Final Report

ENGAS RI

Environmental Gas Management Research Infrastructure

Transnational Access

Implemented as

Specific Support Action

Contract number: **RITA-CT-2003-506502**

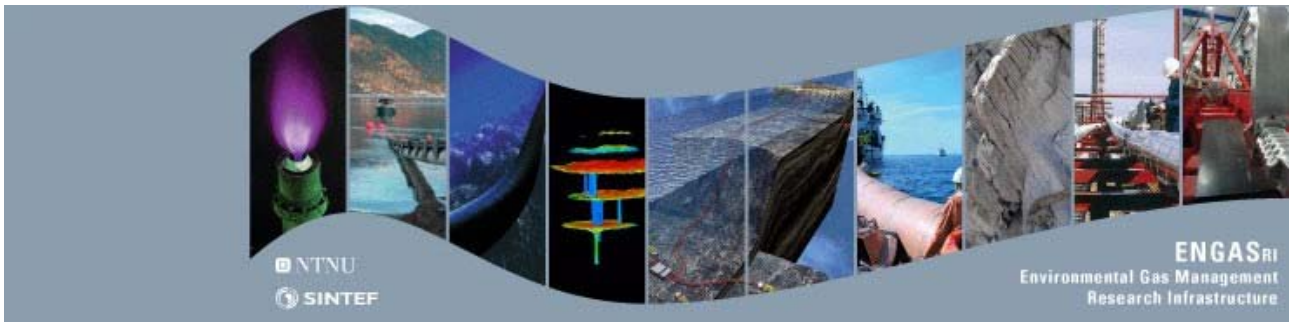
Project coordinator: **Arne M. Bredesen - NTNU**

Project website: **http://www.ntnu.no/engas/**

Project Duration: **60 months from 01.01.2004 to 31.12.2008**

Project funded by the European Community
under the "Structuring the European Research Area" specific programme
Research Infrastructures Action

A. ACTIVITY REPORT



www.ntnu.no/engas

Over the last 30 years NTNU and its technology transfer partner SINTEF have jointly developed a 8,000 square metre research facility worth 38 million Euro: the ENGAS Research Infrastructure. At this infrastructure, 600 people work at ways of cleaning up CO2, NOx, SOx and other greenhouse gases, and removing them from the oil and gas production processes and their use in industry, buildings and transport. A secondary thrust has been to cross-link this research with the development of clean new renewable energy technologies.

The ENGAS Research Infrastructure has had as an objective to open the laboratories to a larger European research community as to enhance science by international collaboration and cross-disciplinarity. Through granting qualified scientists access to a wide range of experimental gas facilities not within their reach, either for economic or geographical reasons, new scientific opportunities have been created. An integrated complex of 14 outstanding laboratories for focused and trans-boundary research within the field of environmental gas management were made available. These laboratories are designed to solve problems related to reducing emissions in the whole technology chain from energy source to end-user. The laboratories have been utilised successfully in bringing forward new innovative technology and solutions together with global industrial partners.

The ENGAS laboratory structure is based upon a long-term goal to establish clean electricity and hydrogen as main energy carriers in the future. **Figure 1** shows the range of processes that can be studied at the 14 different laboratories included in the ENGAS research infrastructure.

Regarding the transnational access activities, the daily running of the project was managed by the ENGAS secretariat, whereas the scientific support and guidance of the access projects was performed by a steering committee. In order to secure a smooth running of the infrastructure and of the individual projects, the committee met approximately twice a year for coordination and internal communication purposes.

An ENGAS user selection procedure was defined at the start of the contract, supported by a standard application form, an evaluation form and a set of assessment criteria. A two-stage selection consisted of an evaluation of the feasibility of the proposed experiments by the facility providers, followed by a scientific assessment performed by at least two members of the User Selection Panel. After two years of operating with fixed calls for proposals, an open call was adopted. This change stimulated a more continuous flow of applicants, allowing researchers to apply whenever it was most suitable. Acceptance of an application required a positive evaluation of a majority of the panel members. In case of equal marks, secondary criteria were used for prioritisation, i.e. number of

female group members and first time users. In total, 33 proposals were received. Of those, 27 were approved, corresponding to a success rate of 82 %.

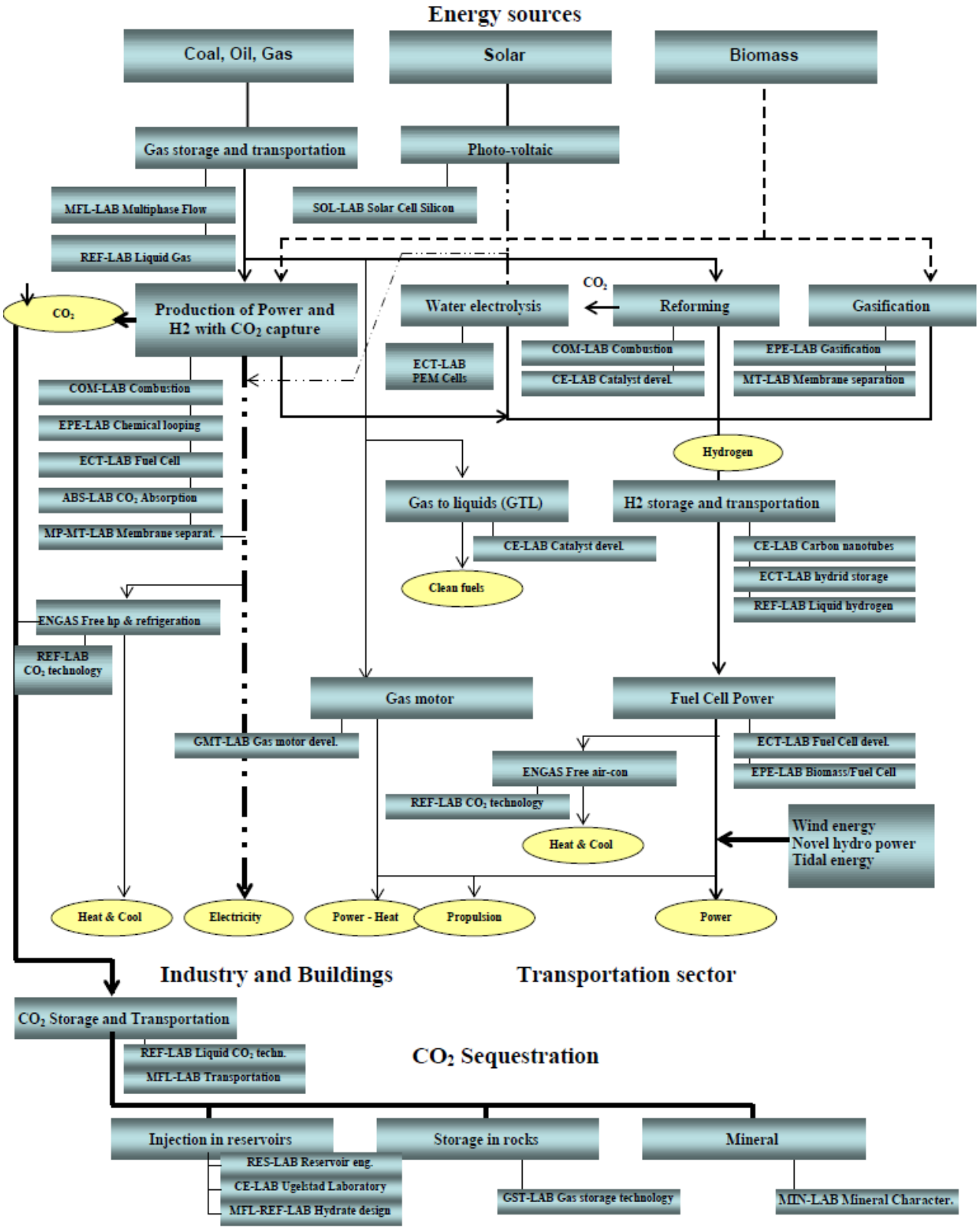


Figure 1. ENGAS Laboratory Roadmap

In total, 27 user groups accessed the ENGAS research infrastructure during the entire project period. This corresponded to 35 users from 13 countries, having used the available facilities for 715 access days.

The development of environmental methods to produce, store and transport different energy sources is becoming increasingly important as evidence of global warming a shown at an increasing pace. Only international collaboration on a high scientific level can advance the sector forward into the desired direction. Cooperation with and training of researchers in experimental gas research across the European Community is crucial in order to strengthen Europe's position in looking for knowledge-based solutions to the climatic challenges the world is facing. The availability of highly specialised laboratory to users not normally having access to these kind of facilities in their home country was explicitly emphasized by many users as an important reason for using the opportunity offered by the ENGAS project. A special contribution to a further integration of new EU Member States was obtained through providing access to users coming from countries such as Hungary, Lithuania, Slovakia, Poland and Turkey.

A large majority of the users had never used the facilities at ENGAS earlier, indicating that the contribution of the European Commission had a decisive role in the promoting of experimental research on greenhouse gasses in Europe. An overview of access details is given in **Table 1**.

Table 1. Overview of estimated and actual access provided, number of supported users and user groups per installation

Installation (s)		**Unit of access**	**Estimated access provided for the whole duration of the project**			**Actual access provided for the whole duration of the project**		
Short name(s)	**No#**		**Minimum quantity of access to be provided**	**Estimated number of users/persons**	**Estimated number of user groups**	**Quantity of access provided**	**Number of users/persons**	**Number of user groups**
MFL	**1**	days	25	3	1	25	2	1
REF	**2**	days	55	1	1	55	1	1
COM	**3**	days	100	6	4	111	7	5
EPE	**4**	days	125	11	7	137	10	7
GMT	**5**	days	0	0	0	0	0	0
ABS	**6**	days	110	3	3	103	2	2
MP	**7**	days	60	3	3	102	4	4
MT	**8**	days	70	4	3	58	3	2
CE	**9**	days	130	4	4	110	3	3
ECT	**10**	days	0	0	0	0	0	0
RES	**11**	days	20	1	1	0	0	0
GST	**12**	days	0	2	0	0	0	0
MIN	**13**	days	20	3	2	14	3	2
SOL	**14**	days	0	0	0	0	0	0
SUM			715	41	29	715	35	27

In total, researchers from 14 different countries came to Trondheim for a period of 4 up to 49 days to perform tests at one of the ENGAS laboratories. An overview of the users at the infrastructure is given in **Table 2**, whereas the geographical distribution is illustrated in **Figure 2**.

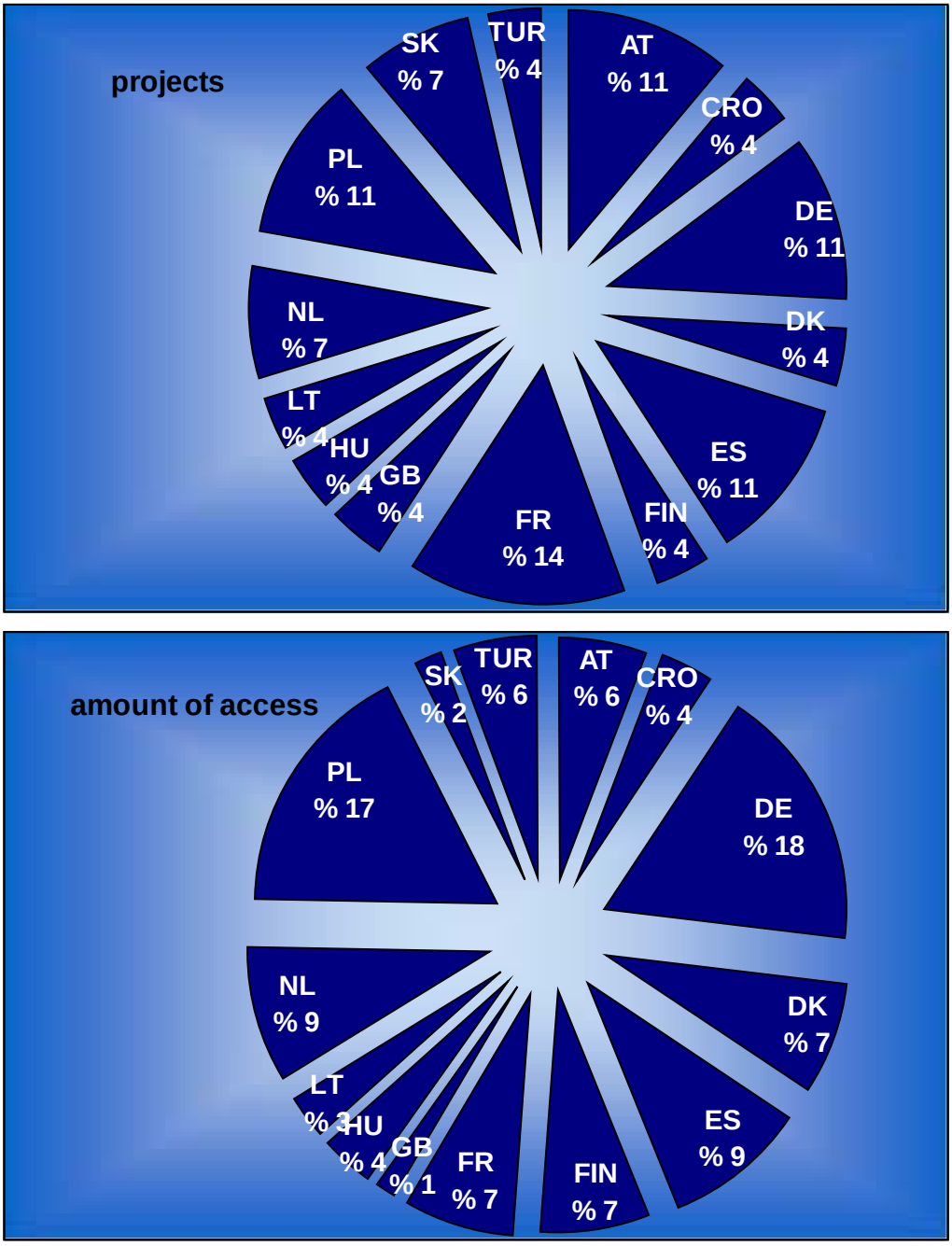


Figure 2. Access at the ENGAS research infrastructure project distributed according to participating European countries as number of projects (top) and amount of access (bottom).

After amendment of the contract in 2007, it was anticipated that 10 out of the 14 different laboratories would be accessed by 29 user groups. In reality, the total number of access days to be provided was achieved by 27 groups using in total 9 facilities. Hence, there was only a limited discrepancy between estimated and actual access. The large variety of laboratories offered was clearly appreciated by the European research community, which was given the chance to select the facility that was answering best to its needs.

The participation of female users was stimulated through inviting in particular women to apply for access, and through using the share of female group members as a criterion for selection. The

gender balance in the 27 access projects performed was 29 male against 6 female researchers, corresponding to a female representation of about 17 %. This was somewhat under the preset expectations, but is nevertheless experienced as a satisfactory result as the target group is a clearly male dominated energy research community. It is therefore believed that the ENGAS research infrastructure has contributed to making a research career in the field of gas technology more attractive, in particular to female and young scientists.

Due to a late start of the access activities in the first reporting period, combined with applications arriving late in the 4th reporting period, an extension of the contract to 5 years was applied for and granted by the Commission. The additional time allowed the contractor to fulfil its obligations towards the Commission regarding the quantity of access provided.

Table 2. Overview over all access projects with users, their home institution, the facilities used and the period of access, from 2005 to 2008.

User project acronym	Name of visitor(s)	Home Institutin	Country
Boubert	Pascal Boubert	Université de Provence – IUSTI	FR

Installation name	Installation No	Duration of stay	Amount of access delivered
COM-LAB	3	11	8

Project title

NO LIF in Hydrogen Flame

User project acronym	Name of visitor(s)	Home Institutin	Country
Mészáros/Várhegyi	Erika Mészáros, Gabor Varhegyi	Hungarian Academy of Science	HU

Installation name	Installation No	Duration of stay	Amount of access delivered
EPE-LAB	4	48	25

Project title

Pyrolysis and Gasification of Biomass from Energy Plantations

User project acronym	Name of visitor(s)	Home Institutin	Country
Sacher/Kutchi	Stephan Sacher, Klaus Kutschi	Technical University Graz	AT

Installation name	Installation No	Duration of stay	Amount of access delivered
EPE-LAB	4	20	11

Project title

Influence of liquid water activation on the reaction of SO_2 with calcium hydroxide

User project acronym	Name of visitor(s)	Home Institutin	Country
Zukauskas	Gerardas Zukauskas	Lithuanian Energy Institute	LT

Installation name	Installation No	Duration of stay	Amount of access delivered
EPE-LAB	4	27	20

Project title

Development possibilities of small scale CHP in Lithuania

User project acronym	Name of visitor(s)	Home Institutin	Country
Nitzsche	Jörg Nitzsche	TU Bergakademie Freiberg	DE

Installation name	Installation No	Duration of stay	Amount of access delivered
CE-LAB	9	49	30

Project title

Investigation of catalysts for steam reforming of natural gas for residential fuel cell applications

User project acronym	Name of visitor(s)	Home Institutin	Country
Sebastian	Victor Sebastian	University of Zaragoza	ES

Installation name	Installation No	Duration of stay	Amount of access delivered
MP-LAB	7	20	15
Project title			
Study of CO_2 separation with different zeolite membranes			

User project acronym	Name of visitor(s)	Home Institutin	Country
Balaz	Peter Balaz	Slovak Academy of Sciences	SL
Installation name	**Installation No**	**Duration of stay**	**Amount of access delivered**
MIN-LAB	13	8	4
Project title			
Carbon dioxide sequestration by mechanically activated minerals			

User project acronym	Name of visitor(s)	Home Institution	Country
Balas	Peter Balaz/Martin Fabian	Institute of Geotechnics, Slovak Academy of Sciences	SK
Installation name	**Installation No**	**Duration of stay**	**Amount of access delivered**
MIN-Lab	13	16	10
Project title			
Carbon dioxide sequestration by mechanically activated minerals			

User project acronym	Name of visitor(s)	Home Institution	Country
Benmami	Mohamed Benmami	University of Paris 13	FR
Installation name	**Installation No**	**Duration of stay**	**Amount of access delivered**
EPE-Lab	4	33	26
Project title			
Acid flue gas cleaning at low concentrations			

User project acronym	Name of visitor(s)	Home Institution	Country
de Lathoudour	Karen de Lathoudour	Delft University of Technology	NL
Installation name	**Installation No**	**Duration of stay**	**Amount of access delivered**
CE-Lab	9	54	40
Project title			
Developing Large-Scale Production of Carbon Nanotubes for Membrane Applications			

User project acronym	Name of visitor(s)	Home Institution	Country
Gabrielsen	Jostein Gabrielsen	Technical University of Denmark	DK
Installation name	**Installation No**	**Duration of stay**	**Amount of access delivered**
ABS-Lab	6	56	52
Project title			
Absorption and desorption of CO2 from AMP solutions in a packed column			

User project acronym	Name of visitor(s)	Home Institution	Country
Kautz	Martin Kautz/Steffen Giesel	TU Bergakademie Freiberg	DE
Installation name	**Installation No**	**Duration of stay**	**Amount of access delivered**
COM-Lab	3	76	55
Project title			
Determination of the radical concentration (OH, CH) in CH4-H2-flames by means of laser measuring technique			

User project acronym	Name of visitor(s)	Home Institution	Country

Knuutila	Hanna Knuutila	Tampere University of Technology	

Installation name	Installation No	Duration of stay	Amount of access delivered
ABS-lab	6	55	51

Project title

Use of sodium carbonate in CO_2 separation

User project acronym	Name of visitor(s)	Home Institution	Country
Maurer	Christoph Maurer	Technical University of Graz	AT

Installation name	Installation No	Duration of stay	Amount of access delivered
EPE-Lab	4	27	20

Project title

Calorific value of volatiles released of a bed of biofuels under pyrolysis condition

User project acronym	Name of visitor(s)	Home Institution	Country
Mühle	Tobias Mühle	TU Bergakademie Freiberg	DE

Installation name	Installation No	Duration of stay	Amount of access delivered
CE-Lab	9	57	40

Project title

Screening and comparison of different catalysts for steam reforming in fuel cell systems

User project acronym	Name of visitor(s)	Home Institution	Country
Ozturk	Bahtiyar Ozturk/Emin Okumus	Ondokuz Mayis University	TU

Installation name	Installation No	Duration of stay	Amount of access delivered
MT-Lab	8	58	40

Project title

Membrane Characterization for Gas separation

User project acronym	Name of visitor(s)	Home Institution	Country
Banasiak	Krzysztof Banasiak	Silesian University of Technology	PL

Installation name	Installation No	Duration of stay	Amount of access delivered
REF-Lab	2	72	55

Project title

R744 (CO2) as a working fluid in refrigeration systems

User project acronym	Name of visitor(s)	Home Institution	Country
Kadri	Usama Kadri/Renè Oliemans	Delft University of Technology	NL

Installation name	Installation No	Duration of stay	Amount of access delivered
MFL-Lab	1	39	25

Project title

Long liquid slugs in stratified gas/liquid flow in horizontal and slightly inclined tubes

User project acronym	Name of visitor(s)	Home Institution	Country
Lianbo	Lianbo Liu	Imperial College London	GB

Installation name	Installation No	Duration of stay	Amount of access delivered
MT-Lab	8	27	10

Project title

Membranes for CO2 capture

User project acronym	Name of visitor(s)	Home Institution	Country

Pucher	Peter Pucher Andrei Kanaev	Graz University of Technology University Paris-Nord	AT FR

Installation name	Installation No	Duration of stay	Amount of access delivered
EPE-Lab	4	15	10

Project title

Photocatalytic gas cleaning

User project acronym	Name of visitor(s)	Home Institution	Country
Shaffel	Natalie Shaffel/Sebastian Werle	Silesian University of Technology	PL

Installation name	Installation No	Duration of stay	Amount of access delivered
COM-Lab	3	46	30

Project title

Experimental investigations of partially premixed flames

User project acronym	Name of visitor(s)	Home Institution	Country
Tiscornia	Inès Silvia Tiscornia	University of Zaragoza	ES

Installation name	Installation No	Duration of stay	Amount of access delivered
MP-Lab	7	34	23

Project title

Zeolite membrane characterization by a novel defect detection

User project acronym	Name of visitor(s)	Home Institution	Country
Torrecilla	Jorge Bosque Torrecilla	University of Zaragoza	ES

Installation name	Installation No	Duration of stay	Amount of access delivered
MP-Lab	7	35	29

Project title

Adsorption measurements on several zeolitic samples

User project acronym	Name of visitor(s)	Home Institution	Country
Boubert	Pascal Boubert	Université de Provence – IUSTI – Marseille	FR

Installation name	Installation No	Duration of stay	Amount of access delivered
COM-Lab	3	18	13

Project title

Determination of Raman spectra of CO2 in a high temperature optical cell

User project acronym	Name of visitor(s)	Home Institution	Country
Cabot	Gilles Cabot	CORIA CNRS UMR 6614	FR

Installation name	Installation No	Duration of stay	Amount of access delivered
COM-Lab	3	8	5

Project title

Effect of CO2 dilution on Flame Stability

User project acronym	Name of visitor(s)	Home Institution	Country
Klenovcanova	Alexandra Klenovcanova	Technical University of Kosice,	CR

Installation name	Installation No	Duration of stay	Amount of access delivered
EPE-LAB	4	35	25

Project title

Study of mechanisms of biomass gasification processes

User project acronym	Name of visitor(s)	Home Institution	Country
Szczepanowicz	Krzysztof Szczepanowicz	Institute of Catalysis and Surface Chemistry PAS (ICSC)	PL

Installation name	Installation No	Duration of stay	Amount of access delivered
MP-LAB	7	50	35

Project title

Preparation of capsules with silica shells for high temperature applications

Along with the start of the ENGAS activities, four European Integrated Projects were initiated at NTNU / SINTEF dealing with related research fields. This strengthened the international profile of the research infrastructure even more and further reinforced the dynamism and quality of the scientific environment that was offered to the visiting researchers.

List of Publications

By the end of the project, 24 publications have appeared or are accepted in peer-reviewed journals or peer-reviewed conference proceedings. Many of those publications are a result of joint efforts between the users and the hosting researchers at NTNU / SINTEF, which is illustrated by a co-authorship. This was experienced as an important additional benefit of the ENGAS project. The user project Banasiak even resulted in a new research initiative, i.e. the project "Development of High-Efficiency, Small-Scale Heat Pumping Units Using an Environmentally Benign Working Fluid R744 and Expansion Work Recovery with Ejectors". It involves the Silesian University of Technology in Poland and the refrigeration team at NTNU/SINTEF and is financed by the Polish-Norwegian Research Fund.

Most of the users in 2008 are still processing their results. It is difficult to monitor and keep track of publications of previous users, since many of the PhD students leave their home Institutions/Universities after earning their PhD-degree and by this changing e-mail address.

1. Martin, A., Fransson, T., Grønli, M., Bredesen, A.M; *SUSPOWER and ENGAS: Two Major European Research Infrastructures in the Gas Turbine and Energy Conversion Fields.* Proceedings of GT2007, ASME Turbo Expo 2007: Power for Land, Sea and Air, May 8-11, 2007, Barcelona, Spain.
2. Gabrielsen J., Svendsen H.F., Michelsen M.L., Stenby E.H., Kontogeorgis G.M., Pilot Plant Studies and Modeling of CO_2 Capture Using an AMP Solution, Proceedings of AIChE Annual Meeting, San Francisco, USA, 12^{th}-17^{th} November, 2006.
3. Gabrielsen J., Svendsen H.F., Michelsen M.L., Stenby E.H., Kontogeorgis G.M., Experimental Validation of a Rate-Based Model for CO_2 Capture using an AMP Solution, Accepted for publication in *Chem. Eng. Sci.*
4. Knuutila H., Anttila M., Børresen E., Juliussen O., Svendsen H. 2006. CO2 capture with sodium carbonate. 8th International Conference on Greenhouse Gas Technologies, 19-22.6.2006, Trondheim, Norway.
5. Sebastian V., Kumakiri I., Bredesen R., Menendez M. Zeolite membrane for CO2 removal: operating at high pressure, Desalination 199 (2006) 464–465.
6. Sebastian V., Kumakiri I., Bredesen R., Menendez M. Zeolite membrane for CO2 removal: Operating at high pressure. Journal of Membrane Science 292 (2007) 92–97.
7. Kadri, U., Mudde, R., Oliemans, R., 2007. On the prediction of the transition from stratified flow to roll waves and slug flow in horizontal pipes. BHR Conf., Edinburgh, Scotland 13, 65-78.

8. Kadri, U., Mudde, R., Oliemans, R., 2007. On the development of waves into roll waves and slugs in gas-liquid horizontal pipe flow. ICMF Conf., Leipzig, Germany 6, 332.
9. Khalil R.A., E. Meszaros, M.G. Grønli, G. Varhegyi, I. Mohai, B. Marosvolgy, J.E. Hustad Thermal analysis of energy crops Part I: The applicability of a macro-thermobalance for biomass studies. J. Anal. Appl. Pyrolysis 81 (2008) 52–59
10. Khalil, R.; Várhegyi, G.; Jäschke, S.; Grønli, M. G.; Hustad, J.: CO2 gasification of biomass chars. A kinetic study. Energy Fuels, 2009, 22, 94-100
11. Baláž, P., Turianicová, E., Fabián, M., Kleiv, R.A., Briančin, J., Obut, A.: Structural changes in olivine (Mg,Fe)2SiO4 mechanically activated in high-energy mills, International Journal of Mineral Processing, 88 (2008) 1-6.
12. Fabián, M., Shopska, M., Paneva, D., Kostova, N., Turianicová, E., Baláž, P., Briančin, J., Kadinov, G., Mitov, I., Kleiv, R.A.: Adsorption of carbon dioxide on mechanically activated olivine, Nanoscience and Nanotechnology 8 (2008) 85-88.
13. Turianicová E., Baláž P.: Sorption of Cd2+ ions by mechanochemically activated olivine (Mg,Fe)2SiO4, Acta Metallurgica Slovaca 14 (2008) 254-261.
14. Turianicová, E., Baláž, P.: Milling of olivine (Mg,Fe)2SiO4 in high-energy mills by wet and dry way, Chemical Papers 102 (2008) 921-923.
15. Turianicová, E., Baláž, P.: Surface and bulk changes of olivine (Mg,Fe)2SiO4 after high-energy milling. In Proocedings of 12th Conf. on Environment and Mineral Processing - Part II, VŠB-Technical University Ostrava, Faculty of Mining and Geology, Ostrava, Czech Republic 2008, 319-325.
16. Turianicová, E., Baláž, P.: Changes in solid state properties of olivine (Mg,Fe)2SiO4 mechanically activated in high-energy mills. In Proocedings of Conf. BALKATRIB 08, Sozopol, Bulgaria 2008, CD: BT-077-1-BT-077-4.
17. Turianicová, E., Baláž, P.: CO2 sequestration on olivine activated in an industrially-scalable mill. In Proceedings of Conf. ACEME 08, Roma, Italia 2008, 439-442.
18. Baláž, P., Turianicová, E., Fabián, M.: Mechanically activated olivine (Mg,Fe)2SiO4 as an *potential mineral for CO2 sequestration. In Proocedings of 11th Conference on* Environment and Mineral Processing - Part II, VŠB-Technical University Ostrava, Faculty of Mining and Geology, Ostrava, Czech republic 2007, 59-64.
19. Fabián, M., Shopska, M., Baláž, P., Kostova, N.G., Turianicová, E., Briančin, J., Kleiv, R.A., Kadinov, G.: Carbon Dioxide Adsorption on Mechanically Activated Olivine. In Proocedings of Conf. BULTRIB 07, Sofia, Bulgaria 2007, 42-50.
20. K. Szczepanowicz , D. Dronka – Góra, G. Para1, A. M. Bouzga , C. Simon, Juan Yang and P. Warszyński, "Chloroform Emulsions Containing TEOS, APS and DTSACl as Cores for Microencapsulation", Submitted for publication in Chemistry Procedia, Elsevier (2009).
21. Tiscornia I., Kumakiri I., Bredesen R., Tellez C.; Coronas J., Titanosilicate ETS-10 membrane for high pressure CO2 separation, Proceedings of 10th international conference on inorganic membranes (ICIM-10), Tokyo, Japan Aug. 18-22 2008.
22. Tiscornia I., Kumakiri I., Bredesen R., Tellez C.; Coronas J., MICROPOROUS TITANOSILICATE ETS-10 MEMBRANE FOR HIGH PRESSURE CO2 SEPARATION, submitted for publication in Separation and Purification Technology
23. K. Banasiak, M. Drescher and A. Hafner, EXPERIMENTAL PARAMETER INVESTIGATION OF R744 EJECTOR. In Proceedings of 8th IIR Gustav Lorentzen Conference on Natural Working Fluids, September 7-10, 2008, Copenhagen, Denmark
24. N. Schaffel, S. Werle, A. Szlęk, R. K. Wilk, and J. E. Hustad. Experimental investigations of partially premixed flames, In Proceeding of ECOS2008 conference, Volume II, Page 921