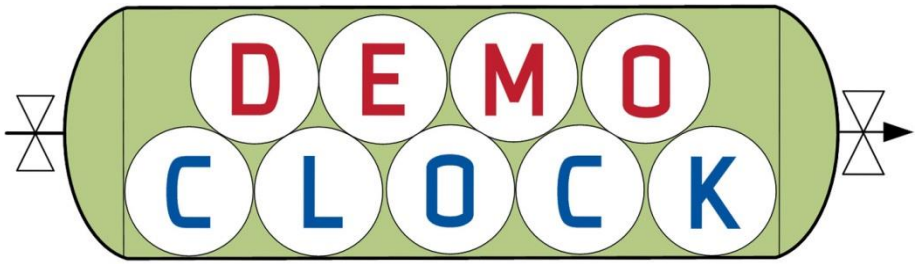


Demonstration of a cost effective medium size Chemical Looping Combustion through packed beds using solid hydrocarbons as fuel for power production with CO_2 capture

(DemoCLOCK)

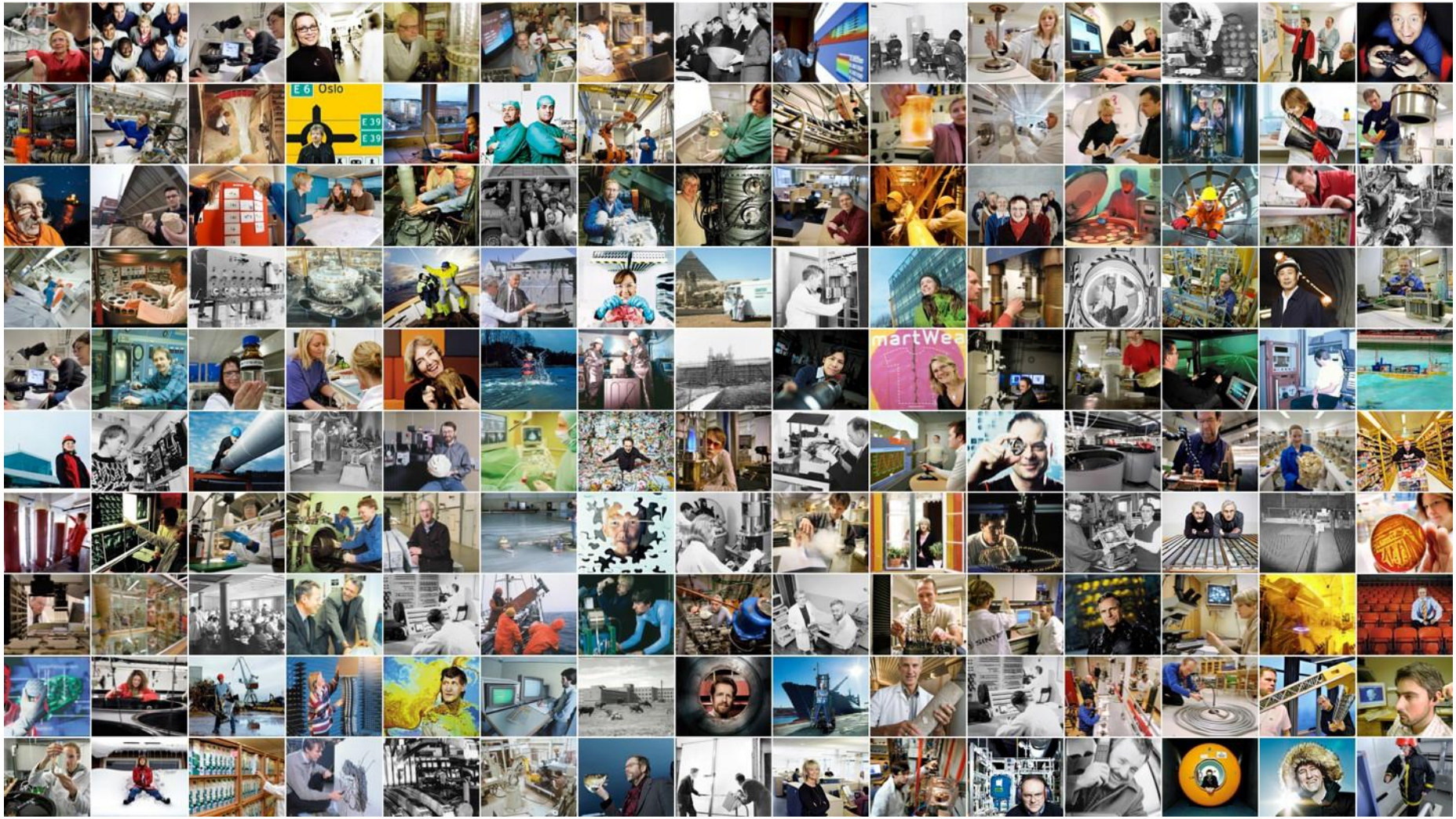
Dr. Shahriar Amini

Project Coordinator

SINTEF Materials and Chemistry, Norway

Content

- Introduction to SINTEF
- Chemical Looping Combustion (CLC)
- Packed bed CLC
- Motivation for DemoCLOCK
- Objectives
- Consortium
- Work packages
- Ongoing activities



This is SINTEF

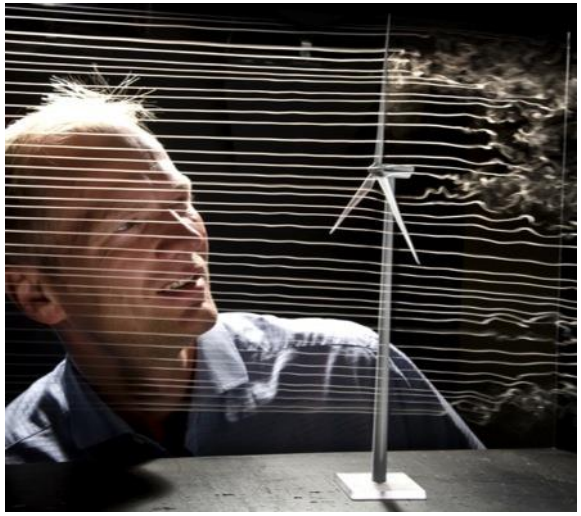
https://www.youtube.com/watch?v=3EAuxDE0C_c

The role of SINTEF

- Provide non-routine solutions to industry
- Create new Businesses
- Management of R&D projects and Infrastructure
- A Knowledge base for Policy Development

SINTEF is the largest independent research organisation in Scandinavia

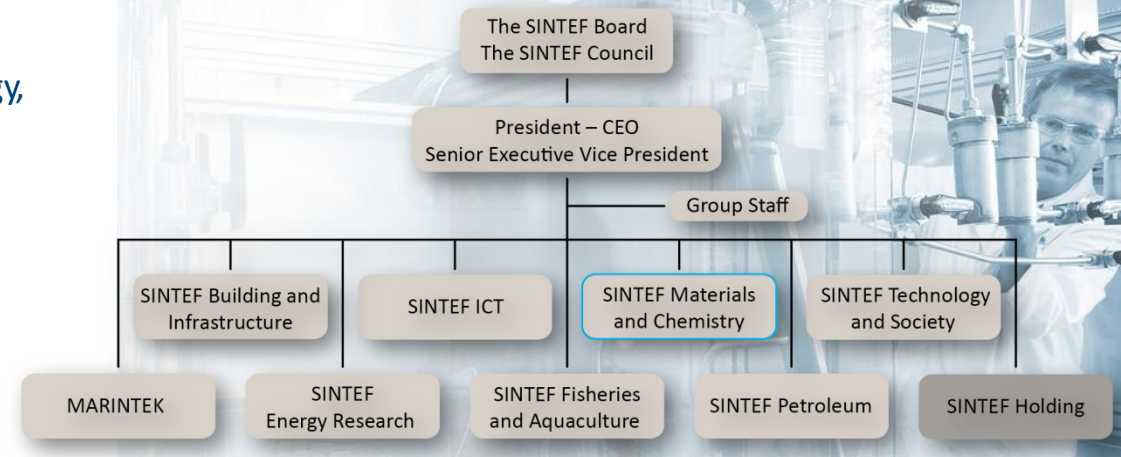
- Leading expertise in the natural sciences and technology, environment, health and social science
- 2000 employees from more than 70 countries
- Annual sales of NOK 3 billion (EUR 400 mill) – customers in more than 60 countries
- An independent, not-for-profit research institute



SINTEF Materials and Chemistry

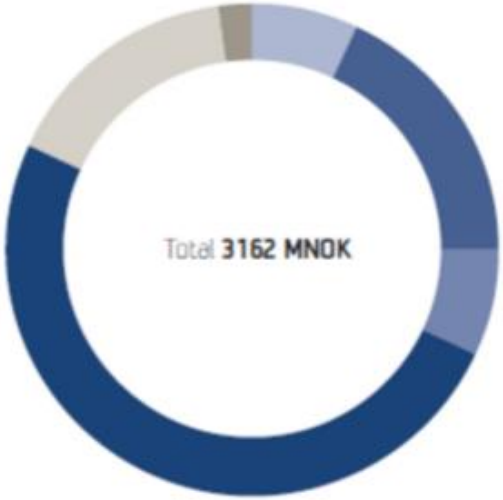
- SINTEF Materials and Chemistry is a research institute offering high competence within materials technology, applied chemistry and applied biology

- Our main research fields are within:
  - ✓ Materials and Nanotechnology
  - ✓ Biotechnology and Nanomedicine
  - ✓ Sustainable Energy Technology
  - ✓ Oil and Gas Process Technology
  - ✓ Industrial Process Technology
  - ✓ Environmental Technology



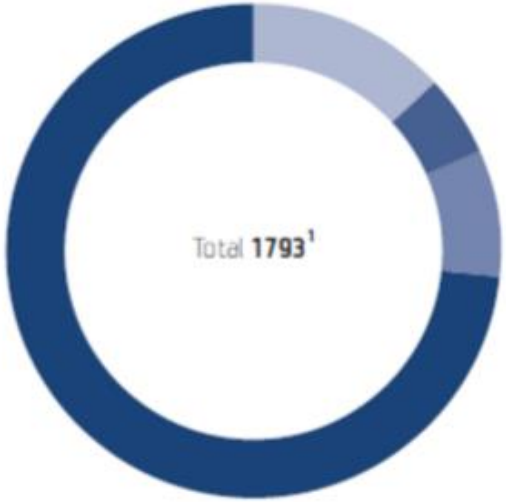
Sources of income

(% of gross operating income)



RCN basic grant	7%
RCN project support	18%
Public sector	7%
Business and industry	50%
International contracts	16%
Other sources of income	2%

Employees

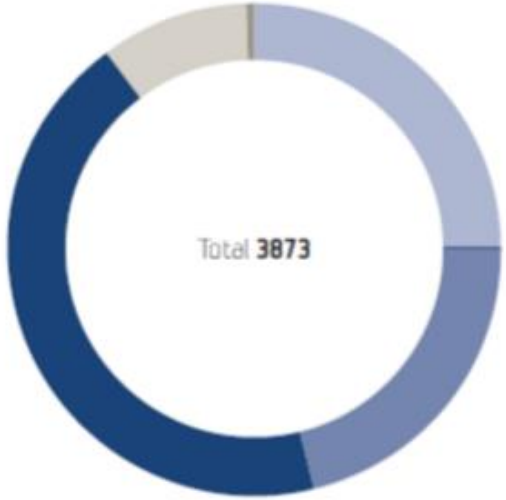


Administration	235
Technical personnel	94
Engineers	153
Researchers	1311[2]

[1] not including SINTEF Holding
[2] of whom 714 hold doctorates

Publications

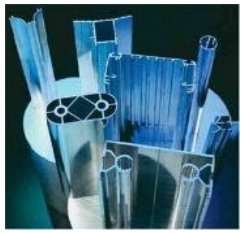
(including popular dissemination)



Academic articles in journals series or anthologies	965
Academic monograph	8
Academic lectures and poster	820
Reports	1692
Popular articles and talks	372
Textbooks, etc.	16

Our customers are typically in the areas of:

- **Oil and Gas**
  - Oil and gas companies
  - The petrochemical and refinery industry
  - Supplier companies for the petroleum sector
- **Sustainable Energy**
  - CO2 capture and storage (CCS)
  - Silicon based solar energy
  - Offshore Wind Energy
  - Hydrogen and Fuel Cells
  - Geothermal Energy
- **Process Industries**
  - Raw materials
  - Aluminium and other light metals
  - Ferro alloys
  - Polymers
  - Chemicals
- **Other Industries**
  - Manufacturing industry
  - Food industry
  - Medical technology incl. nanomedicine
  - Pharmaceuticals
  - Clean water



Sustainable Energy

Our research area in sustainable energy covers technology within CCS, renewables, energy storage, hydrogen and fuel cells. The applied and innovation-driven research aim at making CCS and renewable technologies and energy systems reliable and affordable.

Competence:

- CO_2 capture and transport
- Hydrogen technology and energy storage
- Renewable energy
- Silicon based solar energy

The transformation of the fossil-based energy sector with large green house gas emission to clean energy is one of the greater global challenges.

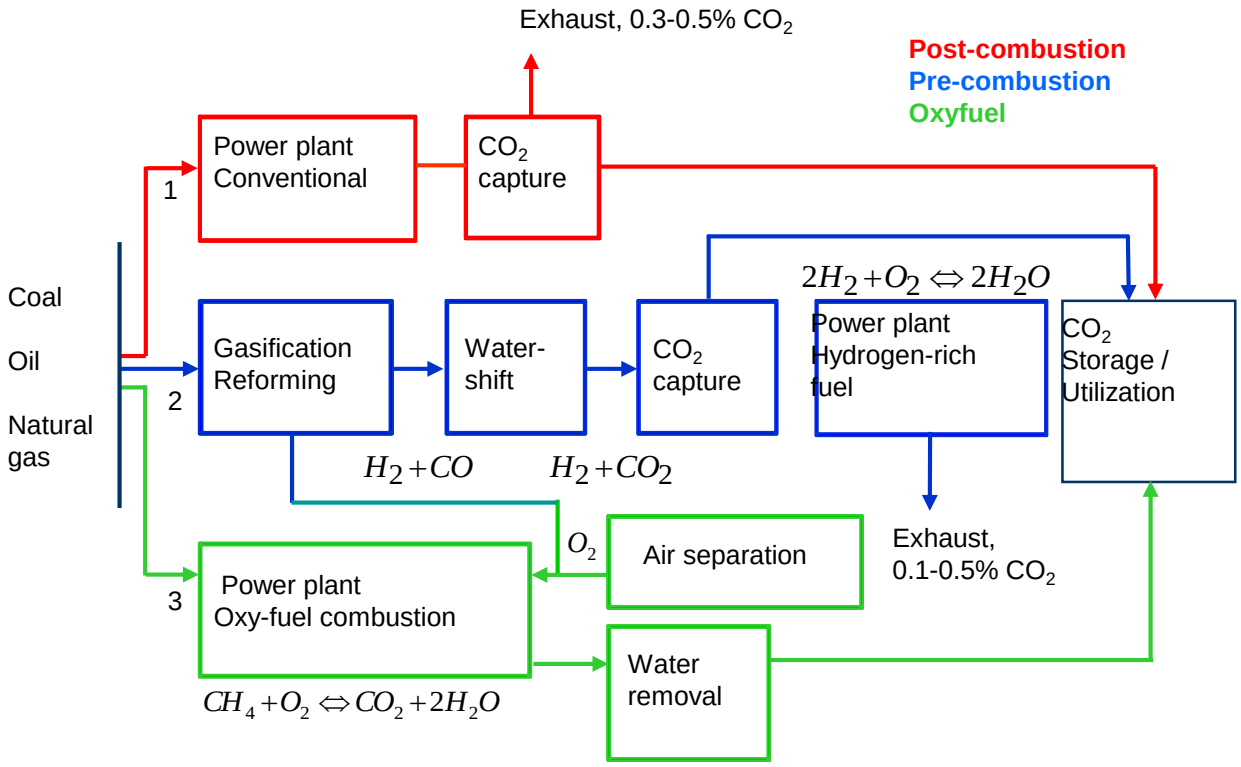
SINTEF - EU

- SINTEF is a major participant in EU research programs
- Participate in 116 projects, with a project volume of EUR 860 million*
- Coordinate 33 projects with a project volume of EUR 202 million*
- SINTEF research funding from EU: EUR 76 million*

*SINTEF's position in EU's t7th Framework Program for Research and Development, by Nov. 2010

CO_2 Capture

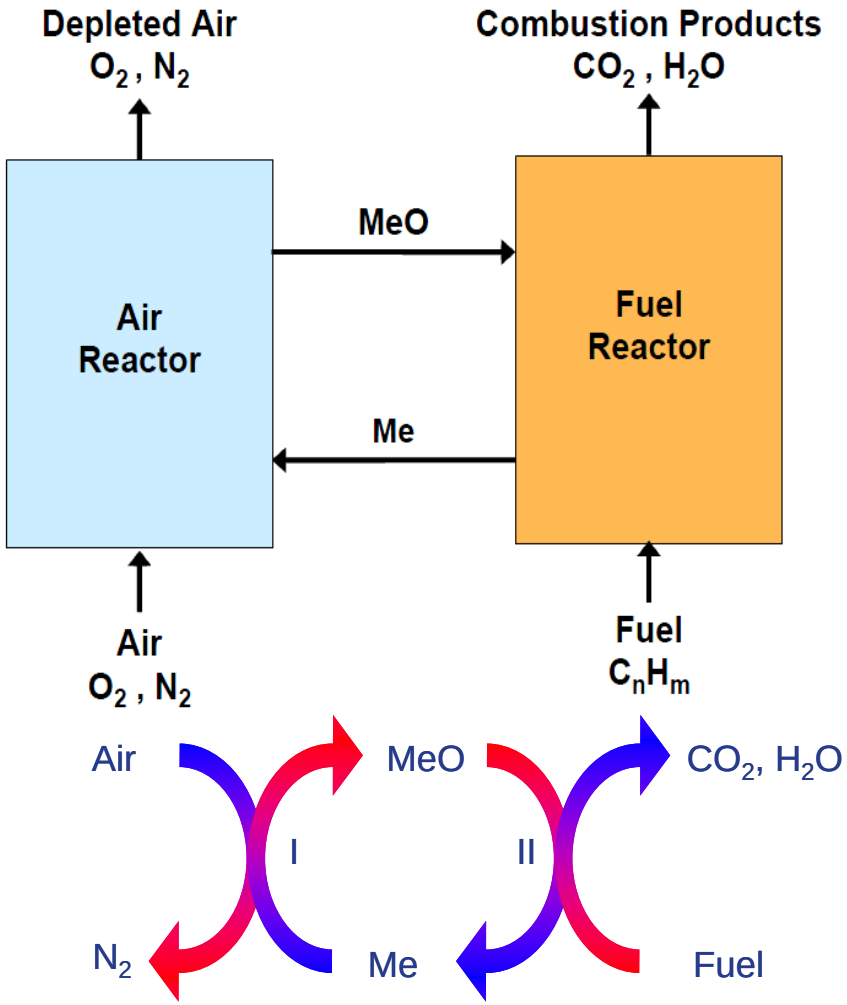
Goal: minimization of energy efficiency penalty



A promising alternative: chemical-looping combustion

Chemical Looping Combustion

1. Air reactor: Reduced metal is oxidized with air. High temperature N_2 stream produced
2. Fuel reactor: Metal oxide (MeO) provides the oxygen for combustion in the fuel reactor. CO_2 is produced
3. Reduced metal (Me) is used again in step 1



I: $4\ Me + 2\ O_2 \rightarrow 4\ MeO\ (\Delta H < 0)$

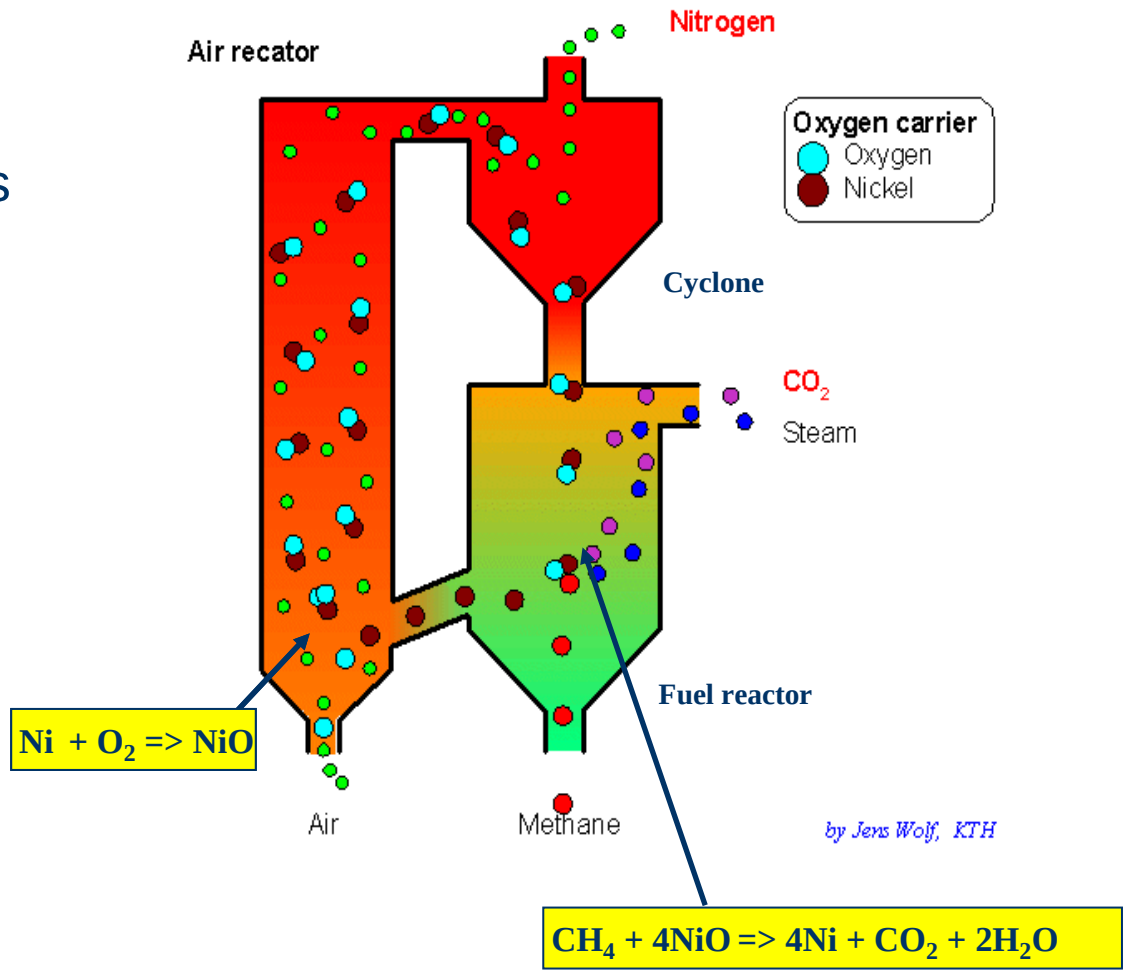
II: $4\ MeO + CH_4 \rightarrow 4\ Me + CO_2 + 2\ H_2O\ (\Delta H > 0)$

Advantages of CLC systems

- Power production with inherent CO_2 separation
- “No” energy penalty for separation of CO_2
- Potential for very high CO_2 capture efficiency
- No NO_x formation (no flame!)
- Direct contact between air and fuel is avoided

Process concepts (circulating fluidized bed)

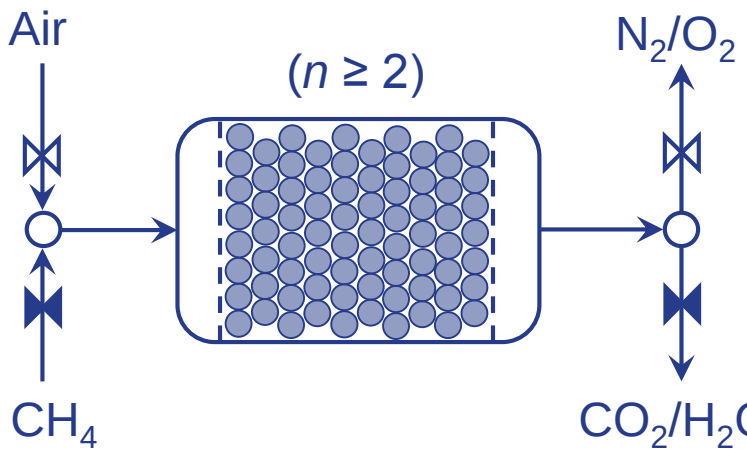
- CFB system:
  - Recirculation of particles
  - Continuous operation
  - Proven technology
- Disadvantages:
  - Equipment erosion
  - Difficult to transport oxygen carriers
  - Difficult gas-solid separation (formation of fines → gas turbine)



Packed Bed Chemical Looping Combustion

- An alternative reactor concept in which the recirculation of the particles is avoided

- Packed bed CLC:
  - Stationary solids
  - Periodic switching of gas flows
  - Dynamically operated parallel reactors for continuous operation
  - Proof of concept in laboratory scale at the research group at University of Twente (now at University of Eindhoven)



Advantages of packed bed system

- System is more compact and much easier to scale up on a technological basis
- Separation of gas from particles is intrinsically avoided to greatly simplify the system
- Better utilization of oxygen carrier

European Commission R&D perspective - Energy

1. To substantially improve efficiency, reliability and cost of coal (and other solid hydrocarbons) fired power plants.
2. The use of coal with significantly reduced emissions by means of enhanced plant efficiency and CO_2 capture and storage.
3. Oxygen-based combustion technologies can play an important role for CCS.

Motivation for DemoCLOCK

- Fossil fuelled power plants are major emitters of greenhouse gases (GHG)
- Coal accounts for 40% of the electricity generated worldwide, while contributing to nearly 29% of all carbon emissions
- Carbon Capture and Storage (CS) is a way to reduce the CO_2 emissions from fossil based power plants
- The current techniques (i.e. post and pre combustion capture) are hampered with high cost for CO_2 capture
- There is a strong need to develop and demonstrate processes which are cost effective in transforming hydrocarbons into energy integrated with CO_2 capture

DemoCLOCK project

- **Duration**: 1 June 2011 - April 2017
- **Funding**: FP7 ENERGY.2010.6.1-1 Efficiency Improvement of Oxygen-based Combustion
  Total budget: € 8,193,476
- 11 partners across Europe

Technical objectives of DemoCLOCK

The main objective: to demonstrate the technical, economic and environmental feasibility for implementing packed bed CLC in large-scale power plants.

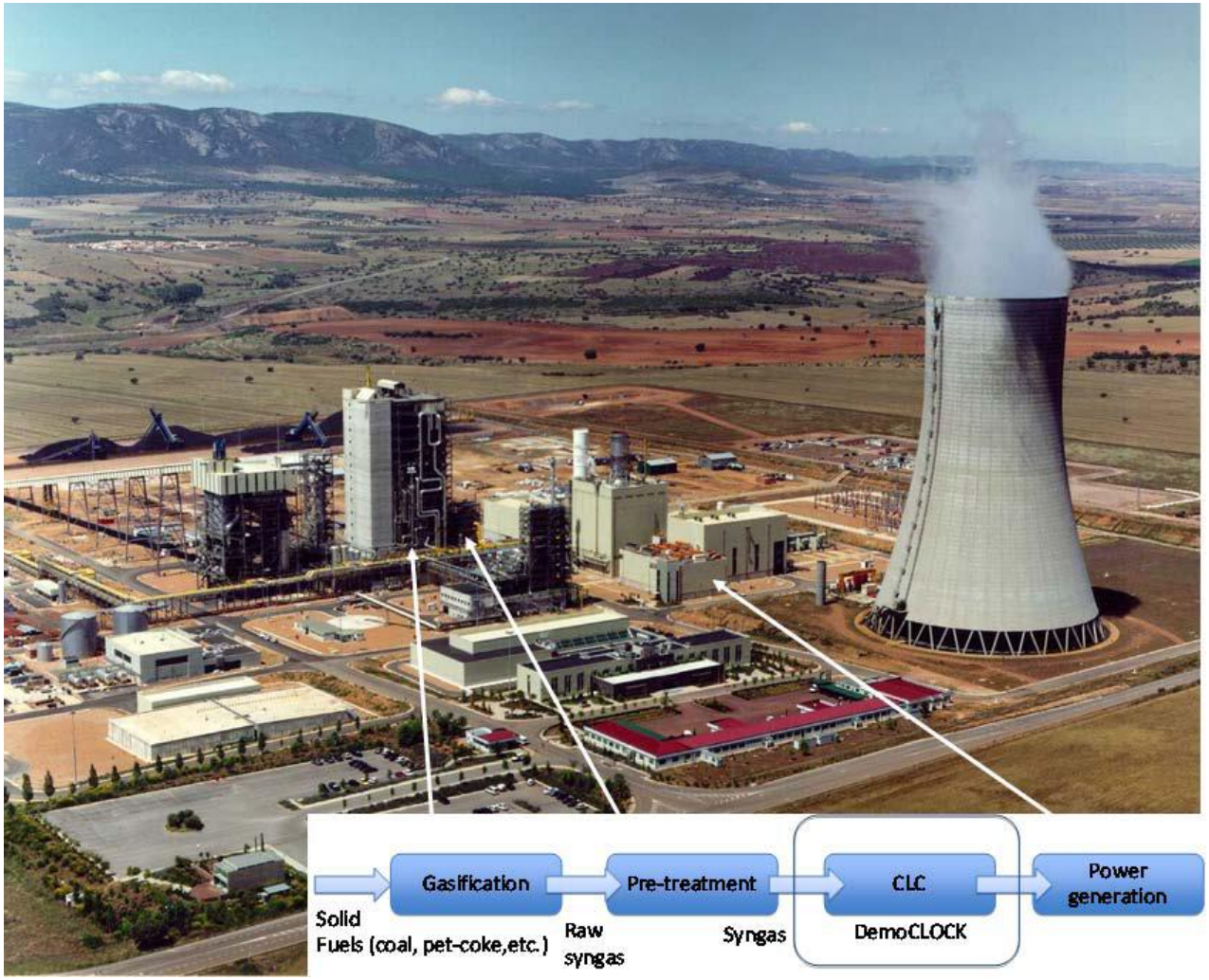
- Demonstrate a medium sized packed bed CLC reactor (500 kW) for IGCC facility at Elcogas (Puertollano, Spain)
- Convert gasified solid hydrocarbons (raw syngas) to energy at high temperature and pressure
- Technological implementation and integration of the process
- Reactor design for medium and large scale
- Selection of suitable minerals as oxygen carrier materials
- Environmental impact assessment and waste management
- Commercialization of the technology

Strategic objectives

- To demonstrate a new generation of power production plants with a reduced energy penalty for CO_2 avoidance in a cost effective way

- To modify the current energy generation system in Europe to make it more sustainable and less dependent on imported fuels.

Demonstration site (1) : Elcogas Puertollano, Spain



Commissioning - Biomass gasification, Güssing Austria

Long term operation

- Possible sites in Eastern Europe
- Coal gassifier

Consortium


SINTEF


POLITECNICO
MILANO


bioenergy2020+


vito
vision on technology


ECN


ELCOGAS


Array
industries


TU/e
Technische Universiteit
Eindhoven
University of Technology

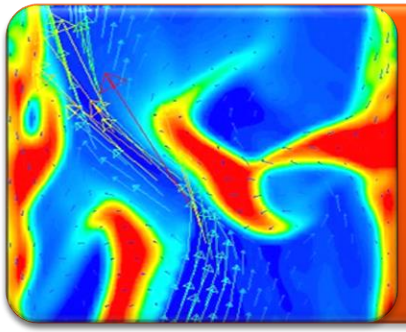

FOSTER WHEELER
Engineering for a Better World

Technical work packages	Lead	Partners
WP1: Performance tests and manufacturing of oxygen carrier materials	vito vision on technology	SINTEF; TU/e Technische Universiteit Eindhoven University of Technology; CTI; ECN Energy research Centre of the Netherlands
WP2: Reactor Design & optimisation	SINTEF	TU/e Technische Universiteit Eindhoven University of Technology; bioenergy2020+
WP3: Basic engineering & pre-commissioning	Array industries	ECN Energy research Centre of the Netherlands; ELCOGAS
WP4: Commissioning & Demonstration	ECN Energy research Centre of the Netherlands	Array industries; bioenergy2020+; ELCOGAS
WP5: Technology implementation plan for a large-scale CLC power plant	POLITECNICO MILANO	FOSTER WHEELER Engineering for a Better World; ECN Energy research Centre of the Netherlands; ELCOGAS
WP6: Environmental impact assessment and waste management	Instytut Ekologii Terenów Uprzemysłowionych Katowice	POLITECNICO MILANO; vito vision on technology; FOSTER WHEELER Engineering for a Better World; ELCOGAS
WP7: Commercialization	FOSTER WHEELER Engineering for a Better World	Array industries; POLITECNICO MILANO; SINTEF; Instytut Ekologii Terenów Uprzemysłowionych Katowice

Reactor design

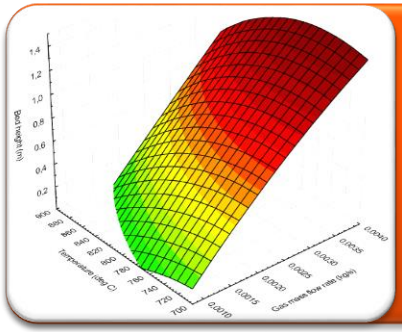
- Design in a view of scale up to pilot scale (~10 MW – 30 MW) towards large-scale (250MW – 500MW)
- The use of reactive and hydrodynamic models to optimize the reactor and permit further up scaling of the technology
- Fuel consumption of raw syngas from the IGCC power plant
- Operation under high pressure and temperature

Simulation-based Engineering



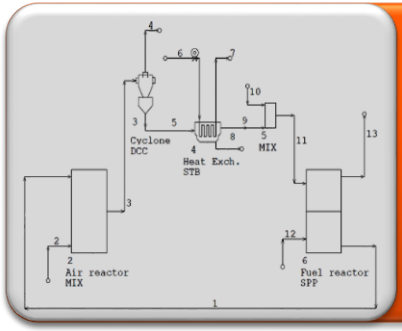
Main advantages

- Investigate any combination of design and operating variables - not limited by physical restrictions
- Detailed system understanding
- Simulate systems at commercial scale and operating conditions – no additional scaling calculations required



Design and optimisation

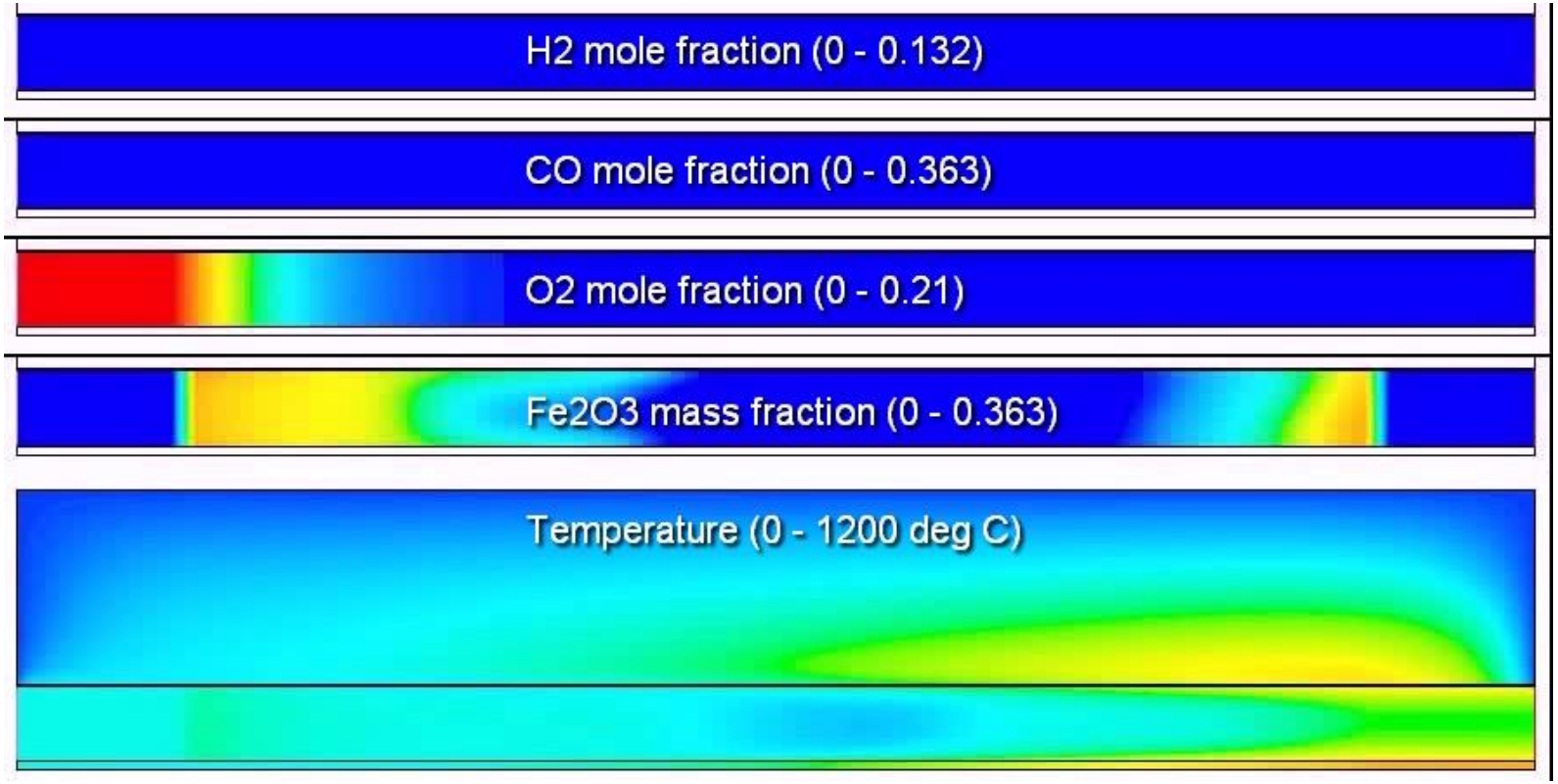
- Assessment of various design criteria
- Mapping out reactor performance as a function of design criteria
- Link cost functions to reactor performance map in order to arrive at a cost optimized reactor design and operational strategy

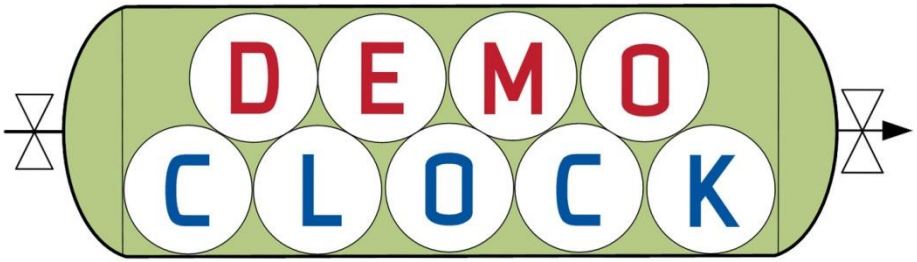


Application

- Development of simple, fast and user-friendly 1D models for industry based on fundamental flow modelling
- Integration with flowsheeting software for a complete system description
- Exploit the freedom offered by simulation-based engineering for virtual prototyping of novel reactor concepts

Packed bed CLC





Thank you

http://www.sintef.no/DemoCLOCK

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Phone: +4746639721