MATESA: Advanced Materials and Electric Swing Adsorption Process for CO_2 capture

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Dissemination Day. Oslo, 16/06/16.

Project objective

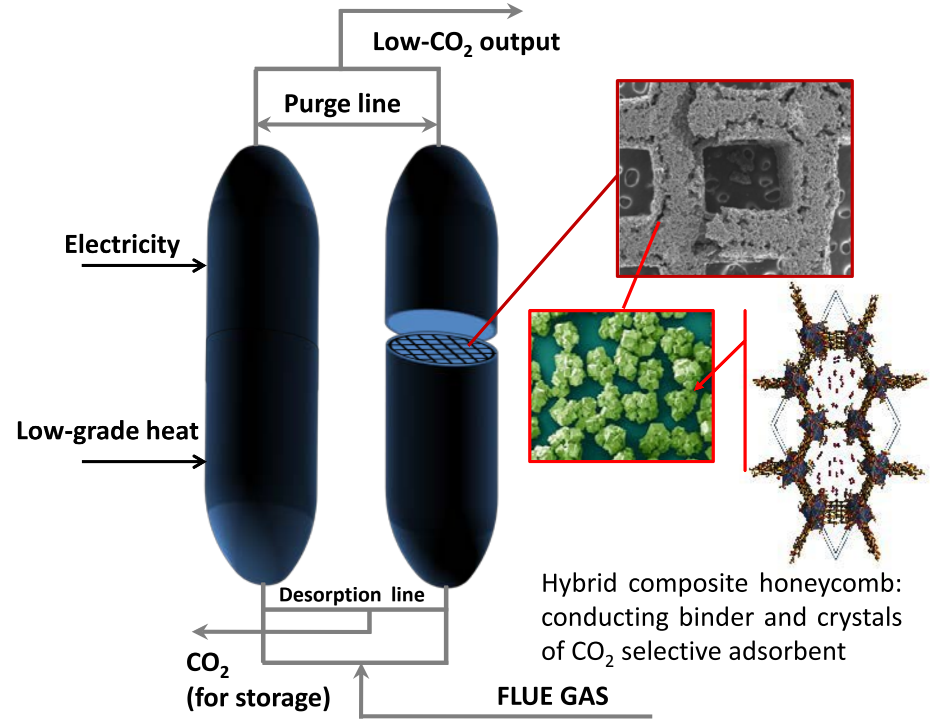
The objective of MATESA is to make a "**proof of concept**" of a new adsorption technique termed Electric Swing Adsorption (ESA) for post-combustion CO_2 capture process. The goal is to reduce energy consumption of the capture process to less than consumption of advanced amine adsorption technology. Other specifications of the process are that CO_2 purity should be higher than 95% and capture rate > 90%. Moreover, the overall performance will be optimized by Life Cycle Assessment to ensure reduced environmental impact of CCS.

Technology Readiness level (TRL)

Materials:
TRL 2 → TRL 4

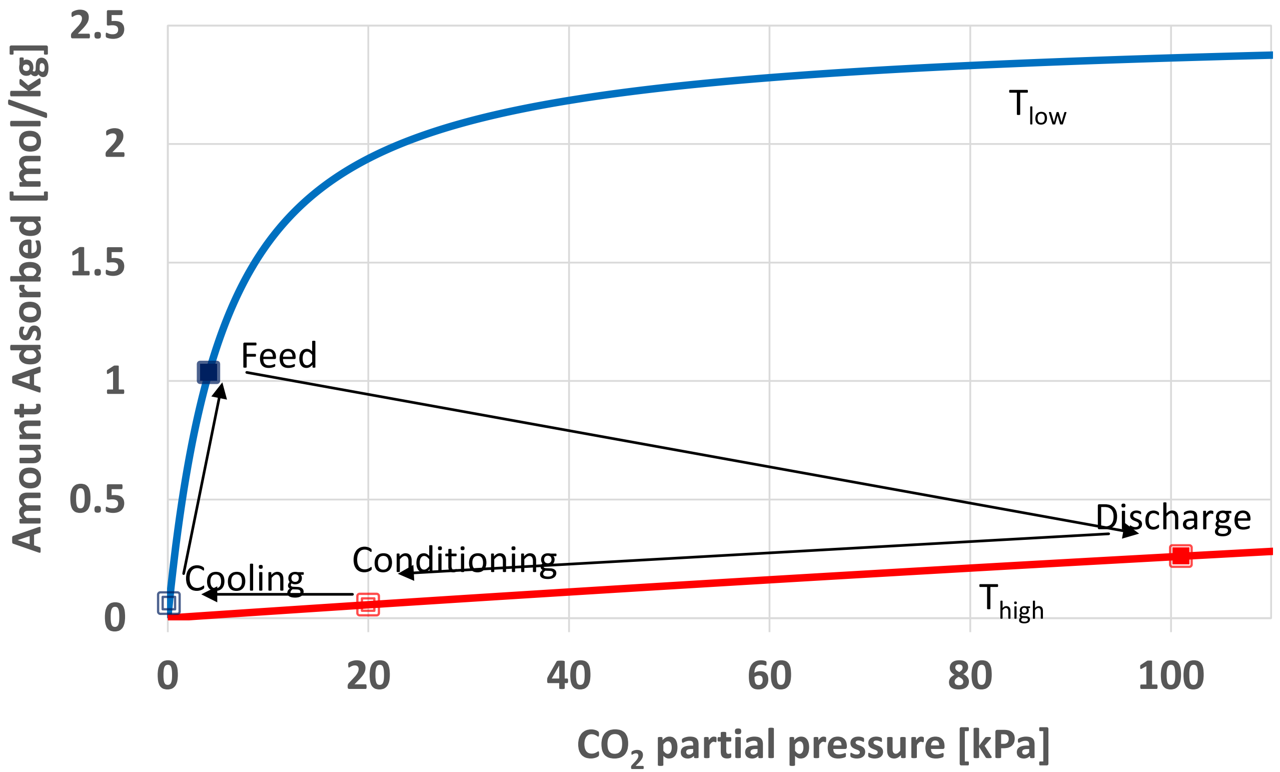
Process:
TRL 3 → TRL 4

Integration:
TRL 2 → TRL 3



Hybrid composite honeycomb: conducting binder and crystals of CO_2 selective adsorbent

Operation principles of TSA

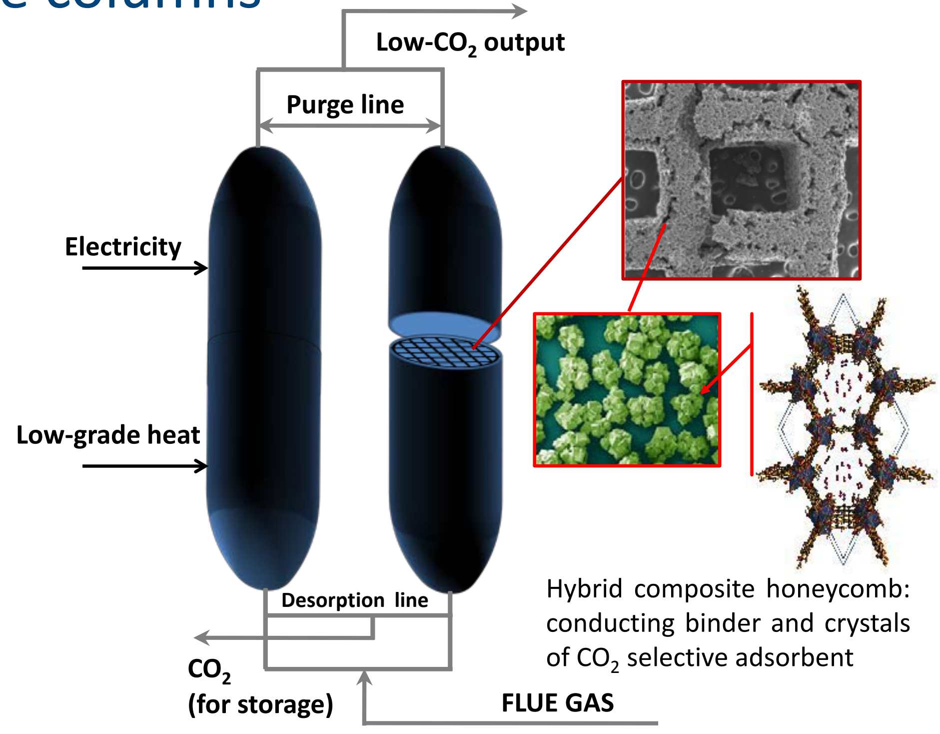


Adsorbent will remove CO_2 from flue gas at a lower temperature and then heated to desorb it. Other conditioning steps should be made followed by a cooling to restore the unit to a new cycle

TSA: cyclic process

Why ESA as CO_2 capture technique?

- Using electricity for heating the time of thermal cycles of traditional TSA cycles will be shorter, reducing costs.
- Honeycomb monoliths offer low pressure drop.
- Cyclic processes need multiple columns



Hybrid composite honeycomb: conducting binder and crystals of CO_2 selective adsorbent

Results before MATESA

ELSEVIER

Available online at www.sciencedirect.com

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Energy Procedia 1 (2009) 1219–1225

Energy Procedia

www.elsevier.com/locate/procedia

GHGT-9

Electric swing adsorption as emerging CO_2 capture technique

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Abstract

The application of Electric swing adsorption (ESA) as a successful second generation technique to capture CO_2 was evaluated. The objective of this work is to demonstrate that under certain conditions, ESA can be used in CO_2 capture from flue gases of power plants. A process with seven steps was developed and tested for CO_2 capture from a flue gas from a natural gas power station with emission levels of 1 Gton of CO_2 per year with a content of 3.5%. The seven steps employed are: feed, rinse with hot gas, internal rinse, electrification, depressurization and two purge steps. Using this process we could obtain CO_2-rich streams with purities of 89.7% keeping recovery around 70% and energy consumption of 1.9 GJ/ton of CO_2 captured.

A fictitious material was used. Process also needs refining.

The current challenges

- Develop high CO_2 capacity AND conductive honeycomb monoliths
- Design a tailored ESA cycle for post-combustion CO_2 capture
- Integrate the ESA with the power plant as much as possible to reduce the overall environmental impact.
- Optimize the life cycle of the process

New hybrid honeycomb monolith adsorbents

Material issues

Industry-oriented fundamental understanding : mathematical models

Process issues

Process design taken into account industrial environment of future CO_2 capture plants : use of steam-based heating

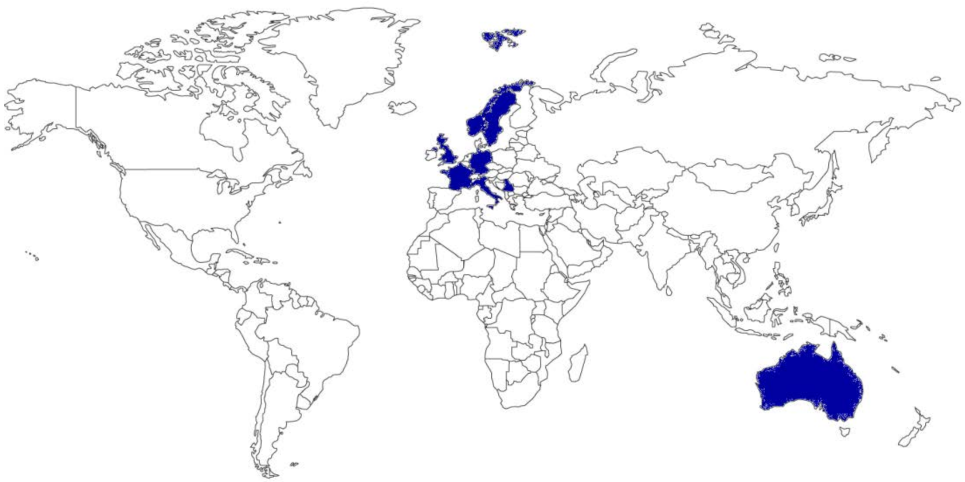
Integration issues

LIFE CYCLE ANALYSIS

MATESA partners

- The consortium is formed by: 5 universities (2 from Australia), 2 R&D institutes, 3 SMEs and 2 large industries.

- SINTEF, Norway
- University of Belgrade, Servia
- Fraunhofer Institute, Germany
- University of Torino, Italy
- Corning SAS, France
- Linde Engineering, Germany
- Politecnico di Milano, Italy
- Cycleco, France
- Biokol, Sweden
- Process Systems Enterprise, United Kingdom
- University of Melbourne
- Monash University, Australia



Project data

- MATESA: Advanced materials and Electric Swing Adsorption process for CO_2 capture.
- Project ID: 608534. 7th Framework Programme, ENERGY
- Sub-programme area: ENERGY.2013.5.1.2
- Starting date: 01/09/2013.
- Duration: 36 months

- Total project budget: € 5 709 173
- EU Contribution: € 2 965 707

Project partners

Development of honeycomb monoliths

Scale-up of MOF

Material properties characterisation

Modelling of process

ESA process testing

Energy assessment and ESA integration

Material issues

Process issues

Integration issues

LIFE CYCLE ANALYSIS

Evaluation of the process by life cycle assessment

All partners have specific activities within the project

Start of MATESA

Criterion 1. Scientific and/or technological excellence (relevant to the topics addressed by the call)

Note: when a proposal only partially addresses the topics, this condition will be reflected in the scoring of this criterion.
- Soundness of concept, and quality of objectives
- Progress beyond the state-of-the-art
- Quality and effectiveness of the S/T methodology and associated work plan

The concept is sound with a novel approach allied to clear thermal energy consumption reduction targets. There is a good focus on the development and testing of capture materials, which is extended to the integration and upscaling of the proof of concept. The state of art is clearly described and how it will be extended is provided in detail and excellently articulated. The methodology and work plan are extremely well developed with a major beneficial element being the proposed integrated activity with and in Australia.

Overall score (Threshold: 3.00/5.00, Weight: 1.00) **5.00**

Criterion 2. Quality and efficiency of the implementation and the management

- Appropriateness of the management structure and procedures
- Quality and relevant experience of the individual participants
- Quality of the consortium as a whole (including complementarity, balance)
- Appropriateness of the allocation and justification of the resources to be committed (staff, equipment...)

The management structure and procedures are commensurate with the delivery of such a high quality demanding collaborative programme. Excellent mechanisms for communication between the partners are described. The consortium is very well balanced with involvement of SMEs and large companies together with technology developers and research institutions. The coordinating organisation has excellent experience in running such cooperative projects. The skills and expertise within the consortium are very high and consistent with undertaking the planned activities. The allocation of resources is fully justified and highly cost effective with efficient use of human resources and with little purchase of new equipment.

Overall score (Threshold: 3.00/5.00, Weight: 1.00) **5.00**

Criterion 3. Potential impact through the development, dissemination and use of project results

- Contribution, at the European [and/or international] level, to the expected impacts listed in the work programme under the relevant topic/activity
- Appropriateness of measures for the dissemination and/or exploitation of project results, and management of intellectual property

There is a comprehensive consideration of the impact of the outcomes of the work, including a detailed SWOT analysis for the selection of post combustion capture together with a good articulation of what steps are necessary to bring about the expected high impacts. This includes an estimated time line of the different phases of scale up and CO2 cost targets to deploy the technology after the proof of concept. The impact of the innovation therefore should be very high and be applicable worldwide on both new and recently installed existing fossil fuel power plant. The management of IPR is considered in a detailed manner, as is the dissemination of the results of the project. Also addressed is the need for multidisciplinary training of specialised human resources where the exchange with Australian universities will be particularly valuable.

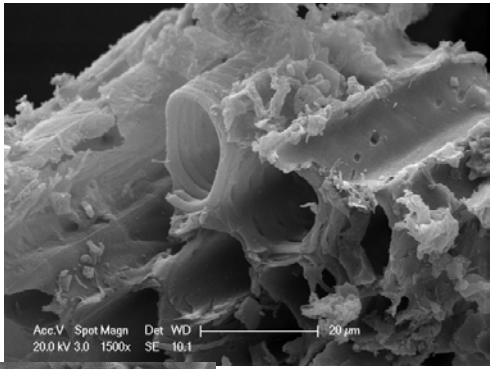
Overall score (Threshold: 3.00/5.00, Weight: 1.00) **5.00**

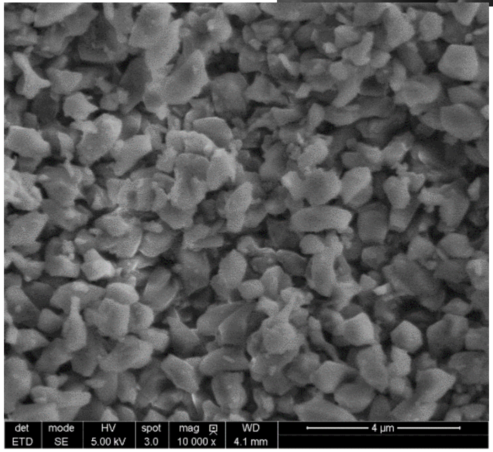
Total score

Total score (Threshold: 10.00/15.00, Weight: 1.00) **15.00**

Materials challenges

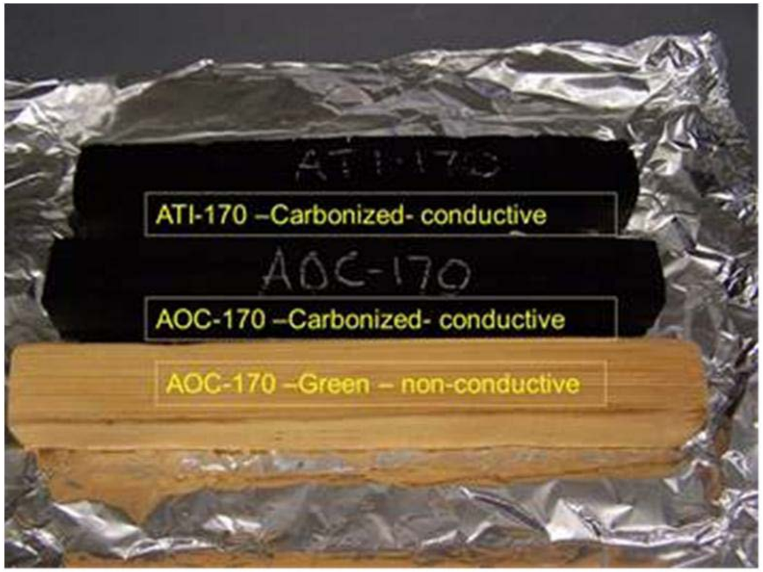
- We need to develop honeycombs with carbonaceous matrix (to conduct electricity) and zeolites and MOFs for high CO_2 capacity.
  - We need a kg-scale of MOFs
  - Improved carbons will also help





Materials challenges

- We need to develop honeycombs with carbonaceous matrix (to conduct electricity) and zeolites and MOFs for high CO_2 capacity.
  - Need to develop extrusion recipes. Recipes for extrusion of zeolites and MOFs are very different…
  - Different samples were prepare: ZSM-5, 13X, CPO-27(Ni)

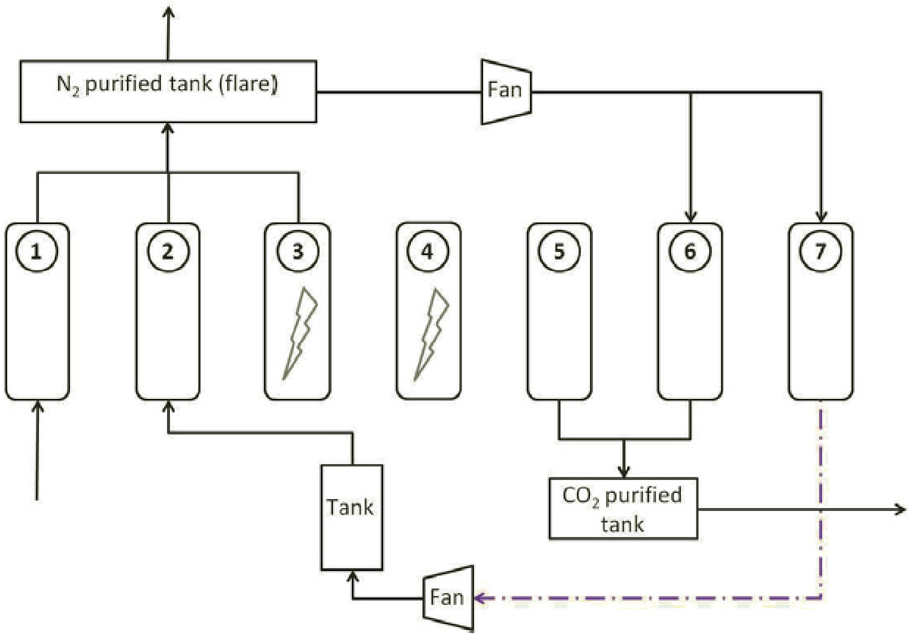


ESA process challenges

- Only solving the material problem will not help us to concentrate CO_2 from 4 to >95% (much inerts in the gas phase).

What is necessary is to remove inert gases from the column (helped by ESA in step 3) and avoid CO_2 losses (step 2).

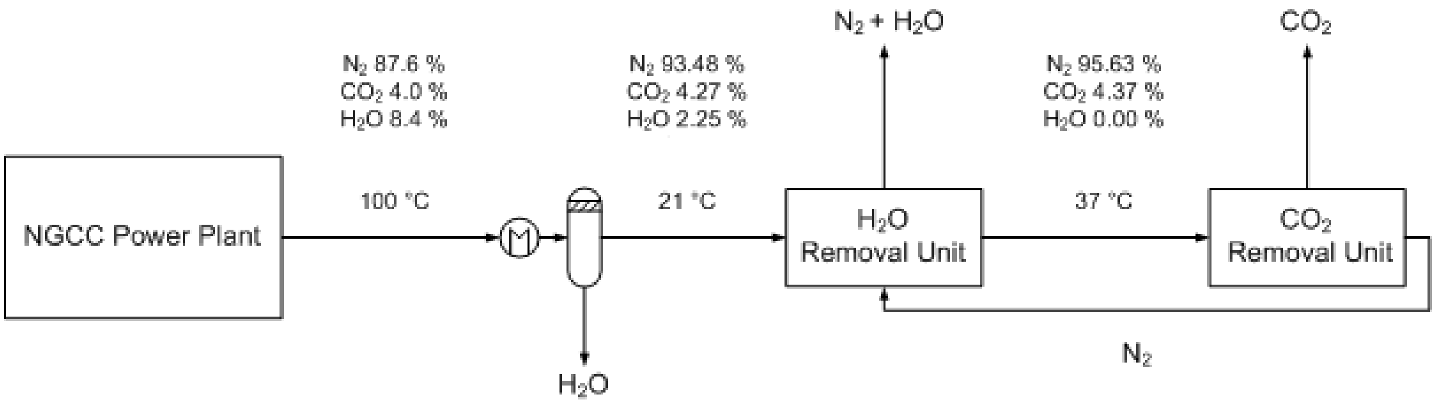
Step 4 is the main CO_2 desorption step and column is pre-purified so in principle it can be done with heat and not electricity…



But several cycles are possible!

ESA process results

- In most of the materials used, water should be previously removed
  - Using a preliminary step to remove water was considered.

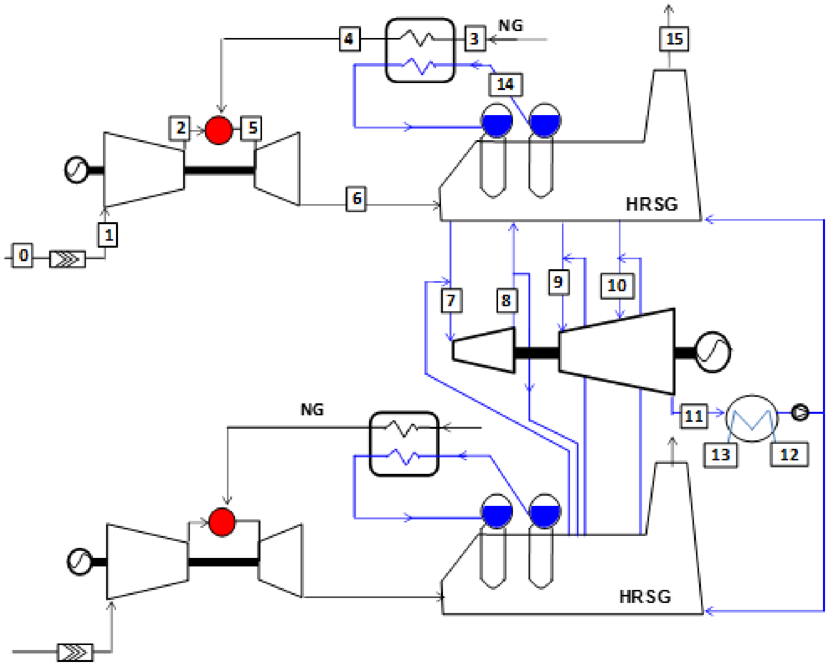


CO_2 puriy: 95.66%
Recovery: 93.39 %

- Water adsorption produces a lot of heat and refrigeration is needed
- Acceleration of bed cooling is required!

ESA integration

- The CO_2 capture plant is not an island in the power plant. Integration can help in minimize total energy consumed and cost.
  - Water should be removed initially (product in dry places).
  - Mixed pool of electricity and heat can be used.



The final accountability: LCA

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  - So … the value cha…

Chemicals

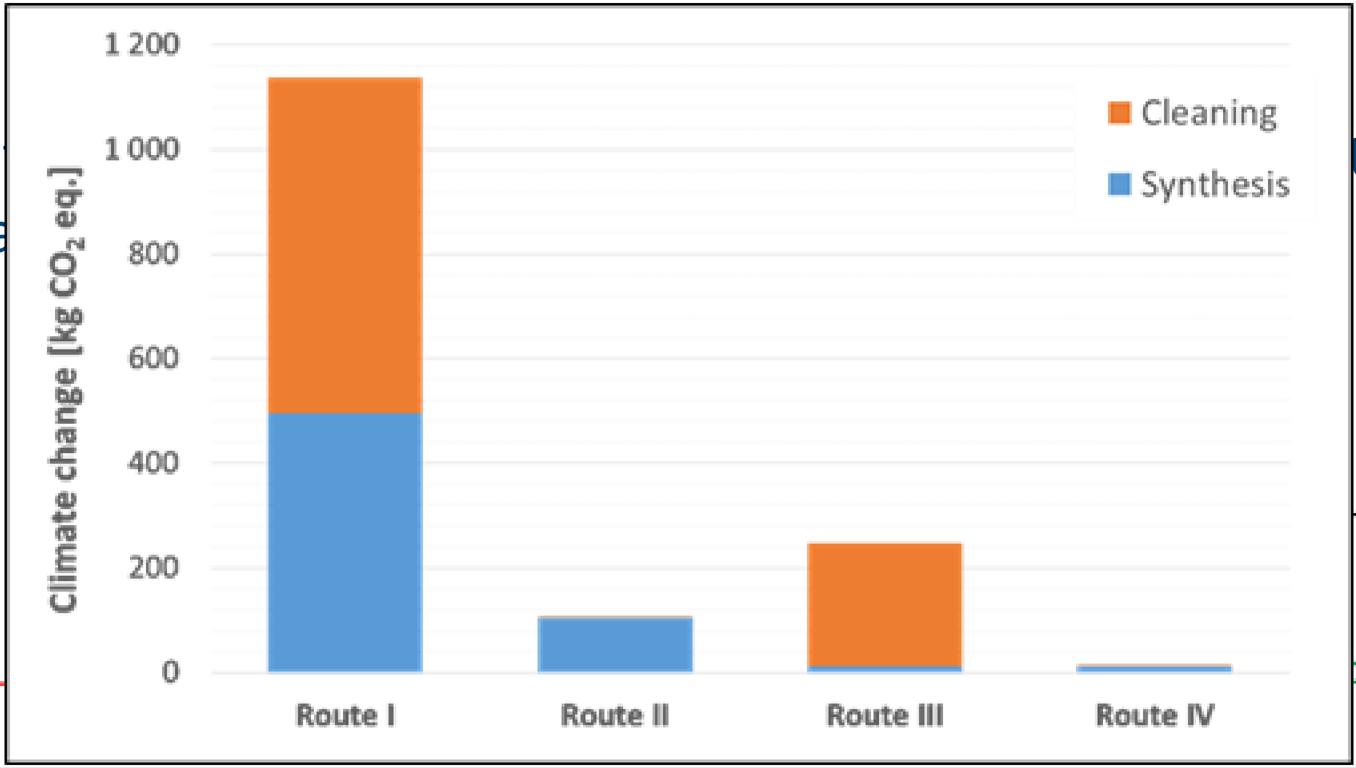
Chemicals

Chemicals

Energy

…rnatant

…D_6H_2)



We have changed the synthesis of CPO-27 (Ni) MOF and reduce significantly the environmental impact of its synthesis.

Some remarks

- We have seen that the development of hybrid conductive-high CO_2 capacity sorbents is possible.
- Significant advances in co-extrusion of materials has been made. But co-extruding high content of zeolites and MOFs is not easy.
- The content of solids affect the electrical properties of the materials. A proper tailor is necessary to minimize power consumption and achieve high CO_2 purity and recovery.
- The CO_2 capture plant is not an island in the power plant. Integration is important to reduce total energy consumed and cost.
  - ESA is an elegant way of displacing inert gases from the column.

Acknowledgments

- The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7 2007-2013) under Grant Agreement 608534 (MATESA project). Web-page: www.sintef.com/matesa

- To all the institutions who accepted to be part of this project.

- To all the people that contributed to the project:
  - Menka, Nikola, Marija, Ivana, Hans-Jürgen, Axel, Johannes, Silvia, Jenny, Michele, Francesca, Alessio, Jean-Jacques, Benedikt, Christian, Giampaolo, Davide, Jérôme, Valentina, Malte, Eva, Alfredo, Nouri, Gerardo, Javier, Paul, Penny, Qinghu, Alan, Marc, Richard, Giorgia, Anna, Aud, Kari Anne, etc.