017-08-31 to 2020-08-31.
- Preliminary budget: 15 643 kEUR.

# ELEGANCY – work packages & chains

**Case studies incl. social acceptance, environmental aspects and CCS-$H_2$ market considerations:** UK (large-scale decarbonization), Netherlands (Rotterdam decarbonization), Norway (full scale CCS chain and $H_2$ production), Switzerland (decarbonization of transport sector), Germany (adapting gas infrastructure and processes to $H_2$) **WP5**

**$H_2$-CCS chain tool and evaluation methodologies for integrated chains:** (ICL, SINTEF, PSI, RUB, TNO) **WP4**

**Business case development:** (AdeB,FirstClimate,SDL) **WP3**

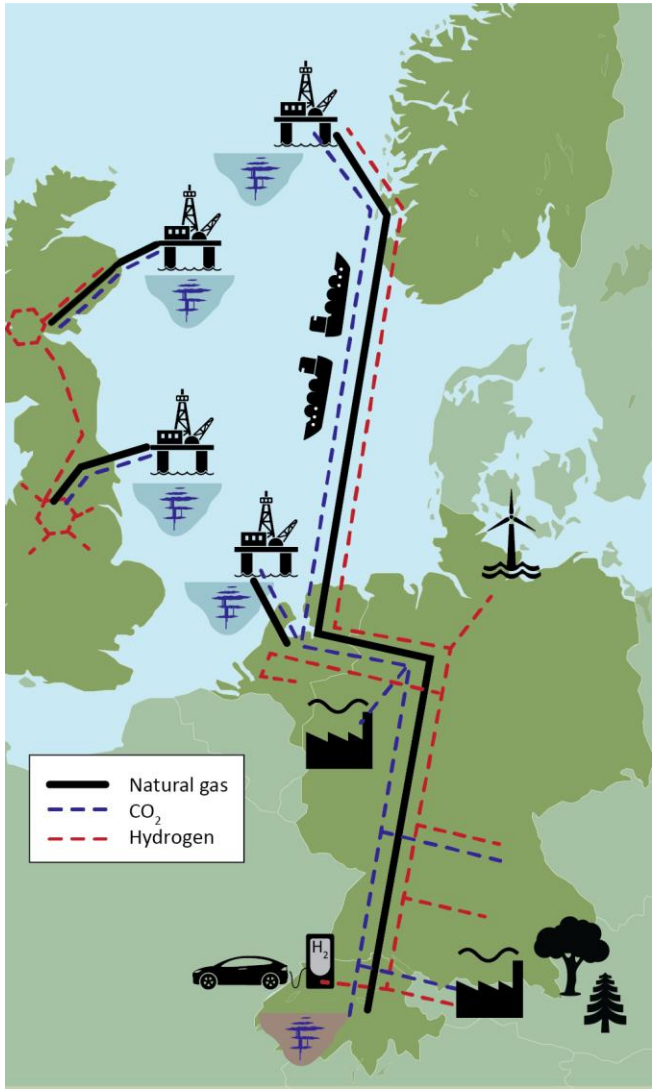
## $H_2$ supply chain including $H_2/CO_2$ separation **WP1**

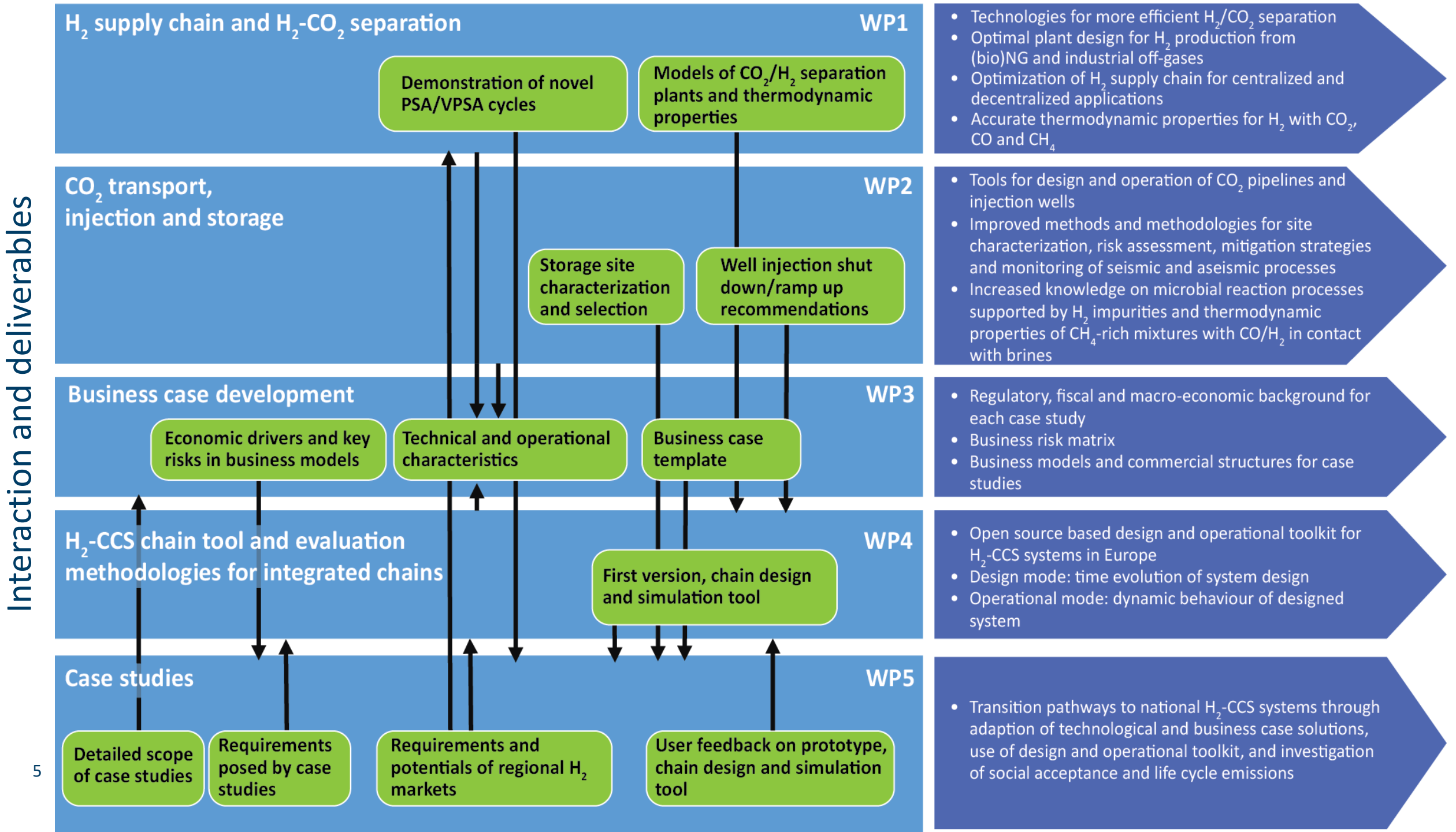
- $H_2$ from natural gas (ETH, PSI)
- $H_2$ from other sources (ECN)
- Characterization of $CO_2$-CO-$H_2$ mixtures (RUB)

## $CO_2$ transport, injection and storage **WP2**

- $CO_2$-brine model (RUB,ICL)
- $CO_2$ transport-injection interface (SINTEF)
- Storage-site characterization and selection (ICL)
- Mt. Terri decametre scale experiment (ETH)
- Impact of $H_2$ in the $CO_2$ stream on storage (BGS)
- De-risking storage

**ELEGANCY project management, network building and dissemination** (SINTEF) **WP6**



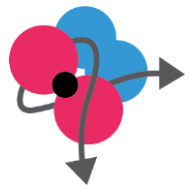

Interaction and deliverables
$H_2$ supply chain and $H_2$-$CO_2$ separation
WP1
Demonstration of novel PSA/VPSA cycles
Models of $CO_2$/$H_2$ separation plants and thermodynamic properties
$CO_2$ transport, injection and storage
WP2
Storage site characterization and selection
Well injection shut down/ramp up recommendations
Business case development
WP3
Economic drivers and key risks in business models
Technical and operational characteristics
Business case template
$H_2$-CCS chain tool and evaluation methodologies for integrated chains
WP4
First version, chain design and simulation tool
Case studies
WP5
Detailed scope of case studies
Requirements posed by case studies
Requirements and potentials of regional $H_2$ markets
User feedback on prototype, chain design and simulation tool
• Technologies for more efficient $H_2$/$CO_2$ separation
• Optimal plant design for $H_2$ production from (bio)NG and industrial off-gases
• Optimization of $H_2$ supply chain for centralized and decentralized applications
• Accurate thermodynamic properties for $H_2$ with $CO_2$, CO and $CH_4$
• Tools for design and operation of $CO_2$ pipelines and injection wells
• Improved methods and methodologies for site characterization, risk assessment, mitigation strategies and monitoring of seismic and aseismic processes
• Increased knowledge on microbial reaction processes supported by $H_2$ impurities and thermodynamic properties of $CH_4$-rich mixtures with CO/$H_2$ in contact with brines
• Regulatory, fiscal and macro-economic background for each case study
• Business risk matrix
• Business models and commercial structures for case studies
• Open source based design and operational toolkit for $H_2$-CCS systems in Europe
• Design mode: time evolution of system design
• Operational mode: dynamic behaviour of designed system
• Transition pathways to national $H_2$-CCS systems through adaption of technological and business case solutions, use of design and operational toolkit, and investigation of social acceptance and life cycle emissions

# World-class research infrastructure

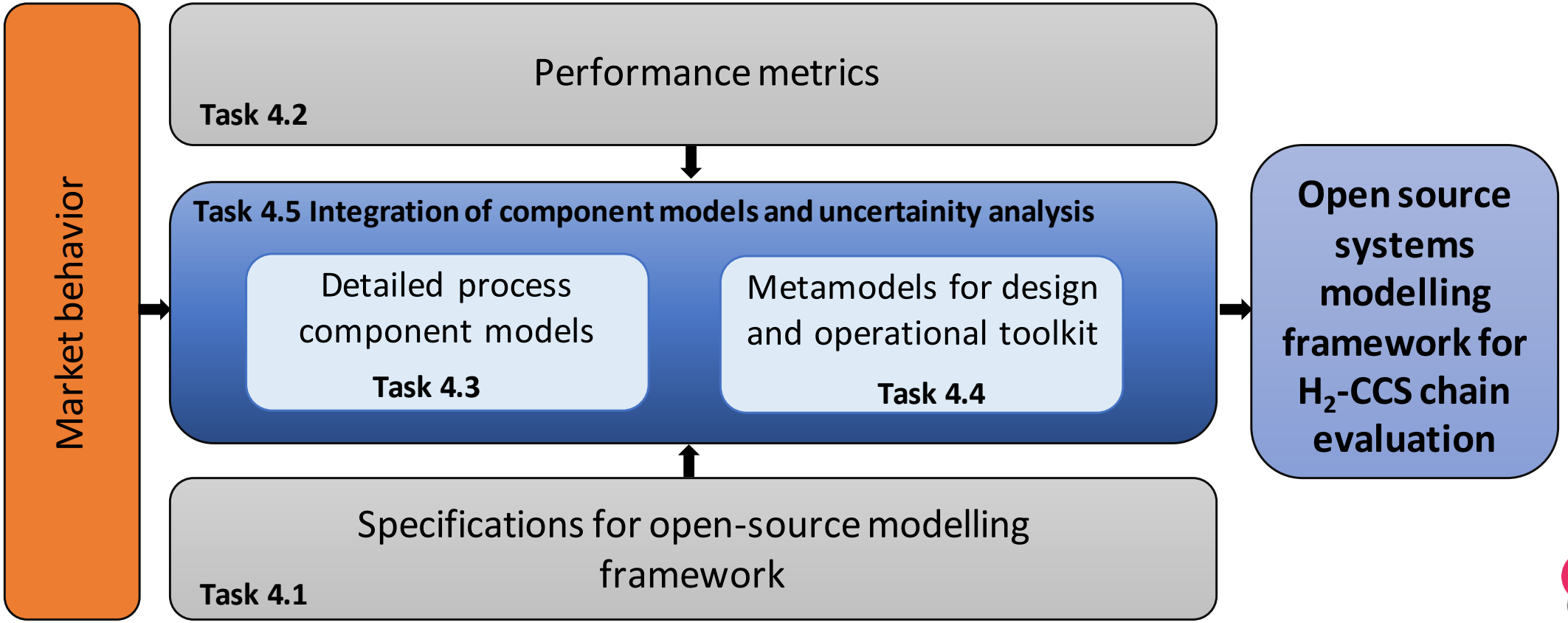
| Description | Scale | Partner |
|---|---|---|
| Adsorption infrastructure (ECCSEL) | Lab-scale | ETH |
| Cycling adsorbent analyser | Lab-scale | ECN |
| Single- and multi-column reactive PSA/TSA equipment | Pre-pilot, TRL 5 | ECN |
| Equipment for measurements of density, speed of sound and dielectric permittivity | Lab-scale | RUB |
| Vertical flow facility | Pilot-scale | SINTEF |
| Pipe and vessel depressurization (ECCSEL) | Lab-scale | SINTEF |
| Core-flooding laboratory | Lab-scale | ICL |
| Batch-reactor for mineral-dissolution kinetics | Lab-scale | ICL |
| Equipment for measurements of $CO_2$-brine-mineral contact angle, interfacial tension and phase behaviour | Lab-scale | ICL |
| Hydrothermal laboratory (ECCSEL) | Lab-scale | BGS |
| Geo-microbiology laboratory (ECCSEL) | Lab-scale | BGS |
| Rock deformation laboratory (ECCSEL) | Lab-scale | SCCER |
| Micro-seismic monitoring arrays | Lab-scale | SCCER |
| Mt. Terri research rock laboratory (EPOS) | Pilot-scale | SCCER |

# Thanks





# $H_2$-CCS chain tool and evaluation methodologies for integrated chains



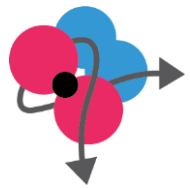
# WP1: $H_2$ supply chain and $H_2$-$CO_2$ separation

- **ETH**, PSI, ECN, MEFOS, RUB, UU
- Enable efficient $H_2$ production and $CO_2$ capture at different plant sizes.
- Find ways to increase the efficiency and productivity of natural gas/biogas reforming and $CO_2$/$H_2$ separation independently of the plant size.
- Integrate $H_2$ production and $CO_2$ capture with significant industrial processes such as steel production
- Characterize the properties of $H_2$ mixed with $CO_2$, CO, and $CH_4$.
- The research spans the range from the phenomenon level (RUB) via lab-scale experiments (ETH and ECN) to the pre-pilot scale (ECN).

# WP2: $CO_2$ transport, injection and storage

- **SINTEF**, BGS, SCCER, ICL, RUB – *De-risk storage*.
- Develop an accurate property model for $CO_2$-brine in the presence of impurities.
- Mature and validate tools for the safe, efficient and cost-effective design and operation of $CO_2$ pipelines and injection wells.
- Perform petrophysical chemical analyses for the characterization and selection of storage sites in Switzerland.
- Design and perform decameter-scale experiments at the Mt Terri research rock laboratory.
- Reduce uncertainties in injection, storage and monitoring of $CO_2$ produced by NG reforming for $H_2$ production.





# WP3: Business case development for $H_2$-CCS integrated chains

- New partner, SDL, FC
- Assess the regulatory background, identify barriers, mitigation strategies and opportunities for $H_2$-CCS.
- Assess the macro-economic, market and fiscal background to identify plausible business models.
- Develop business models and business case templates for use in the WP5 case studies.

# WP4: $H_2$-CCS chain tool and evaluation methodologies for integrated chains

- **ICL**, SINTEF, PSI, RUB, TNO
- Enable the evaluation of integrated $H_2$-CCS chains with respect to technological and economic efficiency, operability and environmental impact
- Develop an open-source systems modelling framework with a steady-state design mode and a dynamic operational mode.
- Develop multiscale models and an integrated modelling approach for the chain components incorporating results from WP1 and WP2.
- Apply the methodology in conjunction with the case studies in WP5 with respect to (i) the potential time evolution of the system and (ii) integrated assessments of proposed designs.

# WP5: Case studies

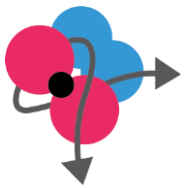
- **SINTEF**, BGS, TNO, UU, ECN, RUB, PSI, ICL, SDL, ETH, SCCER, CW, FC, INEOS, SE, AKSO, GERG
- Develop a roadmap for decarbonizing the Rotterdam industry
- Decarbonize the Swiss transport sector and prepare the way for a Swiss $CO_2$ storage site
- Support the UK H21 roadmap
- Decarbonize German natural gas as an energy carrier
- Evaluate the benefit of converting Norway's NG resources to $H_2$ with CCS

# Status

- 1. August: Consortium Agreement signed
- 8 September: ACT R&D Project Agreement Document signed
- 19–20 September: Kick-off meeting (Brussels)
- ELEGANCY has a
  - relevant
  - ambitious
  - high quality

  work plan.
- I think we can make a difference.





# Acknowledgement

ACT ELEGANCY, Project No 271498, has received funding from DETEC (CH), FZJ/PtJ (DE), RVO (NL), Gassnova (NO), BEIS (UK), Gassco AS and Statoil Petroleum AS, and is cofunded by the European Commission under the Horizon 2020 programme, ACT Grant Agreement No 691712.

# ELEGANCY – objectives

Fast-track the decarbonization of Europe's energy system by exploiting the synergies between two key low-carbon technologies: CCS and $H_2$. To this end, **ELEGANCY will:**

- Develop and demonstrate effective CCS technologies with high industrial relevance
- Identify and promote business opportunities for industrial CCS enabled by $H_2$ as a key energy carrier by performing 5 national case studies
- Validate key elements of the CCS chain by frontier pilot- and laboratory-scale experiments using inter alia ECCSEL and EPOS research infrastructure
- Optimize combined systems for $H_2$ production and $H_2$-$CO_2$ separation
- De-risk storage of $CO_2$ from $H_2$ production by providing experimental data and validated models
- Develop simulators enabling safe, cost-efficient design and operation of key elements of the CCS chain
- Provide an open source techno-economic design and operation simulation tool for the full CCS chain, including $H_2$ as energy carrier
- Assess societal support of key elements of CCS