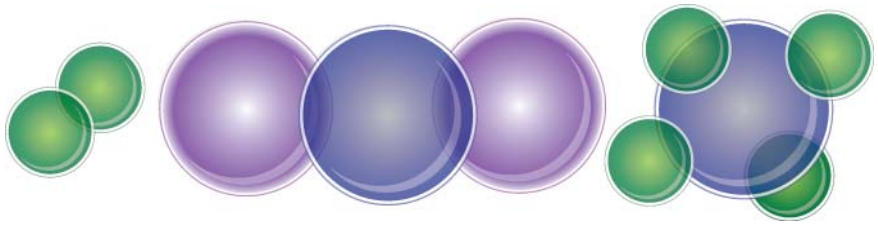
CCS Norwegian national initiatives within CO_2 capture



Dr. Maria Barrio
Vice President Gas Technology
Gas Technology Centre, SINTEF/NTNU, Norway
Bratislava, 4th March 2009

Presentation contributors:
Dr. Mona Mølnvik, Dr. Grethe Tangen, Dr. Marie Bysveen and Dr. Karl A. Hoff (SINTEF)

Outline

- The BIGCO2 R&D Platform
  - BIGCO2
  - BIGCLC
  - BIGH2
- SOLVit
- BIGCCS Centre

A true commitment to be an international Centre of Gravity for CCS

The Norwegian University of Science & Technology (NTNU) - and the SINTEF Group

Number of employees (2007):

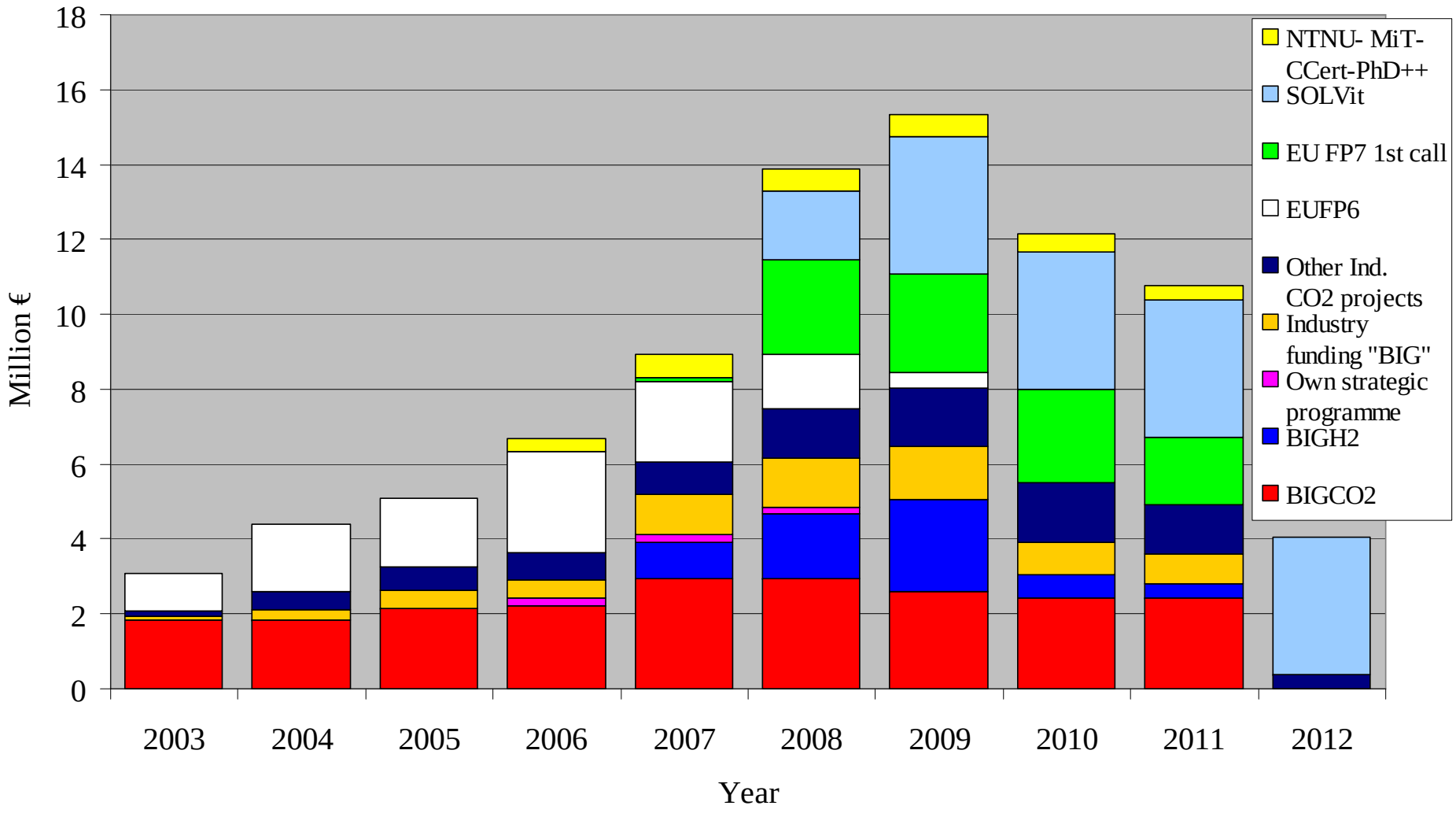
NTNU	4.800
(Scientific	2.500)
SINTEF	2.000
(Scientific	1.350)

Students: 20.000
10.000 in Engineering & Science

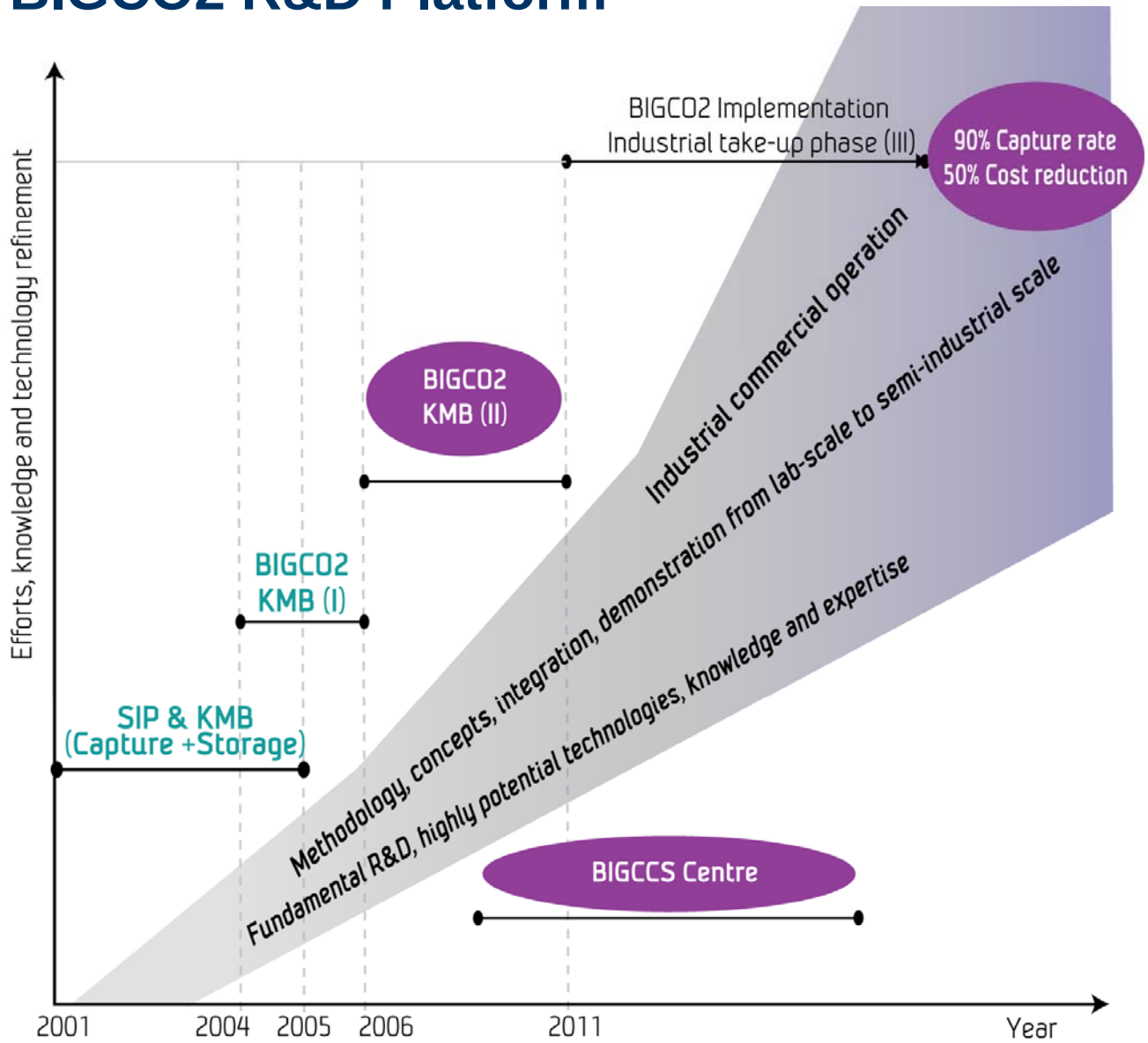
Total externally financed research:
385 Mill €

A technological cluster with education, basic & applied research, innovations and business developments
- of large importance for Norway

Our CO_2 project portfolio



Build-up of the BIGCO2 R&D Platform



BIGCO2 Partners and Funding

- Co-ordinator SINTEF Energy Research
- R&D providers
  - SINTEF, NTNU
  - CICERO
  - University of Oslo
  - DLR (Deutsche Zentrum für Luft und Raumfahrt)
  - Technische Universität München-TUM

- Funding
  - Approx 75/25 % funded by RCN and Gassnova/Industry
  - 2001- 2006: Total of approx. 13 M€
  - 2007 – 2011: (130 MNOK) 16M€

- Industrial consortium
  - Aker Clean Carbon
  - GE Global Research (DE)
  - Statkraft, StatoilHydro
  - ALSTOM (CH)
  - SHELL, ConocoPhillips, TOTAL

Objectives of BIGCO2

Coordinator: Mona J. Mølnvik (SINTEF Energy Research)
Project manager: Grethe Tangen (“)

- To pave the ground for **gas power generation that employ CO_2 capture and storage** with the potential of fulfilling the following compound target:
  - **90% CO_2 capture rate**
  - **50% cost reduction**
  - **fuel-to-electricity penalty less than 7%**

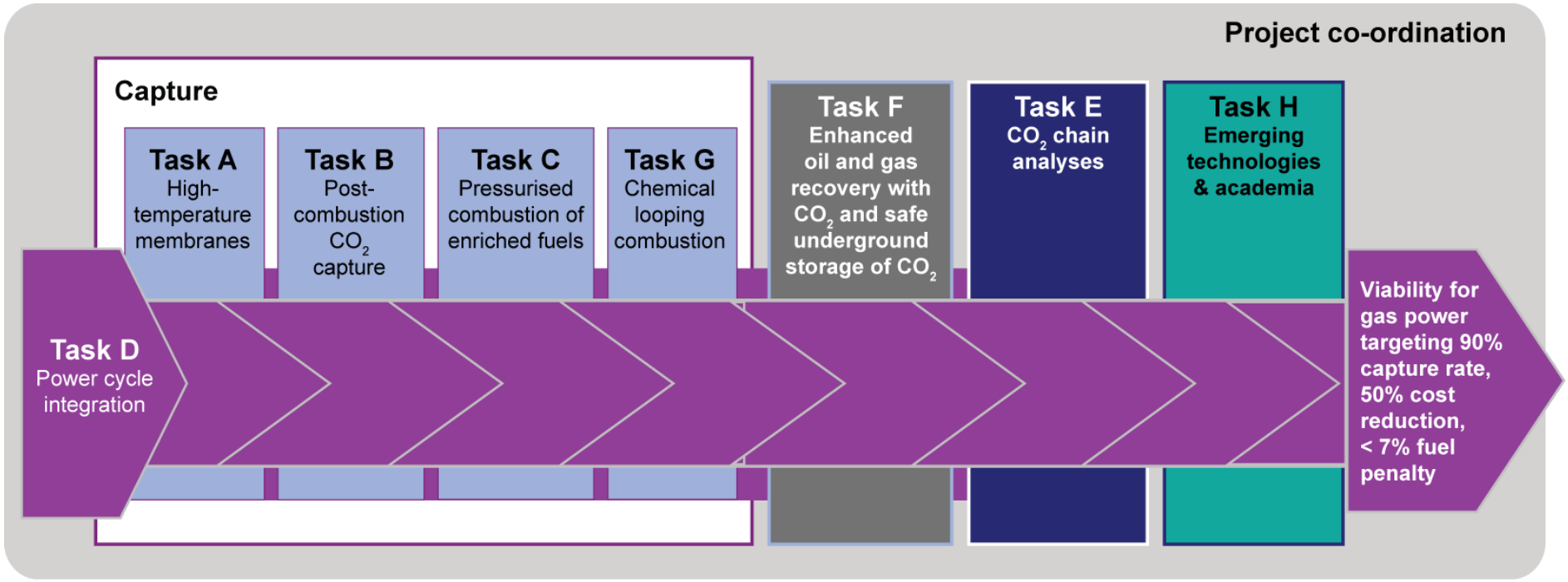
  compared with state-of-the-art gas power generation

- To **generate and refine knowledge and topical comprehension** of power cycle integration via systems engineering (synthesis), capture technologies (combustion, flue gas scrubbing, membranes) and underground storage.

- To **shorten the lead-time** and **improve certainty** of plant characteristics and **limit the technical and commercial risk at an acceptable level**, which jointly may lead up to a decision of setting up a green-field gas power plant in Norway

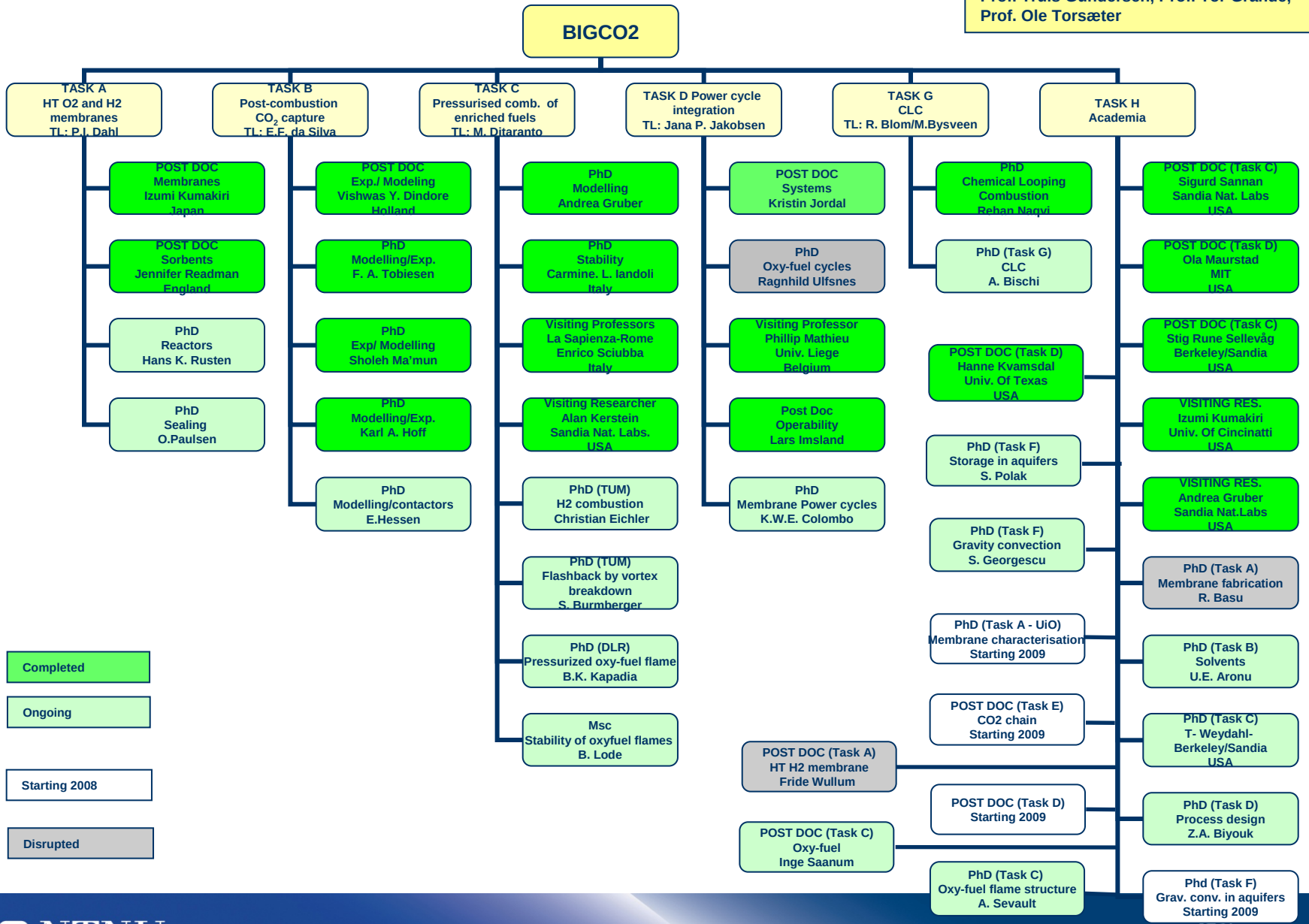
Long term ambitious innovative R&D

BIGCO2 Project structure



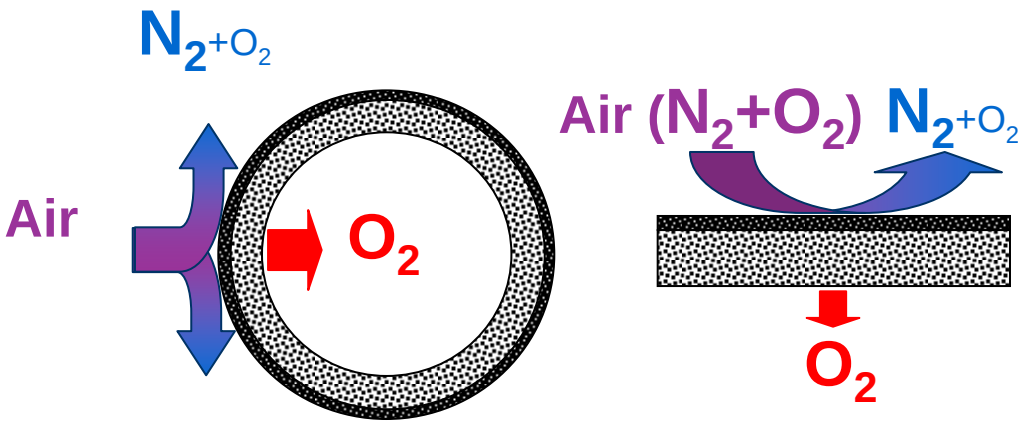
Educational Program (Phase I and Phase II)

Scientific advisors for PhD's and Post Doc's:
Prof. Hallvard Svendsen, Prof. Hugo Jakobsen, Prof. Inge Gran, Prof. Olav Bolland, Prof. Bjarne Foss, Prof. Truls Gundersen, Prof. Tor Grande, Prof. Ole Torsæter

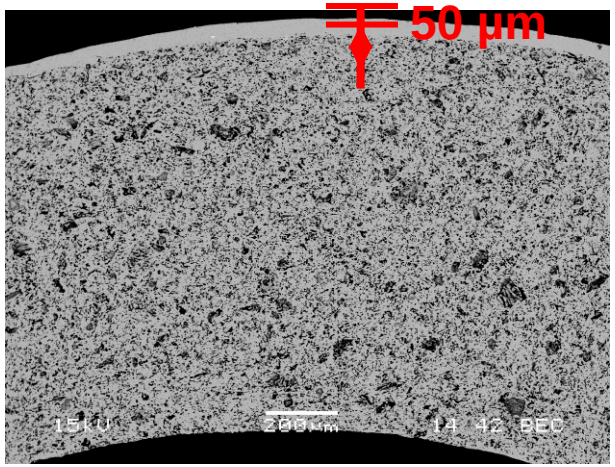


Task A: High temperature oxygen and hydrogen transport membranes

Task leader: Paul Inge Dahl, SINTEF MK



Tubular and planar membranes



Oxygen membrane: Dense layer on porous support. Prepared in BIGCO2

Objectives

- Establish and develop **fabrication and sealing technology** for ceramic high temperature membranes
- Use the technology for **production of membrane modules** for oxygen or hydrogen separation

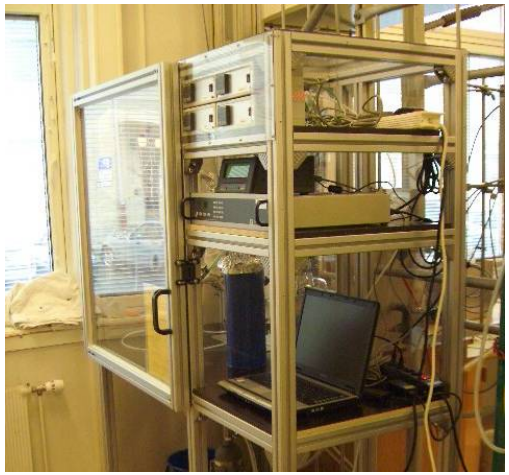
Task B: Post Combustion CO_2 Capture

Task leader: Eirik F. da Silva, SINTEF MK

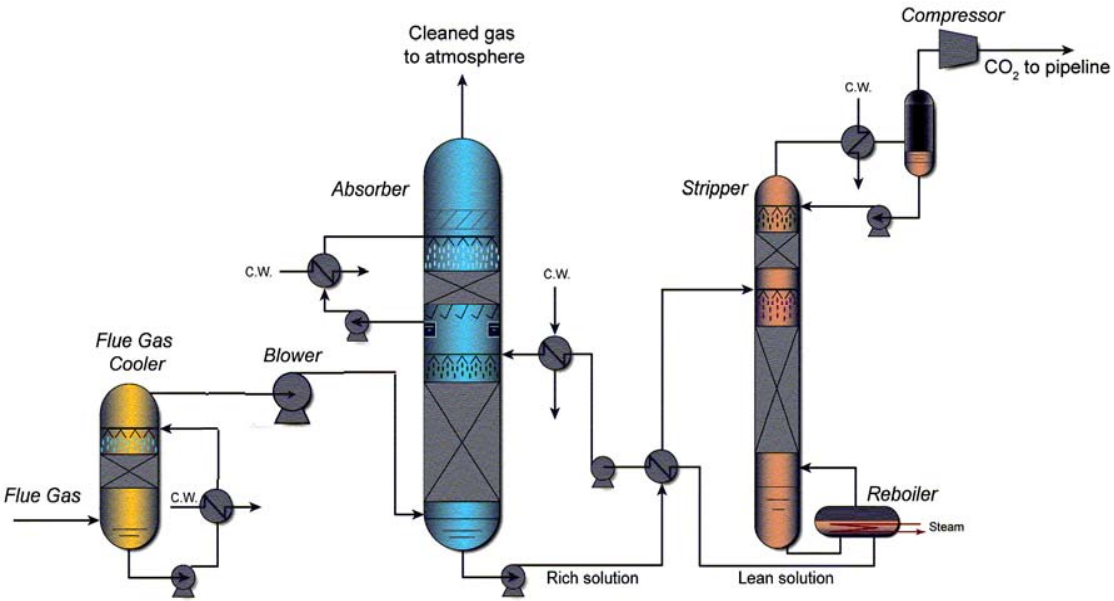
Objectives

- Reduction in energy requirement for post combustion capture down to **2 GJ/t CO_2** and **50% reduction equipment cost**.
- Secure long-term build-up of expertise
- Establish new methodologies and perform early testing of novel concepts with a large potential

Environmental impacts



Novel solvent development



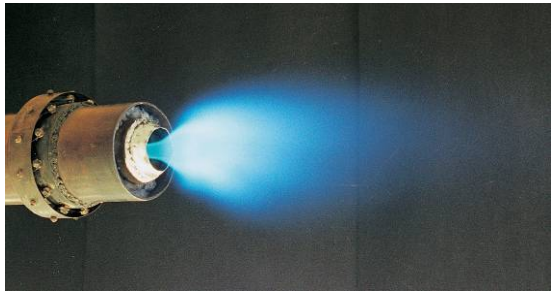
Process modelling and simulation

Task C: Pressurised combustion of enriched fuels

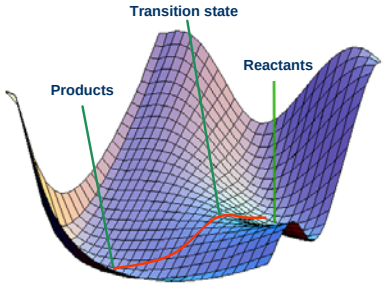
Task leader: M. Ditaranto, SINTEF Energy Research

Objectives:

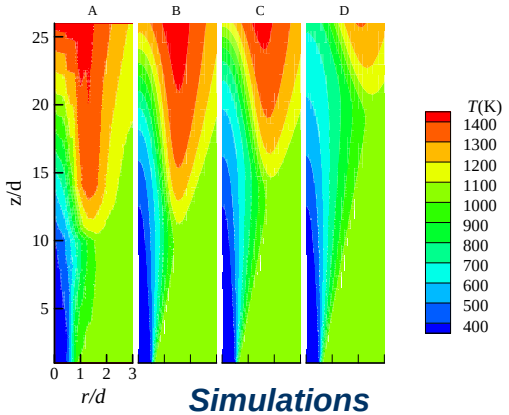
- To advance the **fundamental understanding of hydrogen and oxy-fuel combustion**



Experiments

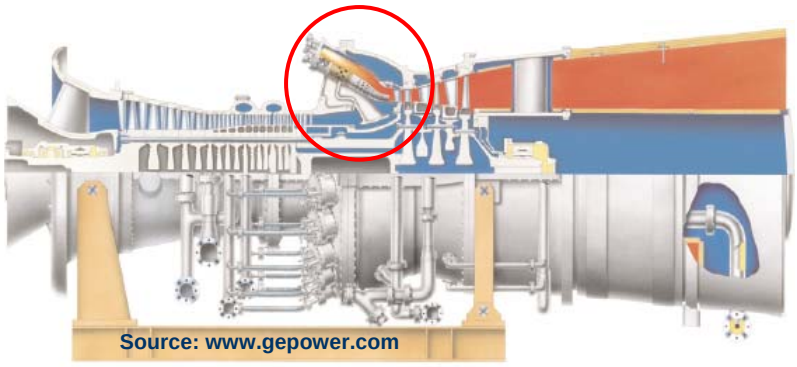


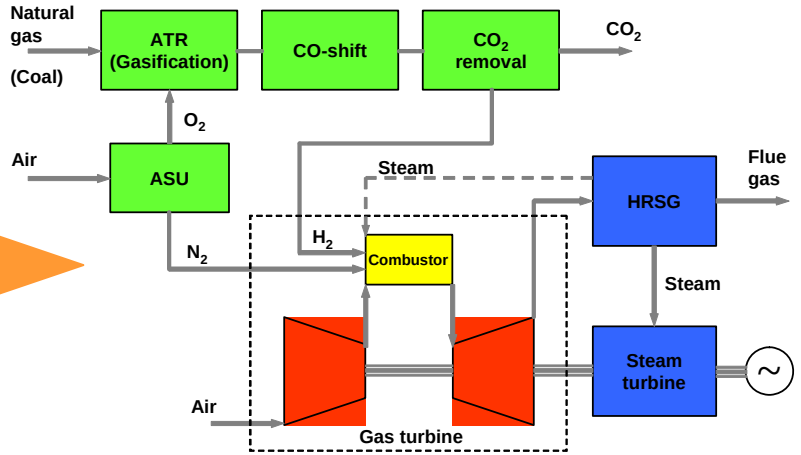
Analyses



Simulations

- To present improved **numerical and experimental tools** to facilitate development of **new concepts and validation of hydrogen and oxy-fuel combustors** and their operational behaviour.



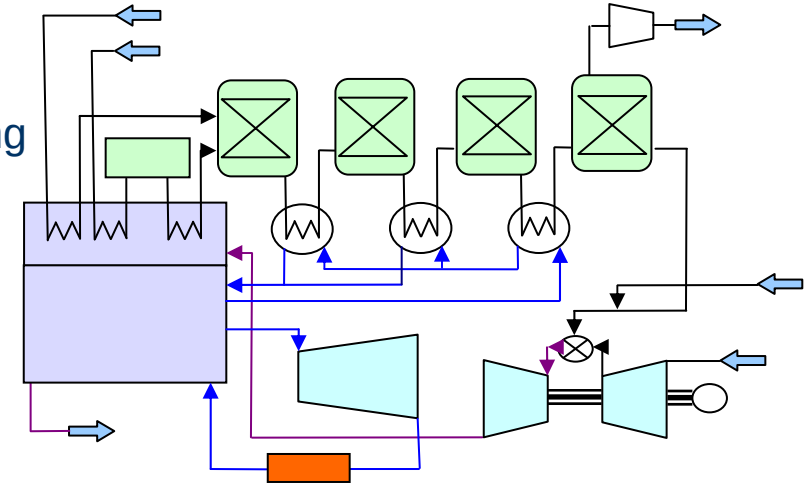


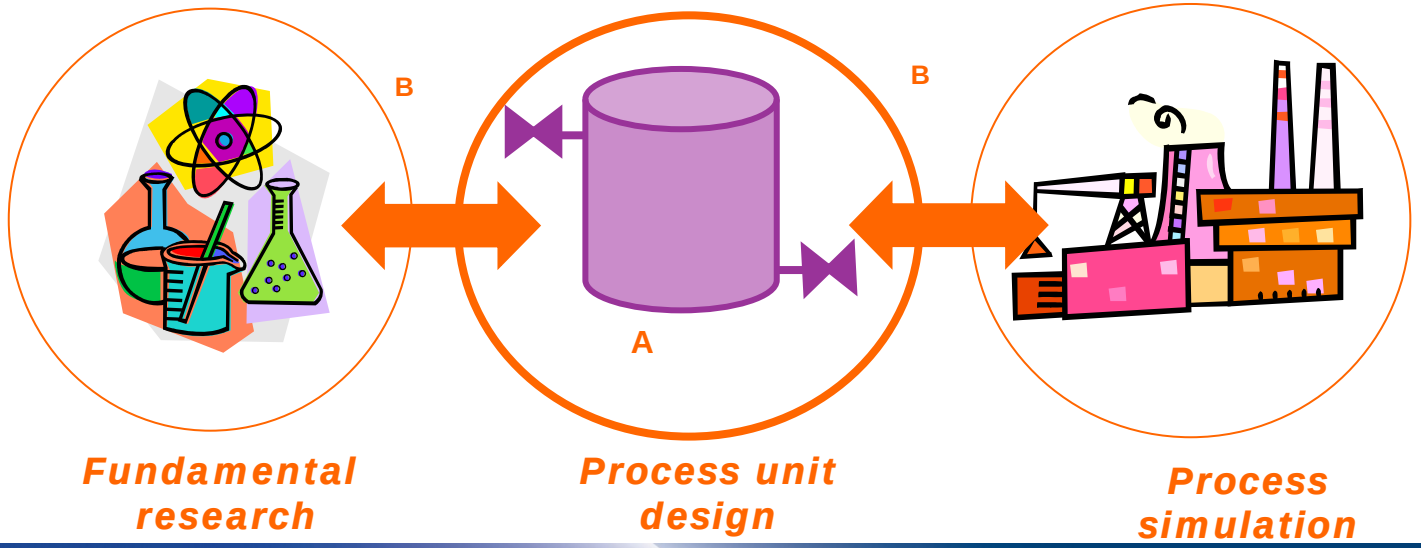
Task D: Power Cycles Integration and Analysis

Task leader: Kristin Jordal, SINTEF Energy Research

Objectives

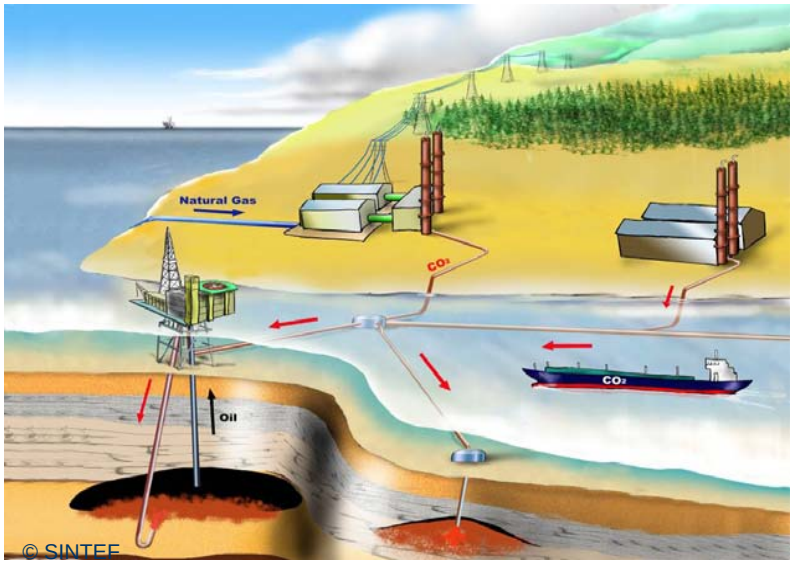
- Evaluate the **potential of novel CO_2 capture technologies** in power cycles and identify promising candidates
- Provide **knowledge and expertise to enable realization of gas-fired power plants** with CO_2 capture





Task E: CO_2 chain analyses

Task Leader: Jana P. Jakobsen, SINTEF ER



Objective

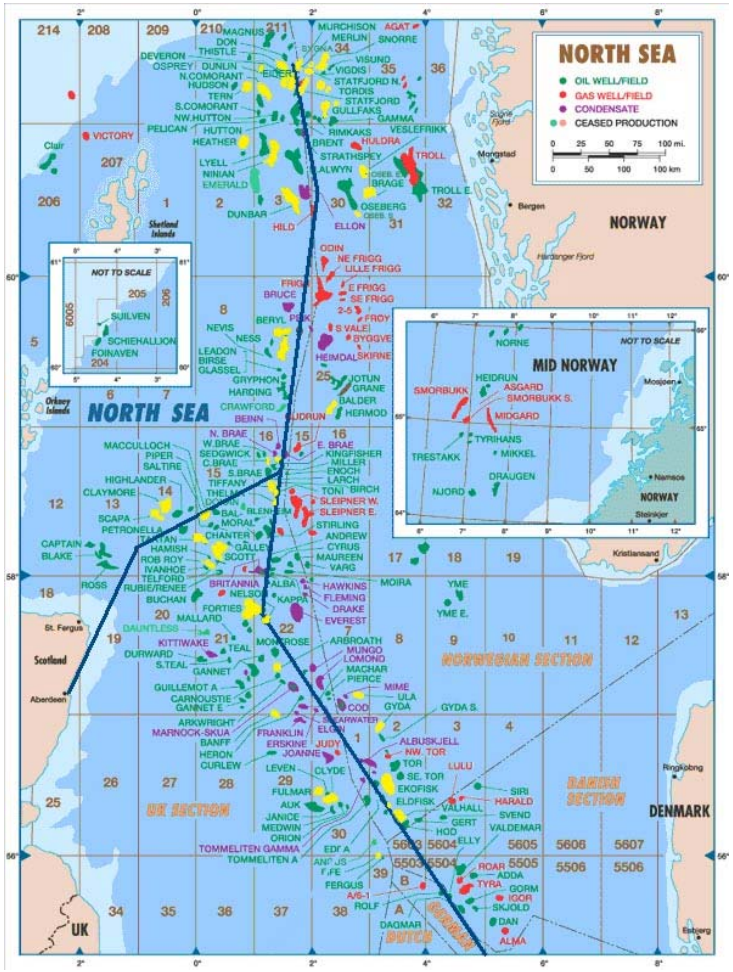
Provide a **framework and methodology for multi-criteria analysis of CO_2 chains**, with special focus on impact of technology development.

Sub objectives are to:

- Create modelling framework
- Define methodology for analyses wrt technology, economy and environment
- Scenario analysis and case studies

Task F: Enhanced oil and gas recovery with CO_2 and safe underground storage of CO_2

Task leader: Alv-Arne Grimstad, SINTEF Petroleum Research



EOR CO_2 value chain

Objectives

- To explore CO_2 underground storage as a safe, economic and large-scale option.
- To increase knowledge and develop the basis of specific technologies within areas of:
  - Reservoir geology and chemistry
  - Carbon cycle
  - Emission and storage scenarios
  - Monitoring and verification of safe storage
  - Long-term climate modelling
  - Economic aspects
  - Institutional aspects
  - Political and legal aspects.

Task G: Design and construction of small, transparent Demonstrator CLC rig (cold)

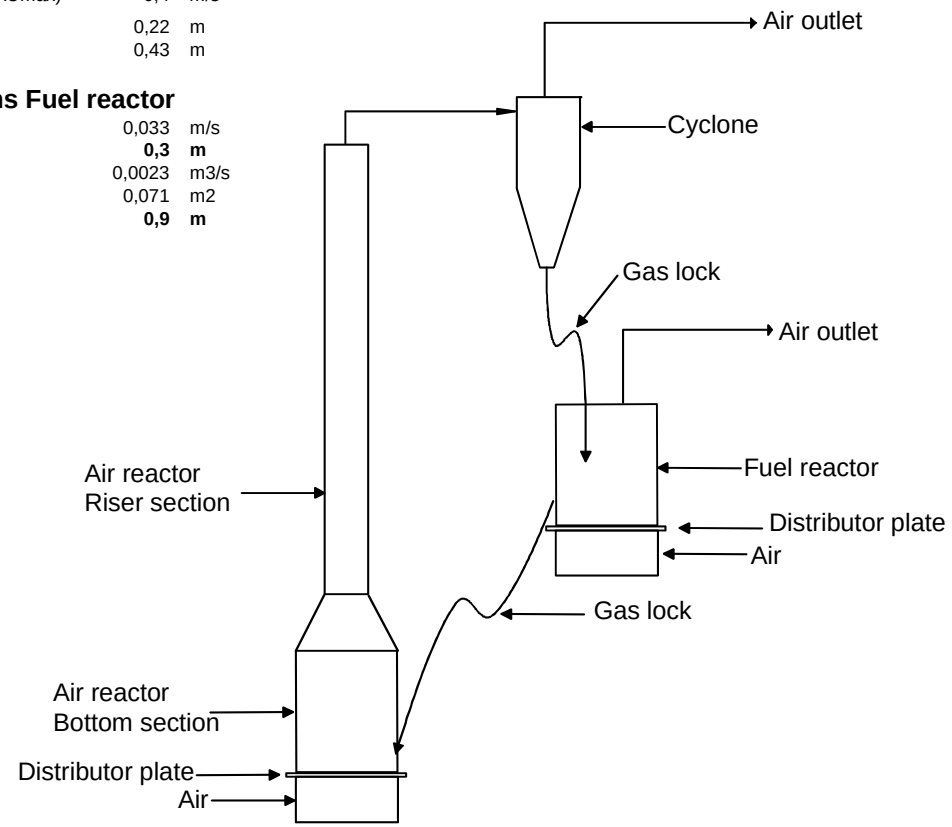
Task leader: Marie Bysveen, SINTEF Energy Research

Reactor dimensions Air reactor

Gas velocity (7xUmax)	1,8	m/s
Diameter riser	**0,1**	**m**
Cross sectional area	0,008	m2
Volumetric flow rate air	0,014	m3/s
Height riser (20xd)	**2**	**m**
Velocity bottom section (1,5xUmax)	0,4	m/s
Diameter bottom section	0,22	m
Height bottom section (2xd)	0,43	m

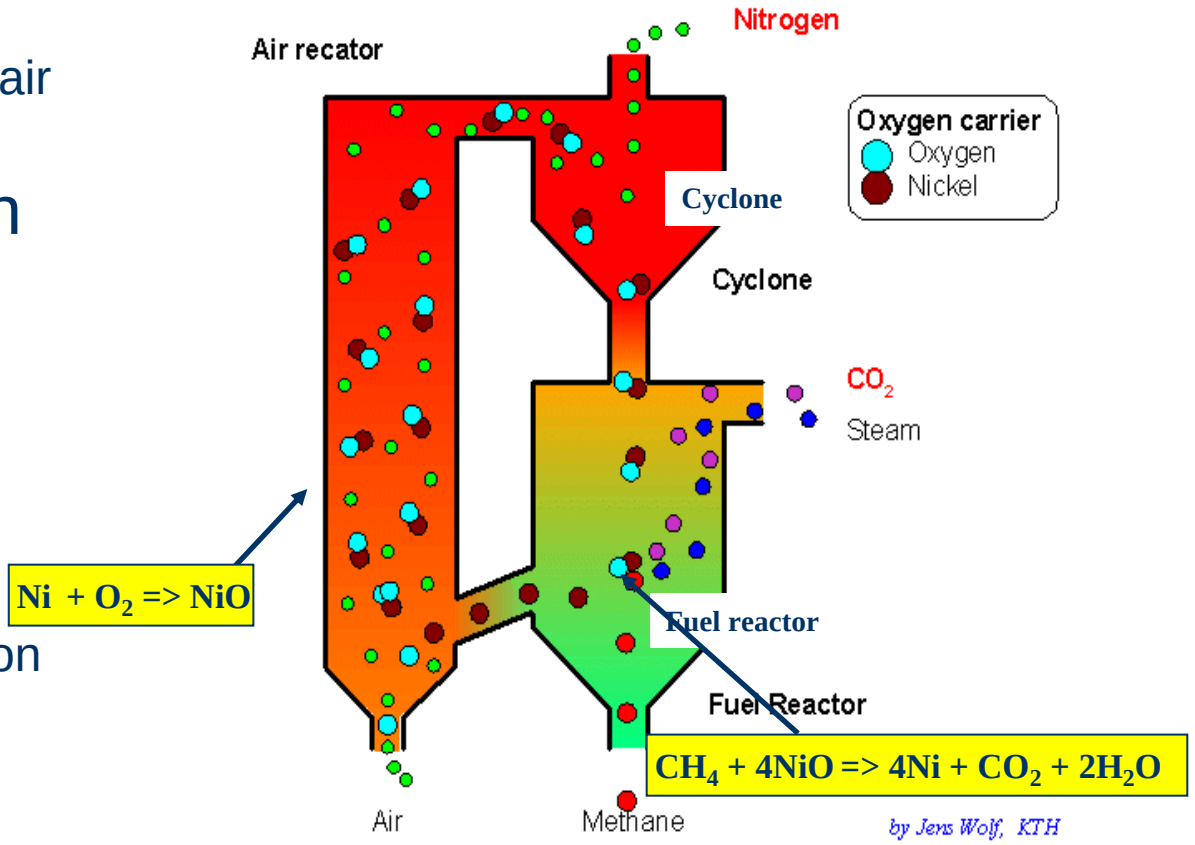
Reactor dimensions Fuel reactor

Gas velocity (10xUmin)	0,033	m/s
Diameter	**0,3**	**m**
Volumetric flow rate air	0,0023	m3/s
Cross sectional area	0,071	m2
Height (3xd)	**0,9**	**m**



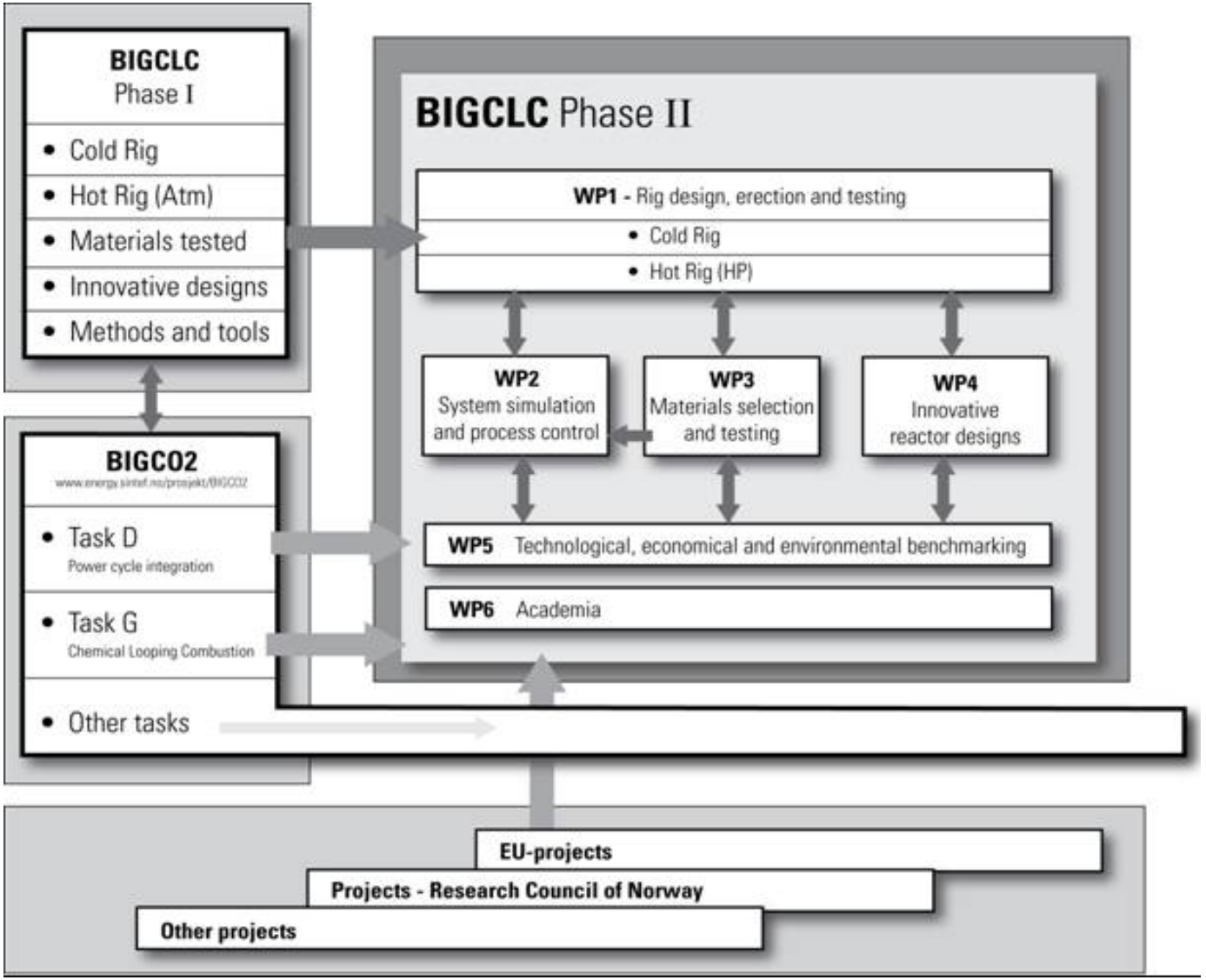
What is Chemical Looping Combustion (CLC) ?

- Combustion with a solid ”oxygen carrier”
  - avoids energy penalty of air separation
- Developments within BIGCLC
  - Evaluation of oxygen carrier materials
  - Design of world’s largest CLC rig
  - Construction and operation of the rig to improve knowledge and pave the road for industrial size



BIGCLC Phase II 2009-2013

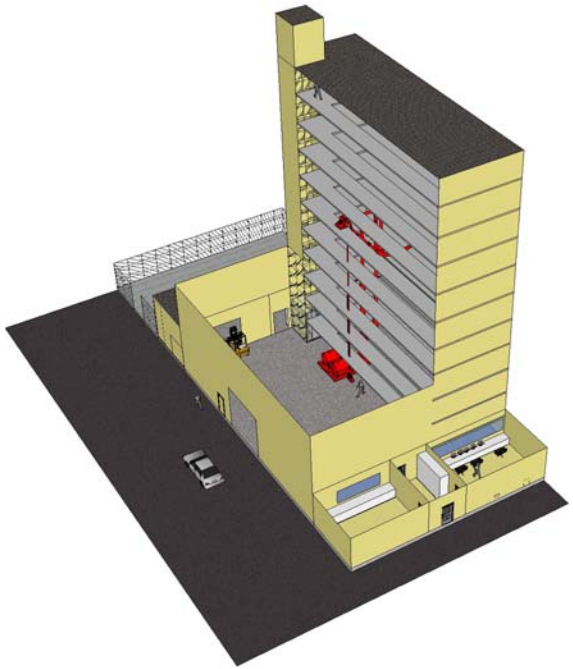
Large-scale demonstration of pressurized CLC in natural gas power generation with CO2 capture

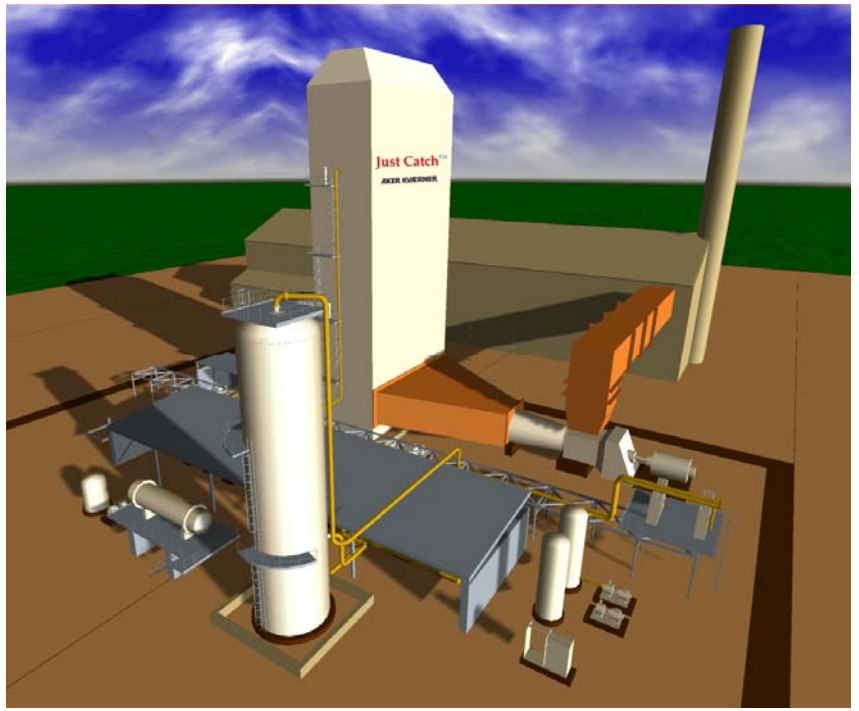


The SOLVit Programme

Solvent development for next generation Post combustion systems
8 yrs, 317 MNOK (~40M€)

GASSNOVA



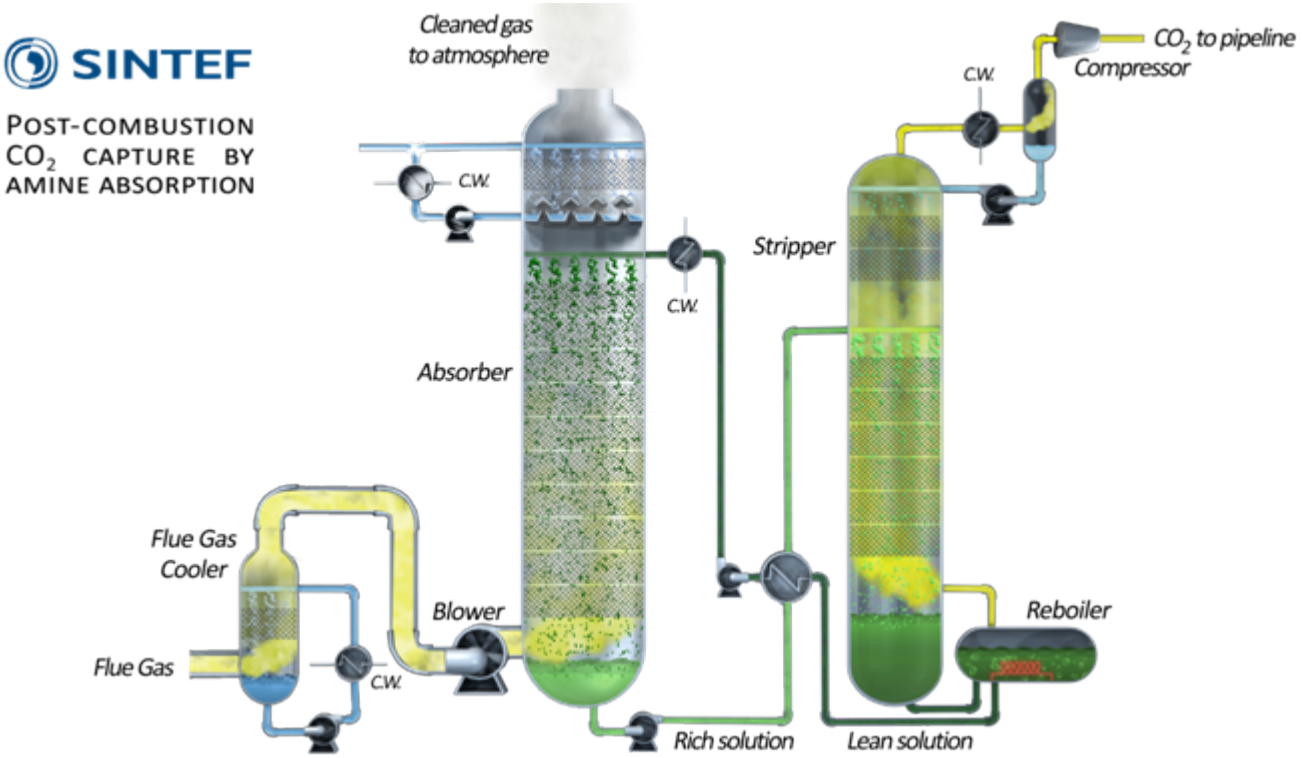


SOLVit objectives

- Qualify **absorption solvents** for **short term deployment** in order to address urgent requirements for realisation of power plants with CCS
- Develop **functional and environmentally friendly post-combustion systems**
- Utilize novel absorption chemistry and adapted process design, enabling a breakthrough in terms of **reducing the costs** of CO_2 capture.

SOLVit-Solvents for the next generation of post combustion systems

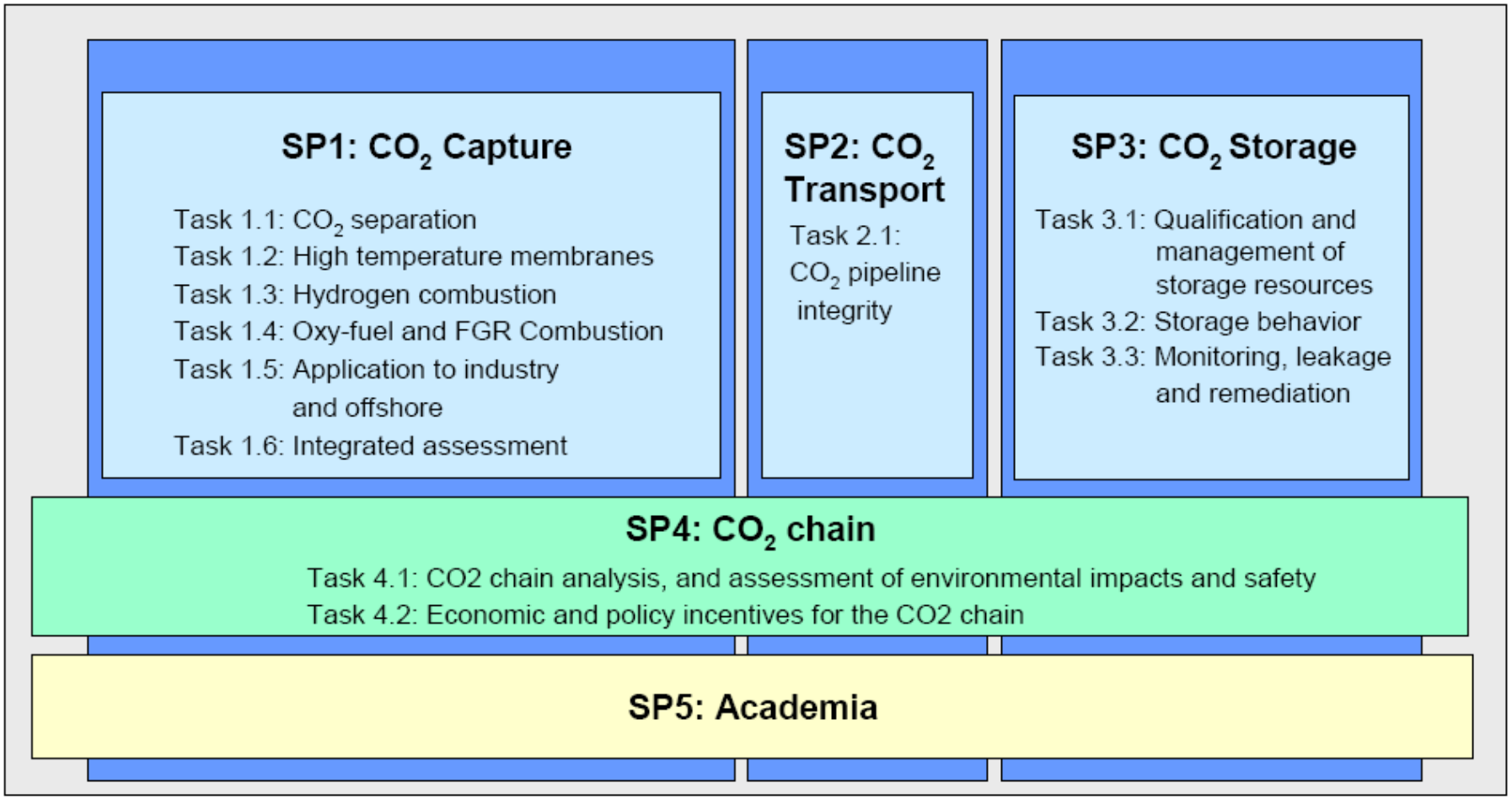
- Development of CO_2 capture technology (post combustion)
  - Development and testing of novel solvent systems
  - New concepts, optimized process design
  - Upgrade and establishment of new research infrastructure



International CCS Research Centre

Proposal coordinator: Mona J. Mølnvik

BIGCCS Centre structure



50 mill NOK/year in 8 years

News from Versailles

Officially put on the Roadmap

81 M€ investment

Pan-European research infrastructure for CCS

www.ntnu.no/eccsel

>Energy

ECCSEL – European Carbon Dioxide Capture and Storage Laboratory Infrastructure

The facility:

The ECCSEL facility combines three approaches to capture (pre and post combustion and O_2/CO_2-oxi-fuel- recycle combustion capture) and three approaches to carbon storage (aquifers, depleted oil/gas fields, coal bed methane). The project includes the upgrading of existing national infrastructures to European level. The upgraded facility is composed of distributed parts in different countries and a coordination centre in Norway.

Background.

Carbon dioxide capture and storage (CCS) is identified as a key technology for reducing emissions from fossil energy use in the future. The demand for it is globally large, in particular in emerging economies. Europe lacks presently a large research infrastructure in this field. There is a very strong need for activities in this field and this topic is highly relevant for the EU Strategic Energy Technology (SET) plan. The core consortium of the upgraded facility consists of 10 European partners, but the network behind CCS is much broader.

What's new? Impact foreseen?

The ECCSEL infrastructure will be unique world-wide in its comprehensiveness for research in CCS and will be open to researchers through a joint management structure. It builds upon developments of the partners' specialised labs in context of national and EU programmes. The core hub of ECCSEL will be in Norway with partner institutions in Germany, the Netherlands, France, Denmark (including Greenland), Poland, Hungary, Switzerland and Croatia. The planned research infrastructure meets the different needs from basic research to experimental activities. In particular it will enable more advanced levels of research in post combustion absorption (needed to address the more near term options), new materials and processes (needed to reduce the cost and reliability of next generation CCS processes), combustion facilities (to enable oxy-fuel CCS processes and efficient hydrogen combustion) and storage facilities (needed for improving the knowledge of storage in aquifers and to develop qualification methods and mitigation strategies). These are all highly relevant to reduce the costs of CCS, improve the reliability of the various concepts and in particular to improve the knowledge of CO_2 storage and to develop qualification methods and mitigation strategies.

By facilitating international research and development ECCSEL will contribute substantially to the targets brought forward in the RoadMap for EU Zero Emission Fossil Fuel Power Plants (ZEP) Technology Platform to achieve CO_2 reduction costs of less than 20€/ton, reduce efficiency loss to less than 6% and to help develop and implement competitive and sustainable CCS technologies.

41

>Timeline.

The facility will be in operation in 2011 and will meet the highest needs in this field.

>Estimated costs.

Preparation costs:	3-4M€
Total construction costs:	81M€
Operation costs:	8M€/year
Research/technology costs:	2M€

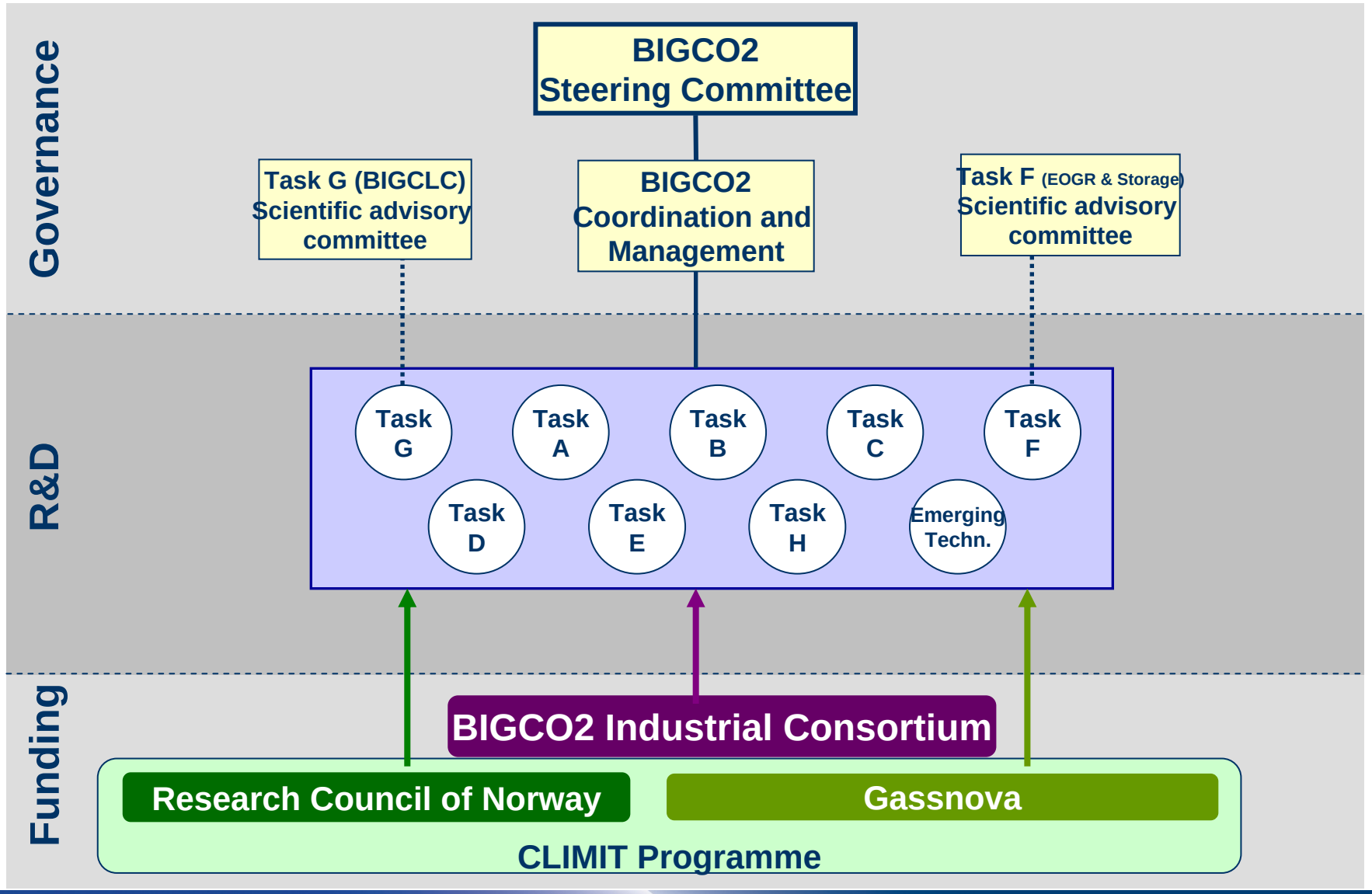
>Website: www.ntnu.no/eccsel

The 5th Trondheim Conference on CCS

- 16-17th June 2009 in Trondheim, Norway
- Scientific conference on CO2 capture, transport and storage
- Expected above 300 participants
- Organized by the Gas Technology Centre in cooperation with the BIGCO2 project
- Conference organizers:
  - Dr. Nils Røkke, SINTEF
  - Prof. Olav Bolland, NTNU
- www.ntnu.no/tccs5

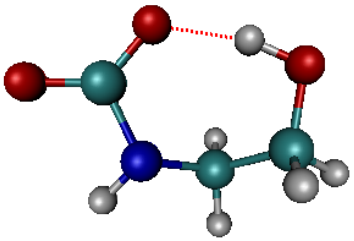
Back-up slides

BIGCO2 Organisational structure



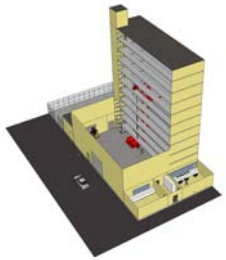
SOLVit

- A consolidation of competence established through 20+ years of research within absorption technology at SINTEF/NTNU
- Merged with Aker experience in technology development and deployment
- Multi-scale approach to solvent development
  - Fundamental chemistry/bench scale experiments
  - Model development/testing at lab-pilot scale
  - Full height test rig with real flue gas + Mobile Test Unit for on site testing and demonstration
  - Qualification for large scale demo (50-100 000t CO2/yr)
- Dedicated tests at the most appropriate level

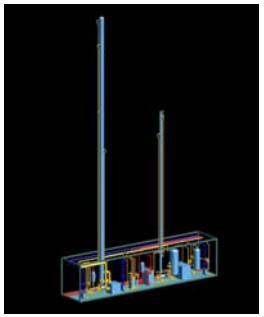


Molecular simulations

Lab/pilot tests



New full height pilot plant in Trondheim



Mobile Test Unit

Large demo/full scale

ACC recently awarded TCM contract