Enabling a Low-Carbon Economy via Hydrogen and CCS

Svend Tollak Munkejord, SINTEF Energy Research, project coordinator

http://www.elegancy.no/

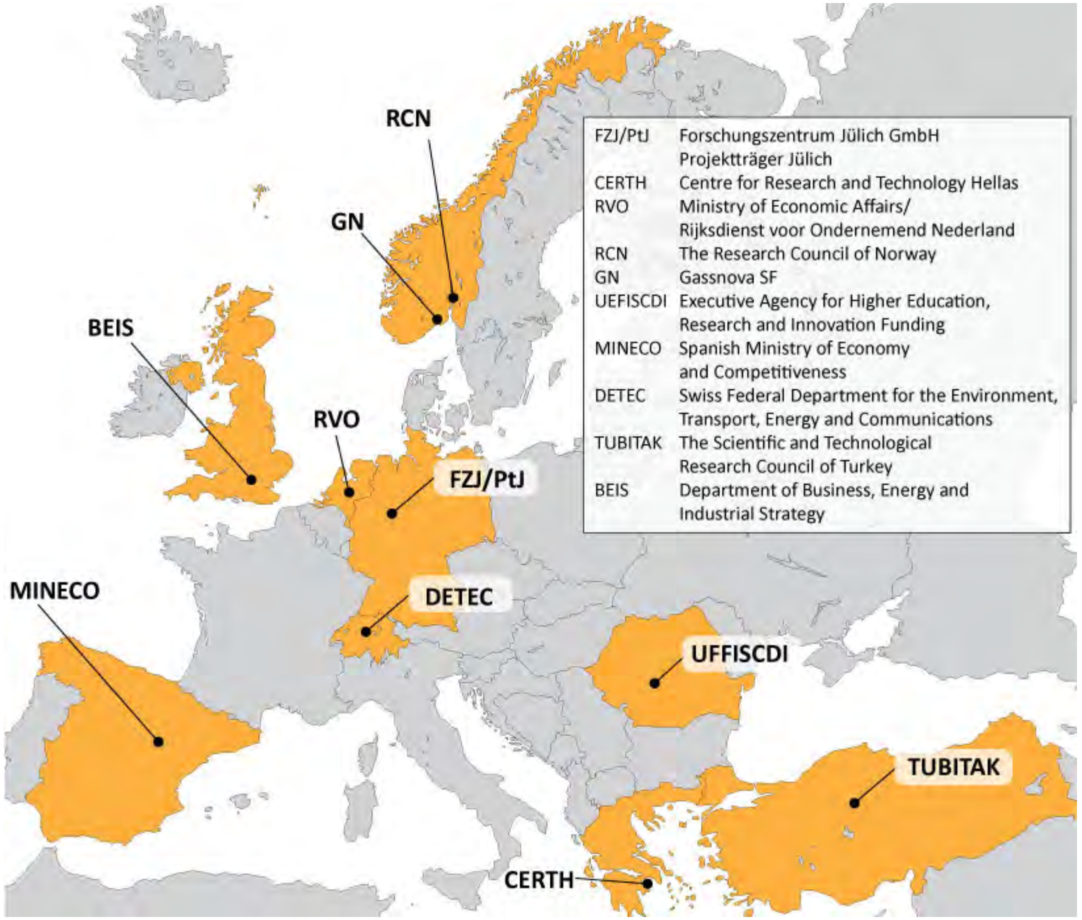
CSLF Technical Group Meeting, Venice, 2018-04-23

Outline of presentation

- Briefly about
  - SINTEF
  - The ERA-NET ACT project
- ELEGANCY
  - Aim
  - Approach
  - Some details

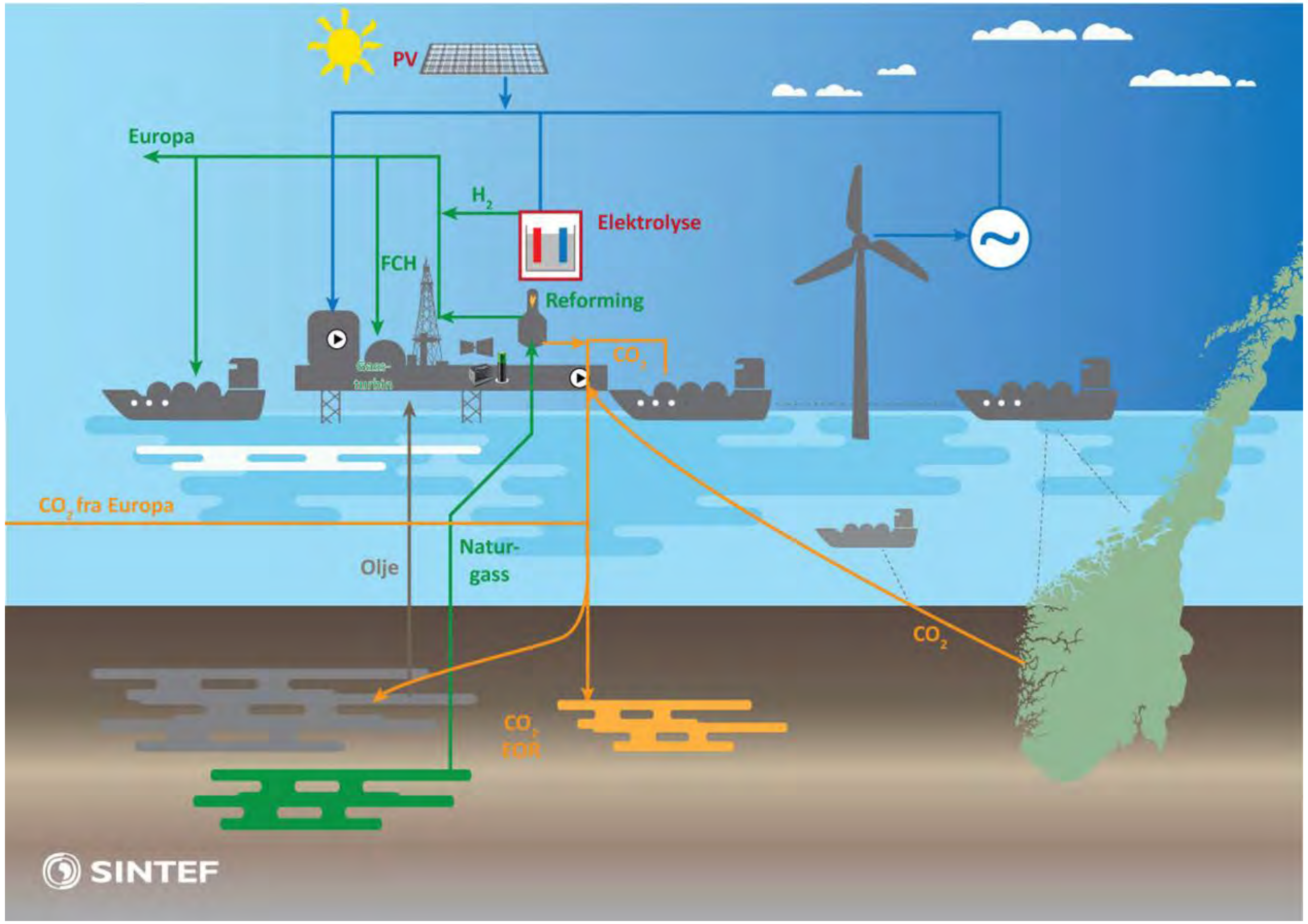

NTNU
CO_2
H_2
NTNU
SINTEF

ERA-NET ACT



- Accelerating CCS Technologies
- H2020
- Ten partners from nine countries
- Led by The Research Council of Norway
- First call budget: 41 MEUR

ELEGANCY – context



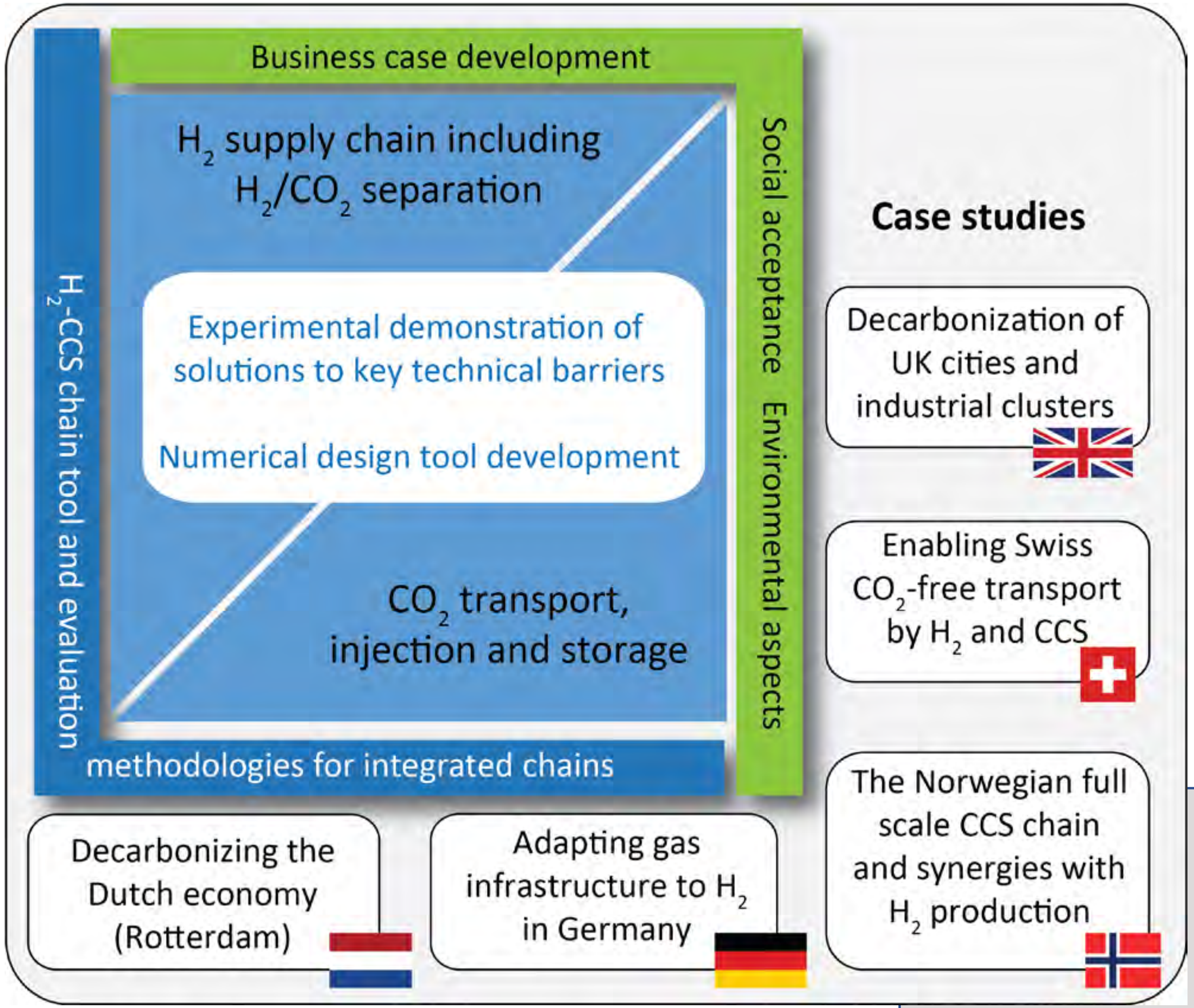
- The low-carbon economy needs H_2
- The low carbon economy needs CCS
- Combining hydrogen with CCS offers an exciting opportunity for synergies and value creation
- ELEGANCY aims at contributing to fast-track the decarbonization of the European energy system

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

ELEGANCY – key information



Sustainable Decisions

- Duration: 2017-08-31 to 2020-08-31.
- Budget: 15 599 kEUR

ELEGANCY – work packages

Case studies incl. social acceptance, environmental aspects and $CCS\text{-}H_2$ 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: (UiO,FirstClimate,SDL) **WP3**

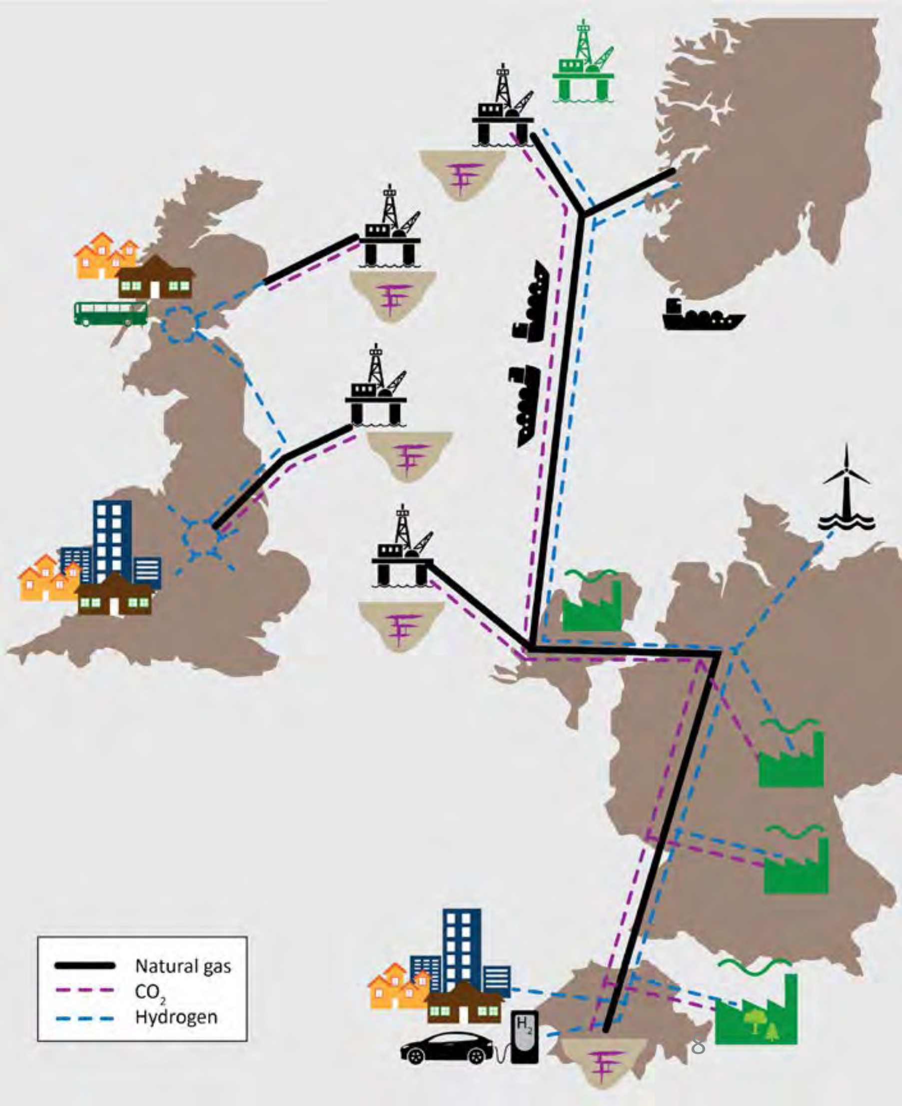
H_2 supply chain including H_2/CO_2 separation **WP1**

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

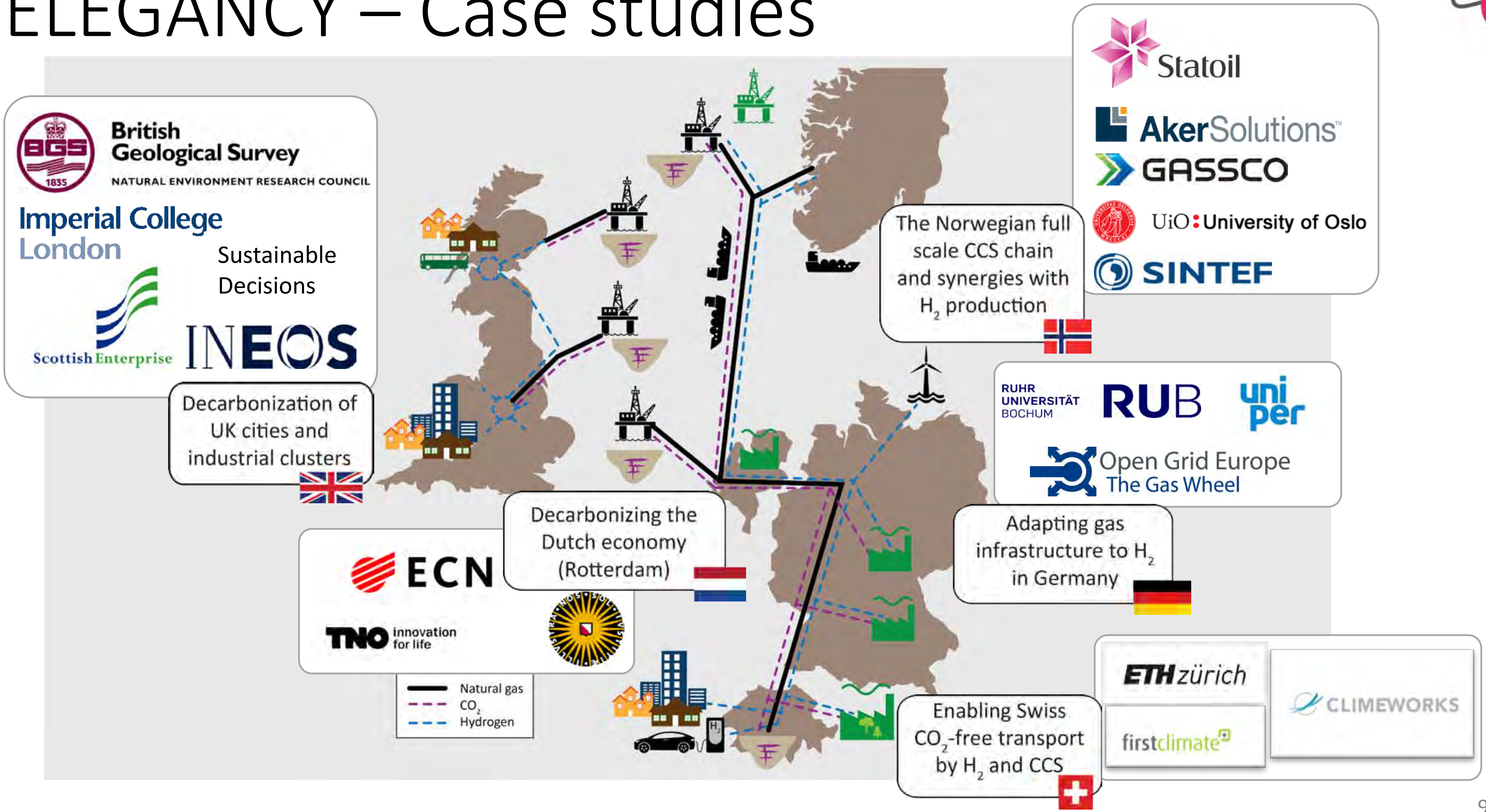
CO_2 transport, injection and storage **WP2**

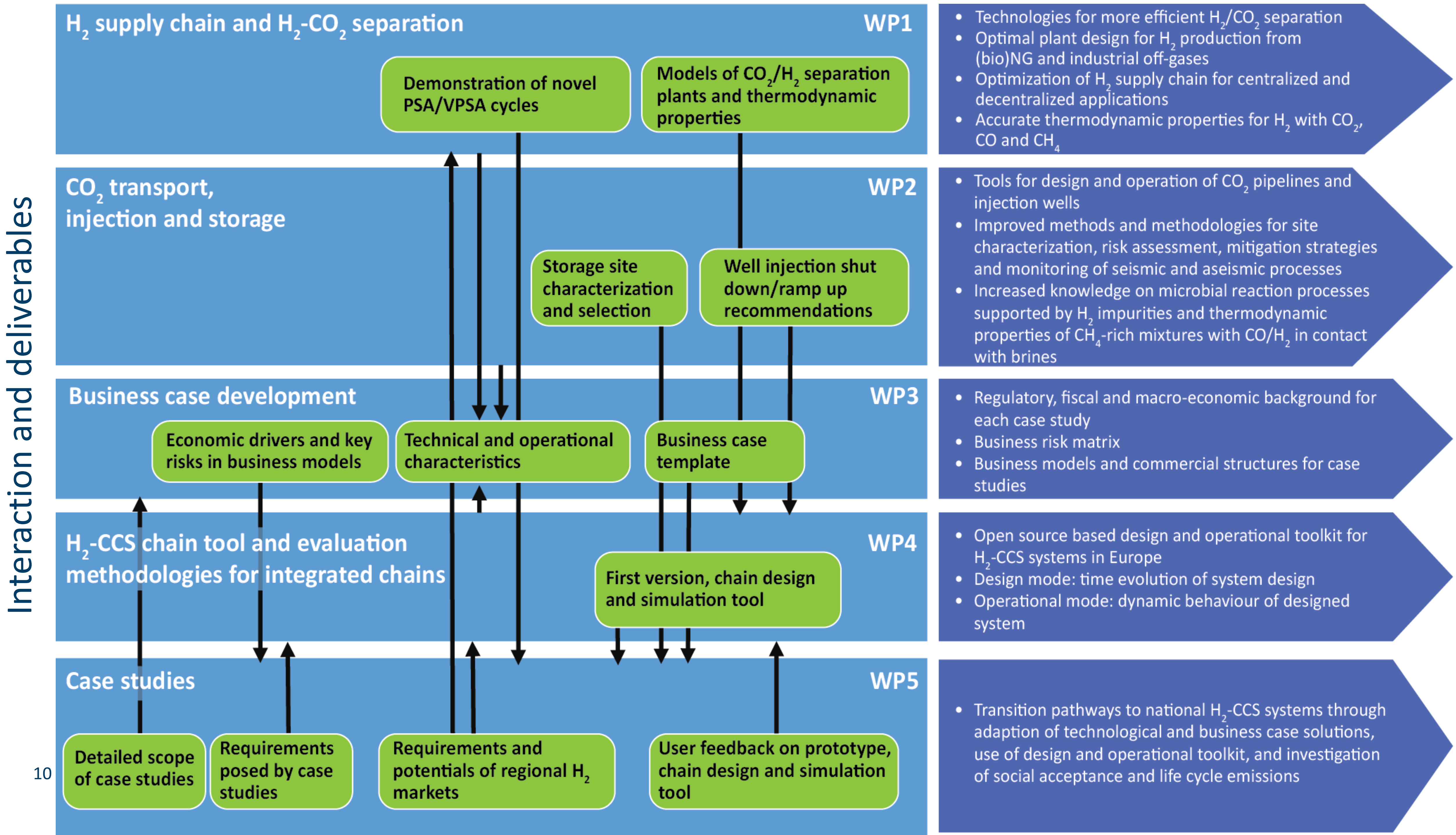
- CO_2-brine model (RUB,ICL)
- CO_2 transport-injection interface (SINTEF)
- Storage-site characterization and selection (ICL)
- Mt. Terri decametre scale experiment (ETH)
- Impact of H_2 in the CO_2 stream on storage (BGS)
- De-risking storage

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



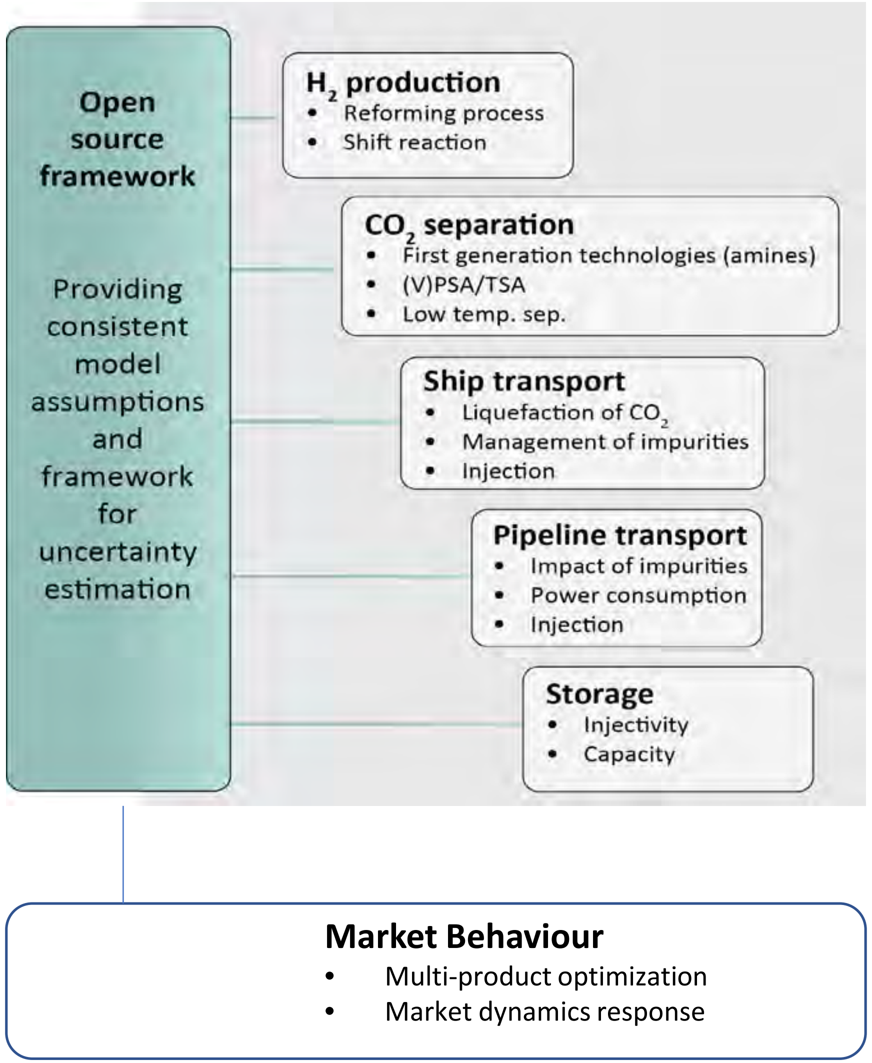
ELEGANCY – Case studies




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
• 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
CO_2 transport, injection and storage
WP2
Storage site characterization and selection
Well injection shut down/ramp up recommendations
• 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
Business case development
WP3
Economic drivers and key risks in business models
Technical and operational characteristics
Business case template
• Regulatory, fiscal and macro-economic background for each case study
• Business risk matrix
• Business models and commercial structures for case studies
H_2-CCS chain tool and evaluation methodologies for integrated chains
WP4
First version, chain design and simulation tool
• 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
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
• 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

H_2-CCS chain tool and evaluation methodologies for integrated chains

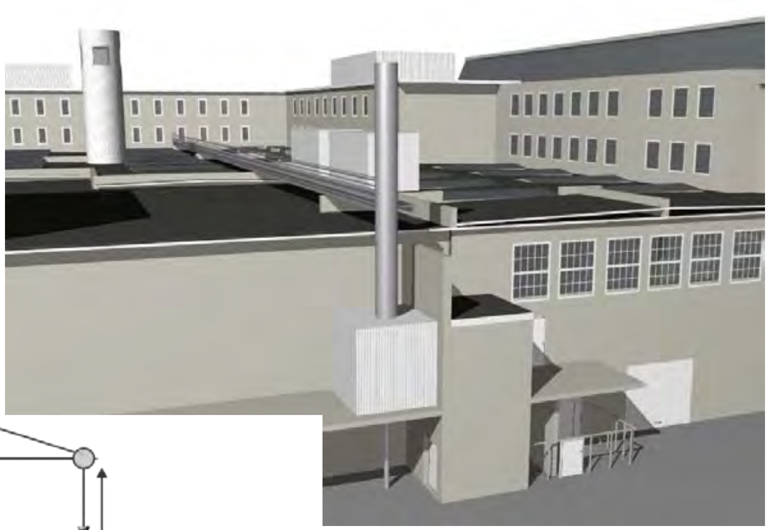
- Open-source framework
  - More widespread use
  - More dynamic
- 'Open' or 'closed' modules
- Stationary design mode
- Dynamic operation mode
- Multi-scale models for the chain components

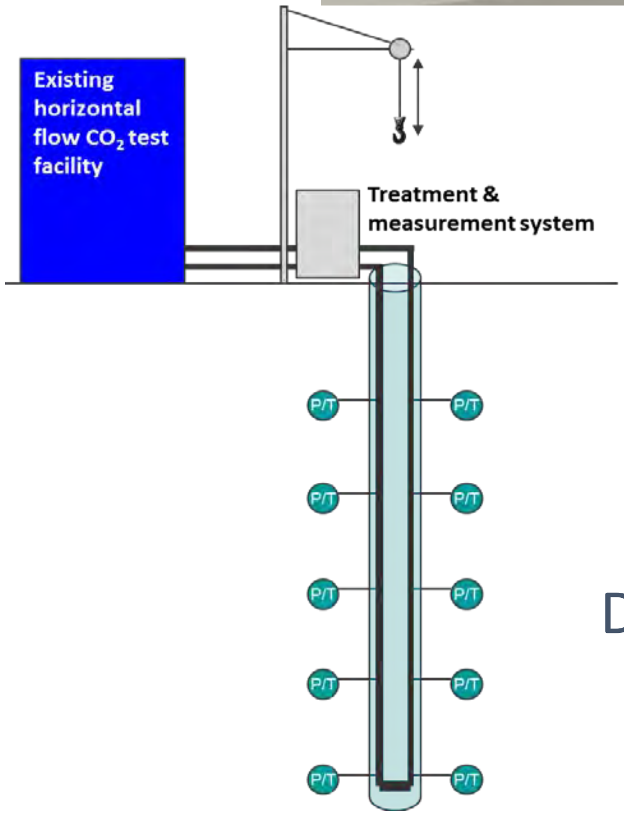


World-class research infrastructure

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

Well flow and transport-storage interface





- Horizontal depressurization
- Vertical flow
- Development of tools for safe, efficient and economic design and operation of CO_2 pipelines and injection wells

DeFACTO

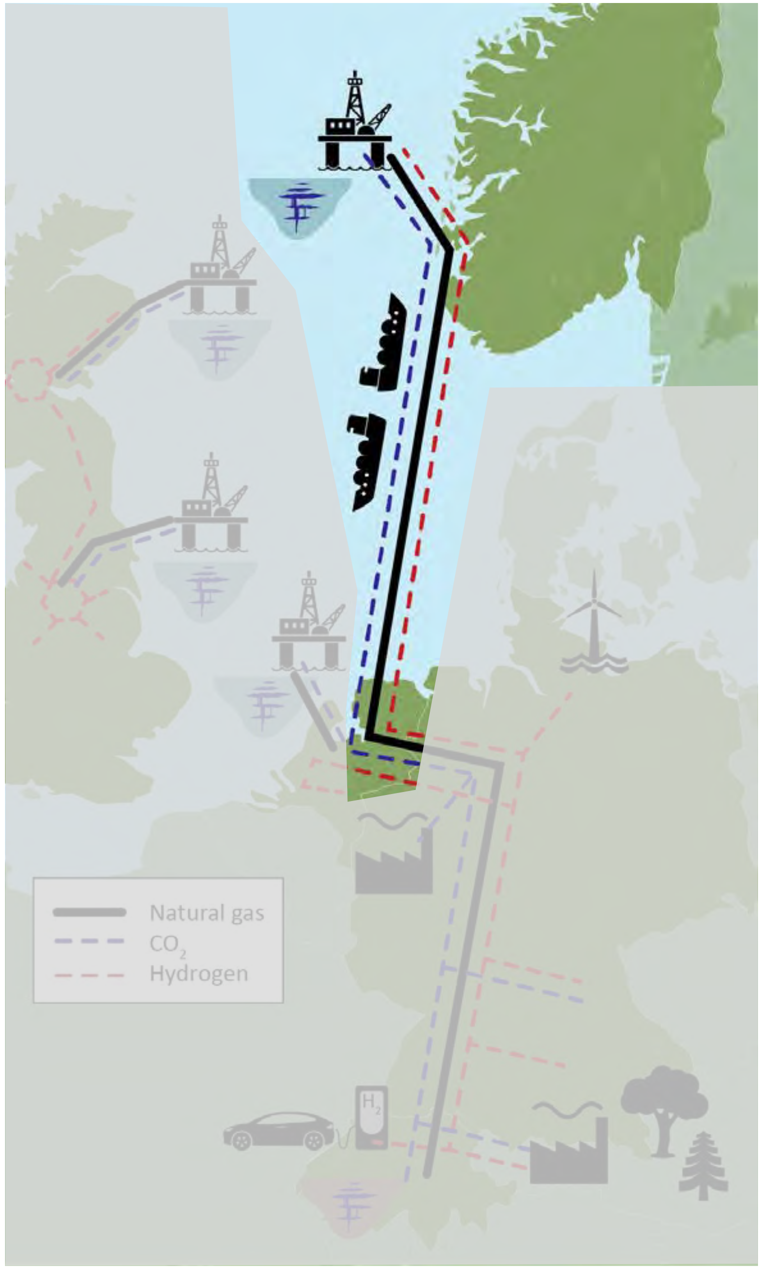
European Carbon Dioxide Capture and Storage Laboratory Infrastructure

Norwegian case study in ELEGANCY

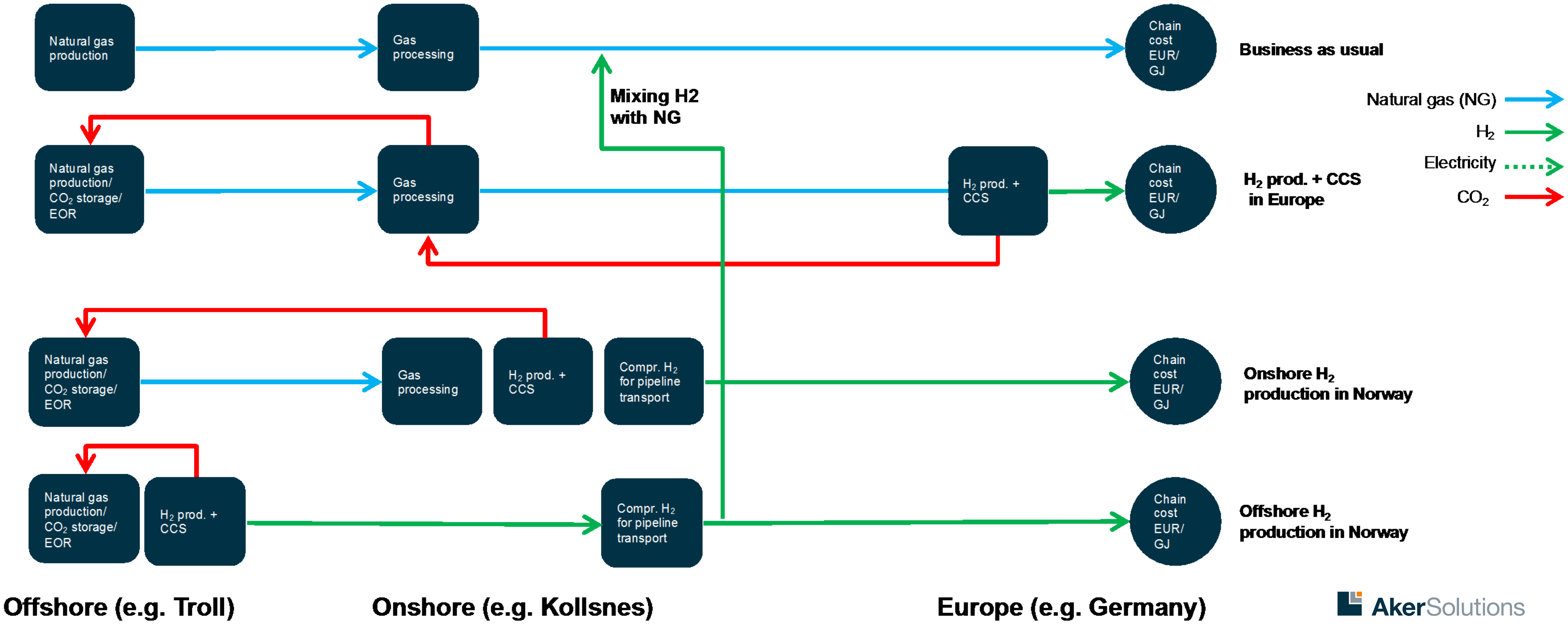
- Partners: SINTEF, Aker Solutions, Statoil, Gassco

Objective:
Identify and develop a business case for a Norwegian H_2 value chain based primarily on natural gas

- Can H_2 produced from Norwegian natural gas be a cost efficient way to decarbonize Europe?
- Can export of H_2 (from natural gas with central CCS) be more economical than export of natural gas and distributed CCS?
- Are there synergies with the Norwegian Full Scale CCS project that can be leveraged?
- Can offshore hydrogen production with CCS/EOR be more economical than onshore hydrogen production with CCS/EOR?

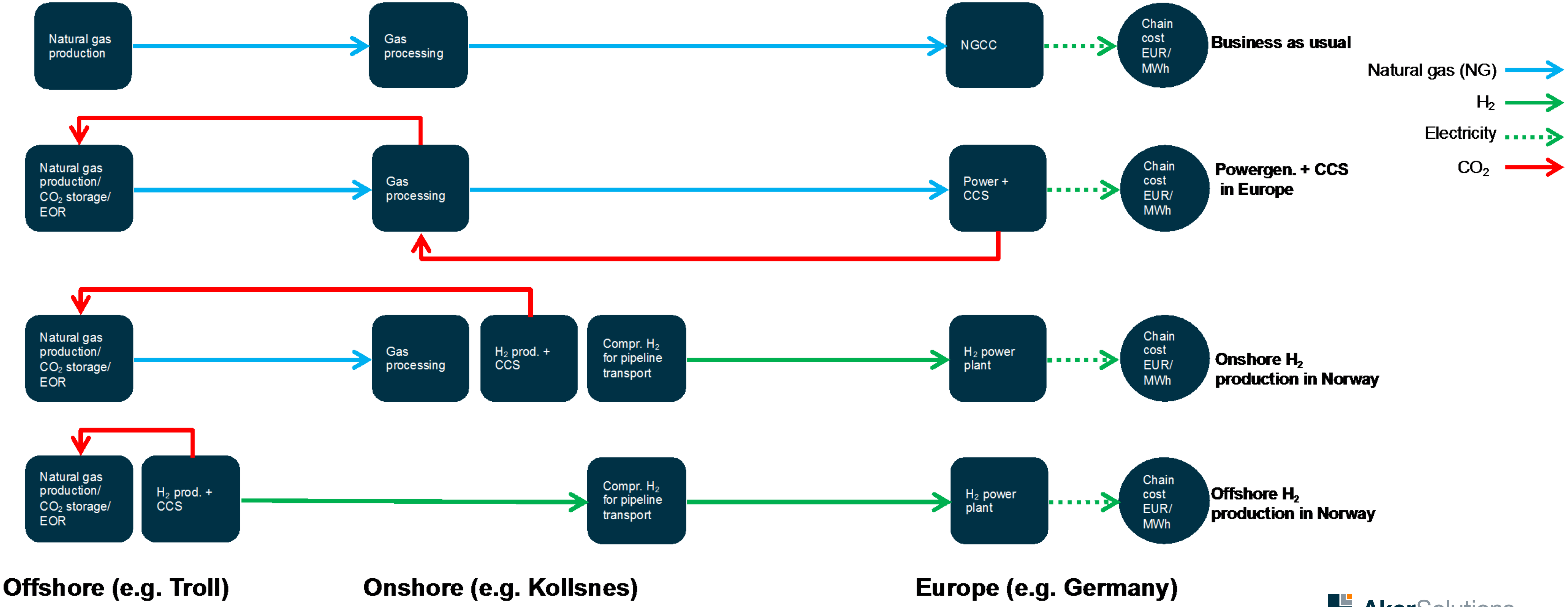


European fuel market - supply options



AkerSolutions

European electricity market – local power generation



AkerSolutions

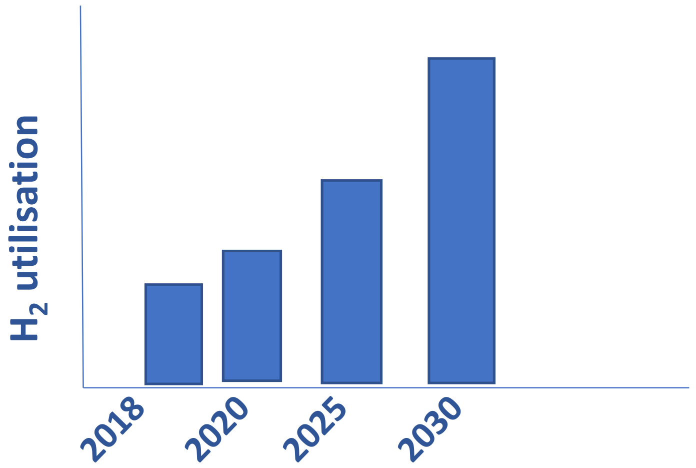
Define H_2 utilisation scenarios

Transport sector
- Cars
- Taxis
- Buses
- Ferries

Industrial sector
- Feedstock (Refining, Ammonia, methanol, petrochemical)
- Fuel (combustion)
- Reducing agent (metal industry

Residential sector
- Home heating
- Fuel cells

Energy sector
- H_2 fired gas turbines
- Fuel cells

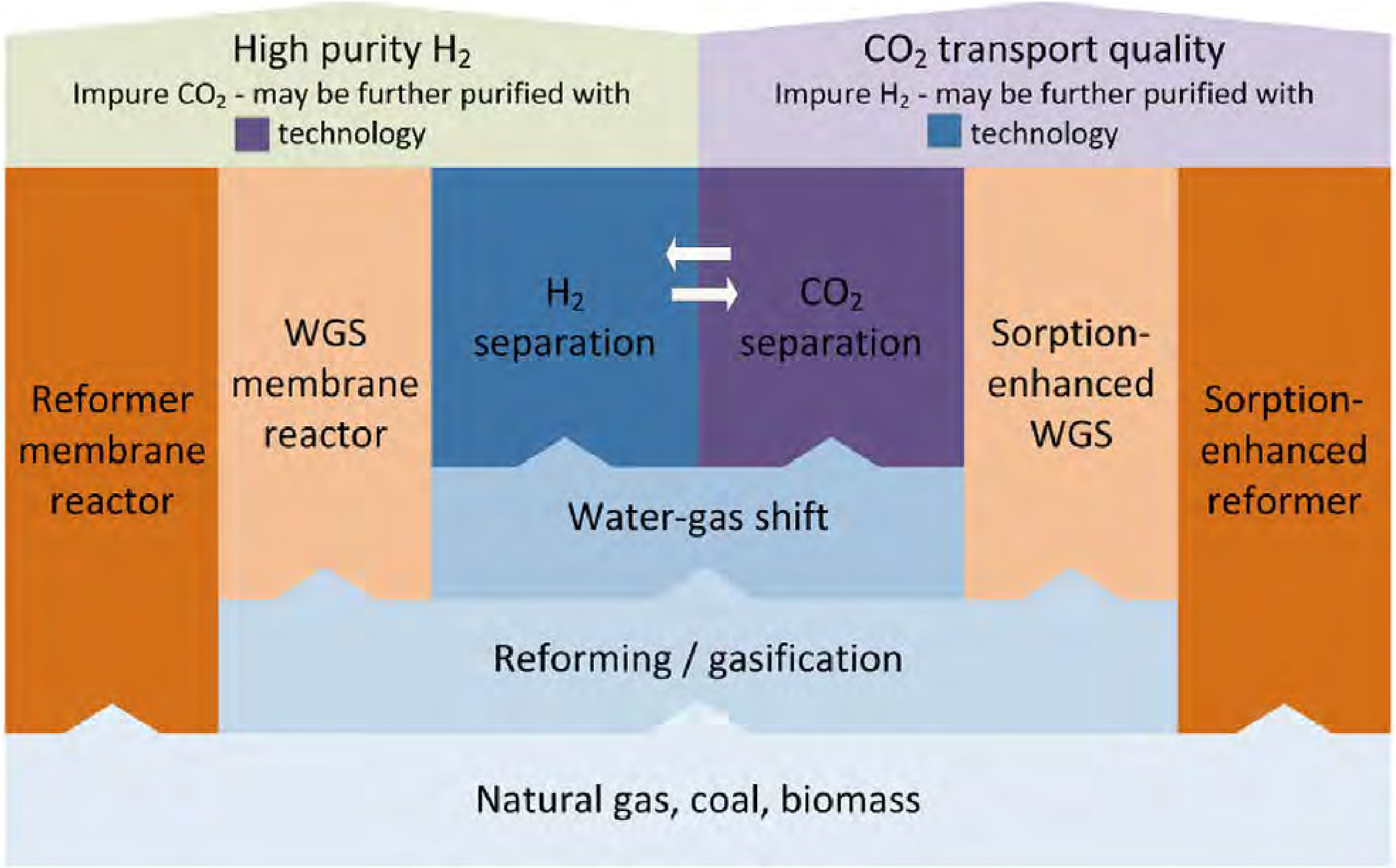


		H_2 purity (min) [%]	Impurity limits (max) [ppm]
Refining		~95	S: low levels
Ammonia		23–25 (N_2:74–77)	CO_2, CO, H_2O and S: low levels
PEM fuel cells for automotive purposes		99.97	H_2O:5, HC:2, O_2:5, He:300, N_2 + Ar:100, CO_2:2, CO:0.2, S:0.004, NH_3:0.1
			H_2O:5, HC:100, O_2:5, He + N_2 + Ar:500, CO_2:2, CO:0.5, S:0.01, NH_3:0.1
PEM fuel cells for stationary purposes[a]	Cat. 1	50	H_2O:NC, HC:10, O_2:200, N_2 + Ar + He:50%, CO:10, S:0.004
	Cat. 2	50	H_2O:NC, HC:2, O_2:200, N_2 + Ar + He:50%, CO:10, S:0.004
	Cat. 3	99.9	H_2O:NC, HC:2, O_2:50, N_2 + Ar + He:0.1%, CO:2, S:0.004
Gas turbines		Low	Limited amount of Na, K, V and S
Industrial fuel (eg. power generation or heat energy source)		99.90[b]	H_2O:NC, HC:NC, O_2:100, N_2:400, S:10

NC = not to be condensed, HC = Hydrocarbons on methane basis, S = Sulfur compounds.
[a] The categories are defined to meet the needs of different stationary applications.
[b] This value is from an ISO standard and should not be taken as a definite limit.

Voldsund, M., Jordal, K. and Anantharaman, R. (2016) 'Hydrogen production with CO2 capture', *International Journal of Hydrogen Energy*, 41(9)

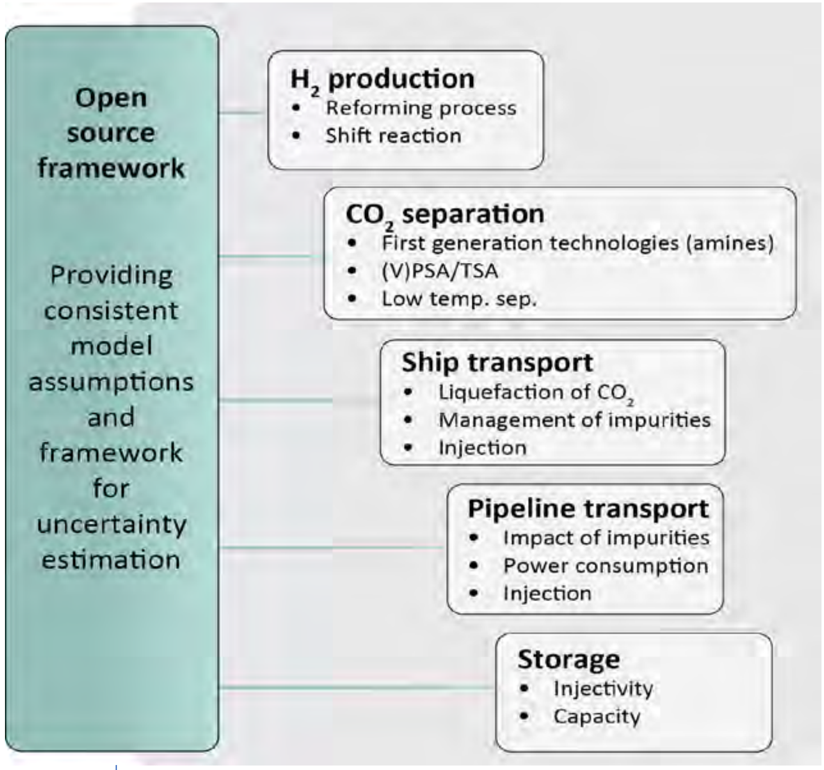
Identify suitable technologies for H_2 production, CO_2 purification and transport



Utilise Value Chain Tool to develop business case

H_2 utilisation scenarios

Norwegian full scale CCS system



Market Behaviour

- Multi-product optimization
- Market dynamics response

Norwegian H_2 value chain
+
Answers to questions raised in the Norwegian Case


ELEGANCY will fast-track
the decarbonization of
Europe’s energy system

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.