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CGS Europe Spring School on CO_2 storage 2

Hosted by GeoEcoMar at Uzlina, Murighiol, Romania
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1 Introduction

Aim of the course
The purpose of the *CGS Europe Spring School on CO_2 Geological Storage* is to provide a full-week specialised training course on CO_2 geological storage (CGS), targeted in particular at young scientists and post-graduate students. The overall objective is to communicate knowledge and understanding of CGS aspects with a focus on the planned CCS demonstration projects and the implementation of the EU Directive on the geological storage on CO_2 (hereinafter called the EU Storage Directive) as well as of the Monitoring and reporting guidelines of the EU ETS directive.

It was planned to run the school twice within the project duration and it should be ready for repetition with small adjustments in the following years. A one week (5 days) run of this school is already being planned for IGME, Greece on September 30 to October 4, 2013.

1.1 Advanced course on geological storage of CO_2

Raising public participation, awareness and societal anchorage is one of the main issues addressed by the CGS Europe project. The Carbon Dioxide (CO_2) Capture and Storage (CCS) environment will change over the coming years with new projects and demo sites, many of them involving participants of CGS Europe. Among other things, the deployment of CCS will bring the need of new young specialists with a sound knowledge of the topic – geologists and engineers who will be active in both industry and research. As contributing to education in the field of CGS is a key objective of CGS Europe, this makes young scientists and students one of the main target audiences of the project's dissemination activities. From this point of view, the CGS Europe Spring School on CGS is the appropriate dissemination tool, which can be used to react to these needs.

Another aspect of the Spring School deals with the regulatory framework of CCS. Rules and guidelines were made available at the EU level to enable the implementation of CCS. Unfortunately, not all Member States have been able to implement this regulatory framework in their national legislation yet, and the awareness of this framework is relatively low in many countries. In this respect, the course aimed to disseminate and share the knowledge in the field of CGS, regulations, monitoring and reporting guidelines to the target student group. This included thorough information on the EU Storage Directive, the related Guidance Documents, as well as the Monitoring and reporting guidelines of the EU ETS Directive.

1.2 Goal of the Spring School

The purpose of the CGS Europe Spring School is to offer the students a tool for learning about CO_2 geological storage from a group of professionals, researchers and scientists involved in international CCS programmes. In this manner, understanding and learning were conveyed of aspects relating to the sink (storage site) where the CO_2 can be stored safely for thousands of years – including the broader perspective of CO_2 capture and transport.

The overall objective of this CGS Europe Spring School was to communicate knowledge and understanding of geological storage aspects of CO_2 with a specific focus on "Monitoring" – an important aspect of CGS required in order to meet the coming years' challenges of new projects and

demo sites. In this respect, special emphasis was put on the European context where the challenge of identifying, mapping and bringing into operation CO_2 geological storage sites is critical.

The goal was to provide students with diverse backgrounds a broad understanding of the issues surrounding CO_2 geological storage as an effective tool in a wide range of climate change mitigation options and encourage their active participation in this area. The overall approach was based on a series of lectures on the whole CCS chain, starting with climate change and ending with monitoring and legislation. In general, there were morning session with lectures and afternoon exercises based on the lectures and a prefeasibility study of one emerging full-chain CCS project. The exercises ended with a poster presentation where each team of students presented a poster designed by them on a CGS aspect, for instance, a demo storage site with a monitoring plan.

Figure 1: Map of Danube Delta and position of Uzlina

The course introduced the following topics:

- CCS in general with a focus on climate change and CCS as a CO_2 abatement technology, an introduction to geology and geological storage of CO_2, CCS and EOR, geological site characterisation & capacity estimates, overview of the whole CCS chain, experiences and status.
- Storage site modelling with a review of seismic data and well data, dynamic modelling and optimizing storage or EOR production.
- Risks and monitoring with emphasis on risk assessment and risk elements, safety criteria, scenario analysis, monitoring methods and a report on leakage events with case stories and natural leakage examples.

- Legal framework and requirements with an overview on the EU Storage Directive, relating to the implementation of CCS, risk assessment required by legislation, regulations and guidelines and monitoring methods considering the EU legislation.
- Non-technical aspects (economics, acceptance and policy) regarding public opinion, acceptance, awareness, information strategies, and greener energy technologies in relation to CCS costs.

Figure 2: CGS Europe Spring School in Romania. Teachers and students in front of the Cormoran hotel in Uzlina

1.3 Target group

The target group was post-graduate students, PhD students and Post Docs from Europe working on geological storage of CO_2. Participation of Master students was possible in the case of free chairs, and for this school two MSc students participated together with PhD students, post-graduate students and young researchers.

1.4 Curriculum

The CGS Europe Spring School on CGS provided theoretical and practical knowledge on CO_2 geological storage and monitoring of storage sites, based on recent international research and development work. Vital elements were geological storage aspects, identification and mapping of sites, safety aspects, injection, monitoring and reporting. The thematic approach included lectures

and exercises based on study groups, and a field excursion. Compendia, articles and/or other material that were made available to the students during and after the course covered most lectures. The Spring School ran for a complete week – Wednesday to Wednesday including transport from Bucharest to Uzlina (Figs 1–2). The lecturers were available throughout the entire duration to meet student's requests and answer their questions, and the lecturers participated actively in discussions when appropriate.

1.5 Language

The official language of the Spring School was English. All lectures were given in English.

1.6 Excursion

An integral part of the Spring School was an excursion in the Danube delta to give students an impression of a deltaic environment (Figs 3–4).

Figure 3: Excursion in the Danube Delta

Figure 4: Excursion in the Danube Delta

1.7 Practical exercises

The students were divided into 4 groups. A daily practical exercise formed part of an overall coherent aim. The practical exercise took place each afternoon based on the morning's lecture (Fig. 4). At the end of the Spring School, each group presented a poster showing the results of their 1-week training (Fig. 5).

The poster designed by each group had to promote their choice of CO_2 geological storage scenario, including monitoring solutions, the best storage site and 'sink'. This involved the group team:

- Forming a 'CO_2 storage monitoring consortium'.
- Using the knowledge gained during the lectures (and previously) and the materials provided in the sessions and exercises.
- Illustrating their poster with images selected from the sheets and materials provided and/or from the internet (if available).
- Using their manual skills – the poster had to be handmade (not computer made).

- At the end of the Spring School, each group gave a 15-minutes presentation of their poster to the rest of the class, explaining all technical terms and adapted to an audience unfamiliar with CCS (e.g. aquifer, storage container, why storage sites below a certain depth are preferable, etc.). The winning group were awarded a small prize for the most attractive poster.

Figure 5: Students working on the daily exercise

1.8 Outcomes of the poster exercise

The students produced four excellent posters that nicely showed a high level of learning and understanding of storing CO_2 and monitoring the storage sites. This included the development of a monitoring plan for a storage site, as well as a good understanding of the EU Storage Directive and the Guidance Documents.

2 Planning of the Spring School

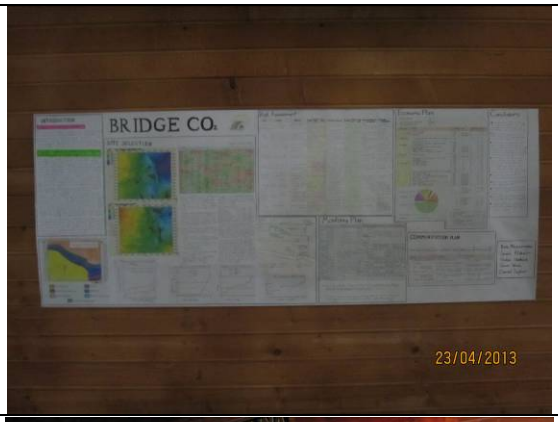
The planning started in May 2012 by appointing the teachers for the second Spring School and hereafter with discussions between the teachers up to January 2013 on the programme (Table 1), adjusting the programme and lectures from the first run of the Spring School, following the student evaluation of first Spring School, for example, to make the lectures more coherent and to give less reiteration of the different substances. The teaching programme with assigned lecturers and topics/exercises was ready in January 2013.

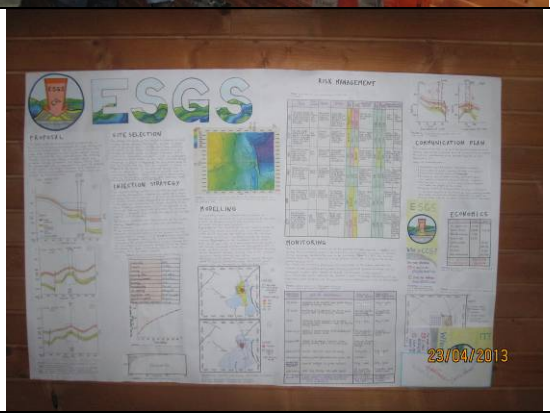
Ameena Camps of IEAGHG, who joined the first Spring School in 2012 as a teacher made her apologies to the second Spring School and her introductory lecture on climate change and CCS was taken over by Niels Poulsen.

Applications for sponsors' support were sent out in the early autumn. All former EU GeoCapacity industrial partners were asked to support the Spring School by a donation for the students' travel, board and lodging. Vattenfall AB was, however, the only company that replied positively and donated 2500 €. In addition, an airline company was asked for support of the students' travel, but with no success.

The Zero Emission Platform (ZEP) supported the first Spring School with useful reports on CCS and a library of key CCS materials (not just from ZEP but also from other CCS stakeholders). This material was also provided to the students of this Spring School, in electronic form on a USB stick. The USB stick also contained all lectures given during the Spring School, as well as the CCS EU Storage Directive and its Guidance Documents.

Figure 6: Poster session. The four groups of students and their posters





Activity	**Status / Period**
Programme & teachers	Teaching plan and teacher's team were ready after the first Spring School; however, some adjustments were made following the evaluation of the first Spring School (May 2012 – January 2013).
Location	Uzlina, Murighiol, Romania, finally decided in April–May 2012
Date for Spring School (Thursday 18 April 2013 to Wednesday 24 April 2013, with arrival on Wednesday 17 April)	Decided June 2012
Sponsors	Approached in the autumn 2012
Announcement (web and universities)	October 2012
Applications from students	Early January 2013
Selection of students upon qualifications for the Spring School	End January 2013
Additional announcement	January – March 2013
Final selection of students	January – March 2013 (applications in reply to the additional announcement)
Detailed planning of programme, adjustment of teaching plan	January – March 2013
The Spring School 2013	Thursday 18 April 2013 – Wednesday 24 April 2013 with arrival on Wednesday 17 April 2013
Table 1: The countdown plan for the Spring School	

GeoEcoMar kindly offered to arrange the Spring School in one of their main working areas within the Danube Delta. This was decided as a good choice because the planned Getica CCS demonstration project in Romania (EEPR/NER300) was expected to attract some additional interest in the course. The venue was the course facility building (Fig. 7) at the Cormoran hotel in Uzlina (Murighiol), which could offer both good and cheap teaching facilities as well as cheap accommodation for teachers and students.

Figure 7: The course facility in Uzlina at the Cormoran hotel

The Romanian CCS Demonstration Project Getica plans to implement a full chain operational CCS system capturing 1.5 million tonnes per annum of CO_2 from an existing 330MW unit of the Turceni Power Plant in Oltenia, Romania. This would involve retrofitting one of the 330MW lignite-fired units at the Turceni energy complex. The preferred capture process for the project is the chilled ammonia technology. It is planned that the captured CO_2 should be transported by pipeline to a deep saline aquifer within 50 km of the plant.

2.1 Announcement

The announcement of the Spring School was posted on the CO_2GeoNet and CGS Europe websites in October 2012 and further announcements were distributed to project partners and to a comprehensive mailing list (about 2000) of CCS stakeholders used for the CO_2GeoNet Venice Open Forum annual event. Further e-mails were sent to all universities where the EAGE / CO_2GeoNet Student Lecture Tour presentations were given. Moreover, CGS Europe project participants also used their national distribution channels to distribute the announcement.

2.2 Selection and grants

Students eligible to attend the CGS Europe Spring School on CGS were selected upon qualifications that were documented in the application forms (CV and recommendation by the supervisor, professor or head of department).

The attendance was free of charge. However, in order to receive the CGS Europe Studies Diploma, students had to attend all the classroom sessions and practical exercise sessions (all students of the Spring School 2013 received their diploma). The students or their institutions covered expenses for travel and subsistence. The sponsor grant by Vattenfall AB, however, lowered the students' expenses at the Cormoran hotel.

Twenty-six applications for the Spring School were received before the final deadline. Based on the qualifications (research objective, the quality of the application), all 26 students were selected for the Spring School by the teachers' team. The selection criteria included the level of education (Master student, Master degree, PhD student, PhD degree and young researcher's position),

research objective, the quality of the application, CV and letter of recommendation. Attendance was limited to around 30 students due to the capacity of the Cormoran teaching facility. Although 26 applicants were accepted, only 21 could find the travel funding at their institute. One of the 21 students sent apologies only one week before the start of the Spring School, so the final number of participating students was 20. The students came from different institutes representing 11 countries, 8 of them from one of the CGS Europe partners and 12 students from other institutes (Fig. 8). However, 3 of the students came from other countries (China and Australia) than represented by their institutes.

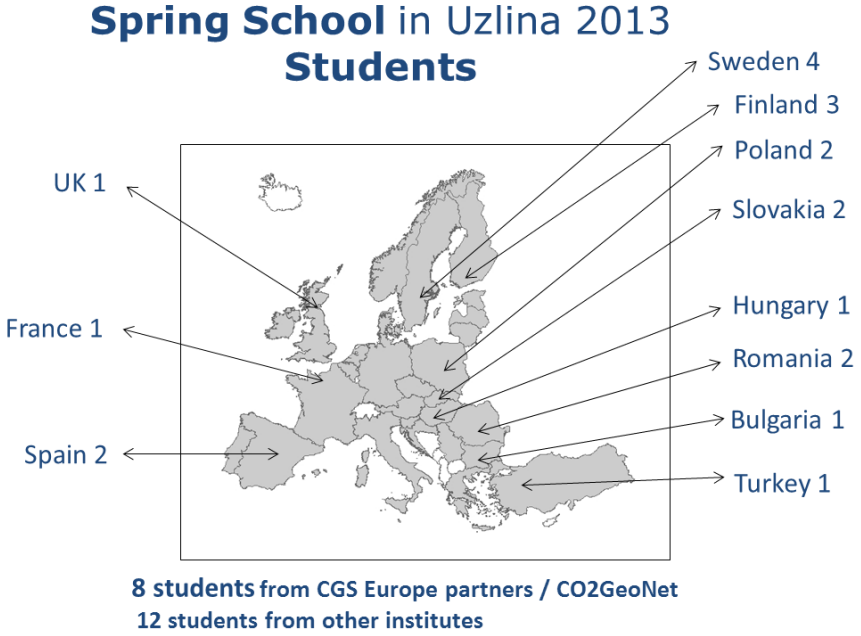


Figure 8: Home countries of students selected for the Spring School

3 Evaluation

An evaluation form was prepared by the teachers and distributed to the students to receive immediate feedback on the quality and perception of the course. Within the last point of the form - "Summarising and concluding the Spring School on CCS", the students expressed a common opinion that they, in general, were very satisfied with the Spring School. We received 17 feedback forms, all showing a high level of satisfaction (Fig. 9).

The evaluation shows that there is a high level of satisfaction with low dispersion of answers related to the content of the Spring School (Fig. 10). Also, concerning coherency of the sessions, a low dispersion of answers is noted (Fig. 10). The results also show that a few felt that the information provided before the Spring School was insufficient, although the main part were satisfied with the information before the Spring School. A few rated the course facilities low (Fig. 10).

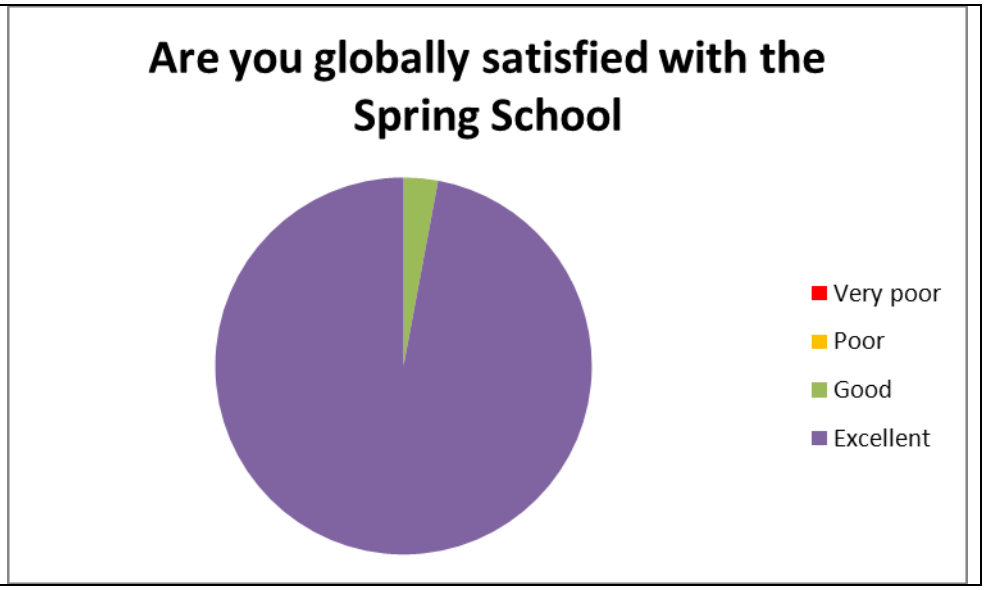


Figure 9: Overall satisfaction with the Spring School expressed in percentages.

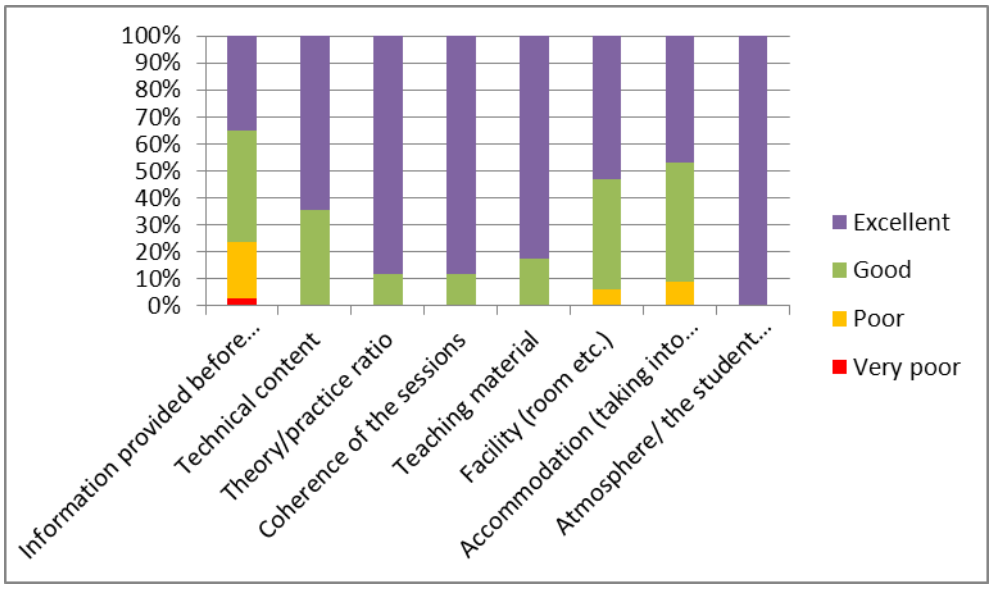


Figure 10: Answers to questions of the evaluation form expressed in percentages.

3.1 Some representative comments from the evaluation forms

- High level of complexity, exercises good for memorization.
- Geochemical modelling missing.
- Good communication between students and teachers, this is very important to understand the material and become part of the Spring School atmosphere.
- Obvious good atmosphere during all periods. Good work in the groups connecting people from other countries. Very good presentation prepared by the teachers. Wide range of issues.
- Wonderful place, very motivating for the work.

- Most appreciated were the lectures and the teachers' cooperation during the whole school and during the exercises.
- The whole course was very well prepared from beginning to end.
- Working in teams is a very good way to share knowledge and to "simulate" a real situation where the people in the group with different background had to work together, come up with ideas that everybody agreed on. Teachers' guidance during exercises to low.
- Lectures giving a broad range of topics, good atmosphere. Aspects of geochemical modelling should be covered in more details.
- Well prepared lessons and helpful teachers. Computer exercises were missing.
- Although not everything was new to me, I appreciated a structured walk through the full CCS chain, exploration, site selection, etc. I now feel more confident about CCS and will estimate some potential storage sites within my own project. More theory and fewer exercises.
- The course was very useful; staying in a refreshing nice place was also great. I was very happy that the relationship between teachers and students was warm and close. With a longer course, more aspects could have been considered.
- The opportunity I got of learning different aspects of CCS from teachers and other people working on it. I have a much better ideas of all technical aspects now. More on site characterization.
- The company exercise I really enjoyed it, it was very technical.
- The most appreciated thing to me was running in good conditions of all activities of the Spring School; (starting with information provided before the course, technical information provided by teachers, atmosphere between us, and accommodation, all was good in my opinion).
- The most what I appreciated were exercises, discussions and lectures. Besides the Spring School, a lot of fun with other mates. The course could be one day longer.

4 Programme

Wednesday April 17th

Transfer to Murighiol and Uzlina

10.00 **Arrival**, registration at GeoEcoMar in Bucharest
13.00 **Departure** for Murighiol and Uzlina
20.00 Dinner and "Get together"

Thursday April 18th

CCS in general and geological site characterisation

9.00 **Welcome** by Constantin Sava (hosting institution) and Niels Poulsen
Climate change and CCS as an international CO_2 abatement technology by Niels Poulsen
Introduction to colloquium and exercises (students to teams) by Niels Poulsen
Students' colloquium (expectations) by Niels Poulsen and all teachers
Introduction to geology and geological storage of CO_2, CCS and EOR by Stefan Knopf & Alexandra Dudu

13.00 Lunch
Site characterisation & reservoir modelling. Screening and capacity estimates by Stefan Knopf

Exercise CO_2 abatement by Niels Poulsen / all teachers
Introduction to Exercise 1
Exercise 1, rest of day
19.30 Dinner

Friday April 19th
Dynamic modelling
9.00 **Summarising the previous day**.
The whole CCS chain, industrial scale CO_2 storage since 1996, experiences, status report on CCS and road mapping by Niels Poulsen
Seismic data, well data by Niels Poulsen
Dynamic modelling by Marie Gastine
Optimizing storage or EOR production by Rob Arts
Introduction to Exercise 2
13.00 Lunch
Exercise 2, rest of day
19.30 Dinner

Saturday April 20th
Risks and monitoring
9.00 **Summarising the previous day.**
Risk assessment and risk elements. Safety criteria by Alexandra Dudu
Scenario analysis for the Schweinrich structure. A probabilistic approach by Rob Arts
Monitoring methods by Rob Arts
Remote sensing methods by Alexandra Dudu
Introduction to Exercise 3
13.00 Lunch
Exercise 3 – rest of day
19.30 Dinner

Sunday April 21st
Legal framework and requirements
9.00 **Summarising the previous day.**
EU Storage Directive relating to the implementation of CCS by Alexandra Dudu
Risk assessment: Legislation, regulations and guidelines by Niels Poulsen
Monitoring methods and EU Legislation by Rob Arts
13.00 Lunch
The ROAD project by Rob Arts
Introduction to Exercise 4 on monitoring
Exercise 4 – rest of day
19.30 Dinner

Monday April 22nd
Non-technical aspects (economics acceptance and policy)
9.00 **Summarising the previous day**.
Public opinion and acceptance by Alexandra Dudu
Leakage events. Case stories (Weyburn, Sleipner, Hungary, and natural leakage) by Niels Poulsen

Public awareness, NGOs, information strategies by Adam Wójcicki
Greener energy technologies. CCS costs by Adam Wójcicki
CO_2 Storage Atlas by Niels Poulsen
Introduction to Exercise 5 on Communication plan and economic plan
13.00: Lunch
Exercise 5 – rest of day
19.30 Dinner

Tuesday April 23rd
Excursion
8.30 **Excursion** lead by Alexandra Dudu and Constantin Sava
13.00 Lunch
14.00 **Excursion** continued, lead by Alexandra Dudu and Constantin Sava
16.00 **Final exercise preparation**
18.00 **Poster session**. All teachers
Summarising and concluding the Spring School on CCS - All students and teachers
19.30 Dinner
20.00 **Students evening** (Fig. 11)

Wednesday April 24th
End of Spring School
8.00 **Departure** for Bucharest
15.00 **Arrival** Bucharest

Figure 11: Games at the students evening. The last evening was dedicated to a social event, where the students prepared some games and entertainment.

5 Students

Name	Country	Institute	Position
Amanda Metcalf Amián	Spain	Fundación Ciudad de la Energía, CIUDEN	PhD-student
Cecilia Aarnio	Finland	Åbo Akademi University	MSc-student
Daniel Sopher	Sweden	Uppsala University	PhD-student
Eva Marinovska	Bulgaria	Dept. Geology, Sofia University "St. Kliment Ohridski"	MSc-student
Fei Huang	Sweden	University of Uppsala	PhD-student
Fengjiao Zhang	Sweden	University of Uppsala	PhD-student
Gabriel Iordache	Romania	GeoEcoMar	Research assistant
Gaurav Tomar	France (India)	Laboratoire de Géosciences Marines Institut de Physique du Globe de Paris	PhD-student
Krzysztof Polański	Poland	AGH University of Science and Technology in Cracow. Natural Gas Department	Research Assistant
Marius Tilita	Romania	GeoEcoMar	Scientist
Michal Jankulár	Slovakia	State Geological Institute of Dionýz Štúr	Research Scientist
Monika Ivandic	Sweden	University of Uppsala	Post doc
Nicklas Nordbäck	Finland	Geological Survey of Finland (GTK)	Geologist
Rami Eid	UK / Australia	University of Edinburgh	PhD-student
Ruxandra Catalina Nita	Spain	IGME	PhD-student
Sanem Elidemir	Turkey	METU	Research assistant
Slavomír Mikita	Slovakia	State Geological Institute of Dionýz Štúr	Research Scientist
Sonja Sjöblom	Finland	Åbo Akademi University	PhD-student
Tomasz Włodek	Poland	AGH University of Science and Technology Drilling Oil and Gas Faculty	Research Assistant
Zsuzsanna Szabó	Hungary	Environmental Physics Department, Centre for Energy Research of the Hungarian Academy of Sciences	Young Scientist position

6 Teachers

- Adam Wójcicki, PGI-NRI
- Alexandra Dudu, GeoEcoMar
- Constantin Sava, GeoEcoMar
- Marie Gastine, BRGM
- Niels Poulsen, CO2GeoNet-GEUS
- Rob Arts, CO2GeoNet-TNO
- Stefan Knopf, BGR

7 Summary of the Spring School

One of the key deliverables of the CGS Europe project's dissemination activities is organisation of two editions of the Spring School, the first one on March 12–18, 2012 at Leszcze near Bełchatów, central Poland and the second on April 17–24, 2013 in the Danube Delta at Uzlina, Romania.

The course targeted in particular young scientists and postgraduate students (PhD and Post Doc), and focused on CO_2 geological storage with special attention paid to the requirements included in the EU Storage Directive as well as in the Monitoring and reporting guidelines of the EU ETS directive. The activity was led by CO_2GeoNet-GEUS, with contributions from CO_2GeoNet-TNO, BRGM, BGR, PGI-NRI and GeoEcoMar. The second Spring School was financed from the project budget, own resources of the participants and a sponsor grant. The course is planned to be ready for repetition in the following years.

The GeoEcoMar hosted the second run of the Spring School. Twenty students from 11 countries participated, forming a true international student community. The teachers came from the above-mentioned partner institutions. The Zero-emission platform (ZEP ETP) provided valuable study materials, and Vattenfall AB contributed by a small sponsorship grant. The course was very positively valuated by the students, as can be documented by the feedback forms they provided.

The purpose of the CGS Europe Spring School on CO_2 Geological Storage was to offer an advanced course on geological storage of CO_2, allowing for knowledge sharing and learning about near zero-emission power generation from CGS Europe and CO2GeoNet researchers and scientists.

The first day was dedicated to an overview of climate change and CCS as an international CO_2 abatement technology, policy, regulations and financial issues for implementation, international status of CCS development and the whole CCS chain, industrial scale CO_2 storage since 1996, and geological site characterisation.

The following days focused on dynamic modelling, risk and monitoring (economic risks, seismic data, well data, modelling, risk assessment, safety criteria and legislation, regulations and guidelines), the legal framework and requirements, monitoring methods, non-technical aspects (public opinion), public awareness, NGOs, information strategies, and leakage events. Within as many of these aspects as possible, the EU perspective and the EU Storage Directive were incorporated both in lectures and in exercises.

The students had lectures in the morning until lunch or shortly after, starting with discussion of the previous day's lectures and exercise. The daily exercise was part of an overall Spring School exercise, where student teams had to prepare a poster and present it on the last evening.

On the last day, there was an excursion where the students visited the Danube Delta to get an impression of a deltaic environment. The afternoon was reserved for the students finalising their poster and preparing for the presentation. The last evening was also dedicated to a social event, where the students had the opportunity to prepare some games and entertainment. The students were asked to fill in an evaluation form on the Spring School during the bus trip back to Bucharest.

The attendance of the course was free of charge. However, the students themselves, with partial sponsorship support, carried direct expenses for travel and board. The students received the CGS

Europe Studies Diploma confirming their attendance. The diploma is based not only on the presence at the classroom sessions, but also on active participation in resolving of all exercises.

8 Final remarks

In retrospect, we can consider the second CGS Europe Spring School to be a successful event. The feedback provided by students was generally very positive. Moreover, the feedback from the previous Spring School in 2012 had helped us to identify several weak points in both the organisation and content of the course. These comments were taken into account to improve the second course held in 2013.