CCS - AN IMPORTANT OPTION FOR ROMANIA

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REZUMAT. Nevoia de reducere a emisiilor de GES (în special CO2) pentru protejarea climei va pune presiune pe utilizarea energiei fosile (în special cărbune – lignit indigen), care va rămâne un element esenţial al aprovizionării cu energie în viitor în România. Luând în considerare dispoziţiile de energie şi schimbările climatice, în general, şi Directiva ETS în special, în România tehnologiile CCS reprezintă o opţiune atractivă, împreună cu RES şi energia nucleară. România este o ţară europeană cu o istorie lungă şi documentată pentru producţia de hidrocarburi şi unul dintre primii lideri în aplicarea metodelor geofizice pentru explorarea şi dezvoltarea terenurilor. Cartografierea detaliată, utilizând datele disponibile public, a fost efectuată pentru a estima mărimea și localizarea potenţialelor situri de stocare a CO_2 în România. S-au studiat toate opţiunile de pe uscat (de exemplu, acvifere, saline profunde, câmpuri epuizate de hidrocarburi). Proiectul românesc CCS Demo va capta, transporta şi stoca, în condiţii de siguranţă, o cantitate de 1,5 milioane tone de CO_2 pe an, avand o eficienţă de îndepărtare a gazelor arse emise de lignitul ars de 85% pentru staţia de alimentare. Proiectul CCS constă în întregul lanţ de componente pentru CCS, inclusiv: stația de captare a CO2, de transport prin conducte şi de depozitare în saline acvifere adânci.

Cuvinte cheie: CCS, hydrocarbon

ABSTRACT. The need of reducing the GHG emissions (especially CO_2) for protecting the climate will put pressure on use of fossil energy (in special coal – indigene lignite) which in Romania will remain a strong pillar of energy supply in the future. Taking into account the provisions of Energy and Climate Change Package in general, and the ETS Directive in special, in Romania the CCS technologies represents an attractive option, together with RES and nuclear energy.Romania is a European country with a long and documented history of hydrocarbon production and an earlier leader in application of geophysical methods for exploration and field development.

Detailed mapping, using the publicly available data, was carried out, in order to estimate size and location of potential CO_2 storage sites in Romania. All onshore options (i.e., deep saline aquifers, depleted hydrocarbon fields) where studied. The Romanian CCS Demo Project will capture, transport and safely store in excess of 1.5 Million tons per year of CO_2, based on a removal efficiency of 85% from the flue gases emitted by lignite fired power station. The CCS project will consist of the full chain of components for CCS including: CO_2 Capture Plant, transportation by pipeline and deep aquifer saline storage.

Keywords: CCS, hidrocarbon

1. INTRODUCTION

Climate change is one of the current challenges worldwide- a complex domain in which we should improve our knowledge in order to take immediate and correct measures for an effective approach, taking into account the principles of durable development and precaution in taking decisions. IPCC (International Panel on Climate Change) calls for atmosphere GHG concentration stabilisation to a level that prevents hazardous anthropic interference with climate system, so that global rise of surface annual average temperature should not exceed more than 2°C comparatively to pre-industrial period.

The European Commission adopted on the January 23rd, 2008 Package of Draft Laws "Energy-Climate Changes". The Package was approved by head of states and government at the European Council from December 13th 2008 and adopted on the plenary meeting of the European Parliament in December 17th 2008. The European Council is firmly committed to reduce by 2020 overall GHG emissions by at least 20% as against 1990 levels and by 30% in case of international agreement . EU focuses on further reduction, by the year 2050, up to 80% as against 1990 levels, the way it is specified in the Strategic Energy Plan for Europe - SET.

2. ENERGY PRODUCTION: present and future

The total power generation in 2009 produced by Romania's sources of domestic primary energy: lignite, hydrocarbons (oil and natural gas), hard coal, hydro, nuclear and renewables (hydro and wind) was of 57,667 GWh.

In 2009 the share of fossil fuel in power generation was around 53% (based mainly on coal - 41%) and renewable output was 27,02% (total hydro production - 27 % and wind - 0,02%).

For Romania the trend of the electricity production by primary energy, according to the approved Romania's Energy Strategy for 2007÷2020 (which is under update process) is presented in the following table:

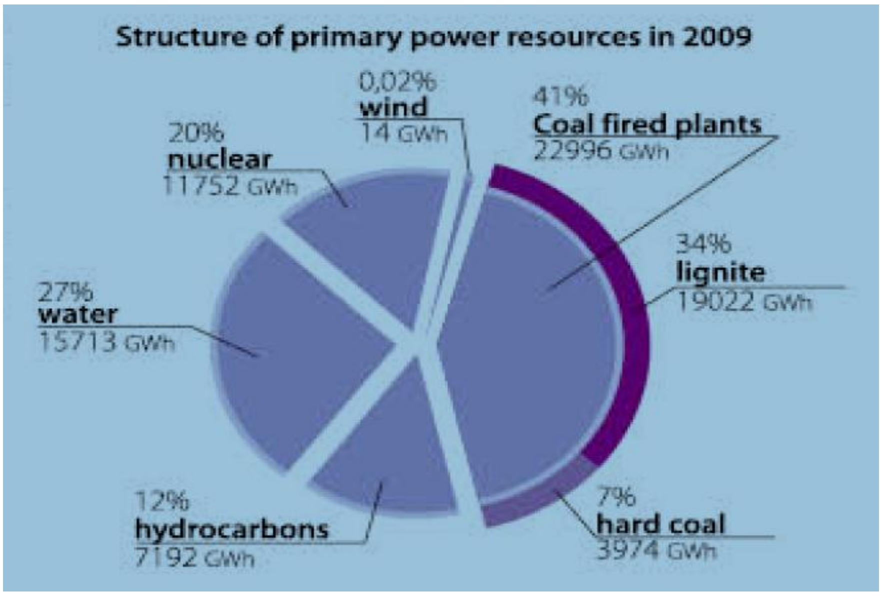

Fig. 2 *Structure of primary power resources, 2009 Source: Annual Report 2009, Transelectrica*

Table 2. *Trend of the annual electricity production by primary energy, in TWh*

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2015	2020
Electricity production for internal demand	54,55	55,30	56,48	58,99	60,7	62,5	64,2	66,1	67,7	69,5	74,5	85
Export	2,08	1,18	2,93	3,41	2	3,0	3,5	4,5	4,5	5	15	15
Total electricity production	56,63	56,48	59,41	62,4	62,7	65,5	67,7	70,6	72,2	74,5	89,5	100
Hydro and renewable	13,57	16,83	20,21	17,75	16	18	19,5	21,7	22,3	23	26	32,5
Nuclear	4,9	5,55	5,54	5,55	7,0	10,8	10,8	10,8	10,8	10,8	21,6	21,6
Fossil fuel plants, from which on:	38,16	34,1	33,6	39,1	39,7	36,7	37,4	38,1	39,1	40,7	41,9	45,9
Coal	*23,34*	*21,47*	*21,66*	*27,1*	*28,7*	*25,7*	*26,4*	*27,1*	*28,1*	*29,7*	*30,9*	*34,9*
Natural gas	*11,19*	*10,46*	*10*	*10*	*9,5*	*9,5*	*9,5*	*9,5*	*9,5*	*9,5*	*9,5*	*9,5*
Heavy fuel oil	*3,63*	*2,17*	*2*	*2*	*1,5*	*1,5*	*1,5*	*1,5*	*1,5*	*1,5*	*1,5*	*1,5*

Source: Romania's Energy Strategy for 2007-2020

As it was presented in the previous chart and table, the coal (especially local lignite with low calorific value and carbon content) is and will be a major player in the electricity market (coal represents around 41% in 2020), which represent a long term potential to reduce CO_2 emissions by implementation of CCS technologies.

Regarding the energy production it has to be mentioned the restructuring process of the energy sector in Romania, which is the new Romania's Government high priority and it refers to a new grouping rules of the power producers, having an immediate positive impact of envisaging the financial capability of thermal power sector.

3. CO_2 EMISSIONS: present and future

Romania signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and ratified it in 1994 by Law 24. Romania signed the Kyoto Protocol in 1999 and ratified it in January 2001, being the first Annex 1 Party that ratified it. Romania committed itself to reduce the greenhouse gas (GHG) emissions by 8% comparing to 1989 (base year) levels in the first commitment period 2008-2012.

In the next chart is presented the historical trend of GHG emissions for period 1989- 2007, comparing with the Romanian target set by Kyoto Protocol, as it was reported in the last Romania's National Inventory Report (NIR) of GHG emissions (2009 submission).

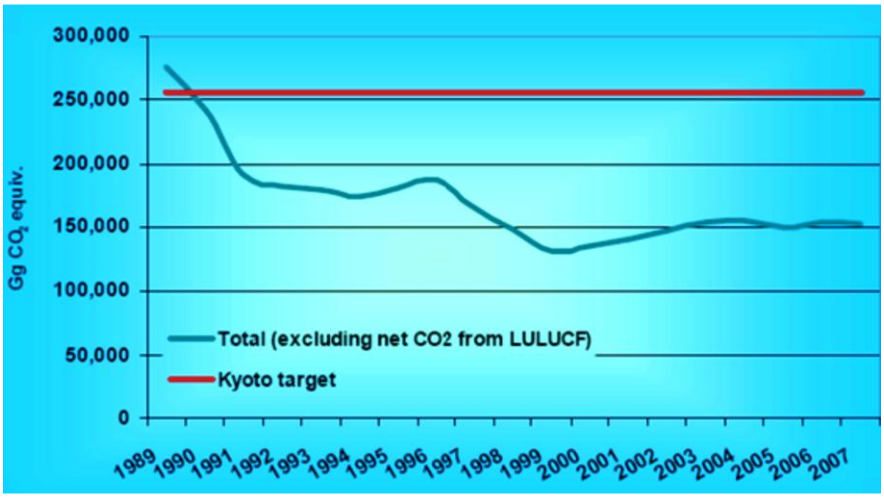

Fig. 3.1 *Total GHG emissions in CO_2 equivalent in the period 1987-2007*
Source: NIR 1987-2007

The GHG emissions evolution reflects the main trends in the economic development of the Country, characterized by a process of transition to a market economy, restructuring of the economy, bringing into operation of the first reactor at the Cernavoda nuclear power plant (1996). The emissions have started to increase after 1999 as a consequence of the economy revitalization.

According to the last National Inventory Report, transmitted in March 2009 to UNFCCC (United Nations Framework Convention on Climate Change), there is a great probability for Romania to meet the Kyoto Protocol commitments in the first period (2008-2012); the GHG emissions (without LULUCF) have decreased with 44.83% since the base year.

The largest contributor to the total national GHG emissions, in terms of average share in period 1989-2007 is CO2 (71,39%) followed by CH4 (17,33%) and N2O (10,77%).

Starting with 2007, Romania implemented EU ETS as a key element for achieving the EU's Kyoto Protocol.

According to National Allocation Plan (NAP) for the period 2008-2012, EU ETS covers in Romania a total number of 229 installations; in the energy sector there are included a large number of EU ETS installations (146 installations), which will receive an important share of allowances (around 60 %) from the total Romania's allowances for the 2nd EU ETS period.

Only a part of EU ETS Romanian's installations generated a quantity of verified CO2 emissions higher than 100.000 tons/year and may be suitable for implementing CCS technologies; the higher number of installations are in the energy sector (38 installations), which have a significant and long term potential to reduce CO2 emissions by implementation of CCS technologies, as it is presented in the following chart:

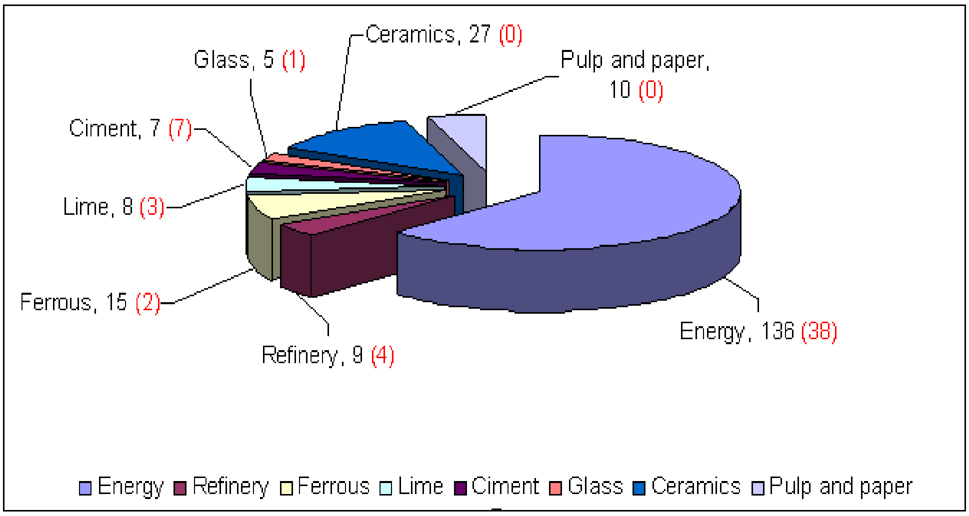

Fig. 3.2 No. *of ETS installation / no of ETS installation suitable for implementation of CCS (year 2008)*
Source:"Promoting CCS in Romania", ISPE & GeoEcoMar

Legend:
In black : Total number of installations per EU ETS sectors, according with NAP;
In red: Number of installations per EU ETS sectors which generated more than 100.000 tons CO_2/year.

In year 2007, the distribution of the verified CO_2 emissions (>100.000 tons/an) in Romanian's development regions are presented in the following map:

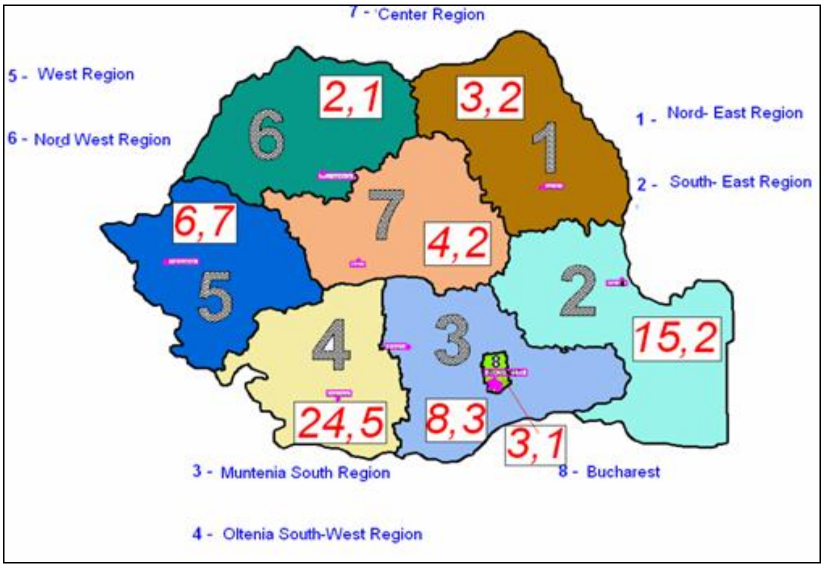

Fig.3.3 *Verified CO_2 emissions per Romanian regions, 2007, in $MtCO_2$*

Source: "Promoting CCS in Romania", ISPE & GeoEcoMar

The higher verified CO2 emissions were generated in:
Development region no. 4, where are located the important power plants on local coal - lignite (which in terms of CO2 emissions represent around 75% of total region's CO2 emissions);
Development region no. 2, where is placed the steel plant ArcellorMittal Galati SA (which generated around 65% of region's CO2 emissions).

For the power plants, the specific CO2 emissions, calculated annually by ANRE (Romanian Energy Regulatory Authority) based on specific CO2 emissions per electric energy production for each producer and each type of fuel used (coal, natural gas, heavy fuel oil) are the following:

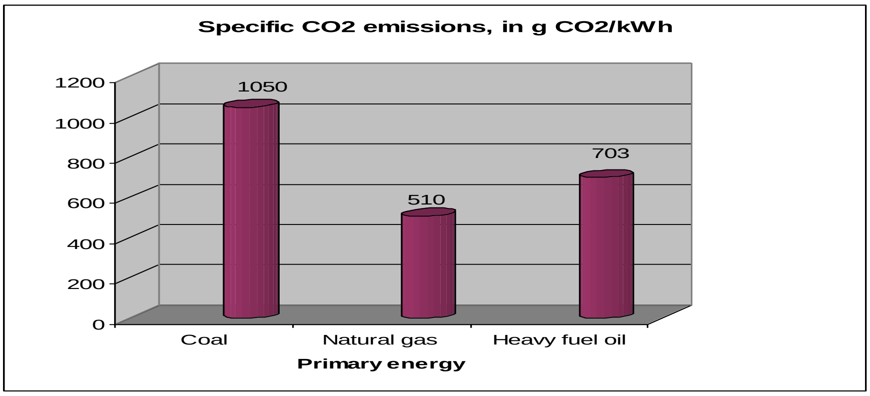

Fig.3.5 *Specific CO_2 emissions for power plants, 2008*

Source: Annual report 2008, ANRE

The values obtained, higher than those at the EU level, based on the actual technical status of power plants (around 80 % of it were constructed in period 1970-1980 and exceeded the projected lifetime), conduct to the need of new power plants, as a target of the Romanian energy policy.

4. STORAGE

4.1 Possibilities with respect to underground storage

The Romanian territory is included in the general geological ensemble of Central and South - East Europe as a part of the Alpidic pericratonic belt of Carpathians - Balkans + Rhodopes - Pontides, of the intracratonic belt North Dobroudja - South Crimea - Great Caucasus as well as of their foreland represented by the East European Platform, the

Central European Platform (Scythian Platform) and the Moesian Platform.

Romania territory is very complex from the geological point of view. Its back bone is made of the Carpathians mountains composed of a large variety of igneous, metamorphic and sedimentary rocks. Outside them the territory covers parts Moesian, and East European Platforms, Dobrogea promontory as well as a part of Pannonian basin. Enclosed by mountains there are Transilvania basin as well as numerous intra-mountain basins.

The major structural units of interest for CO2 geological storage on the Romanian territory are:

Pannonian Depression:

- Pannonian Depression North (PDN);
- Pannonian Depression South (PDS)

Transylvanian Depression (TD)

Moesian Platform:

- Moesian Platform West (MPW);
- Moesian Platform East (MPE);

East Carpathians Paleogene Flysh (ECPF)

Carpathians Foredeep:

- East Carpathians Foredeep (ECF);
- Diapir Fold Zone (DFZ);
- Getic Depresssion (GD);

Moldavian Platform (MP)

North Dobrogea & Predobrogean Depression (NDPD).

Romania has a long and documented history of hydrocarbon production and an earlier leader in application of geophysical methods for exploration and field development. The first oil production of the world has been officially recorded in Romania, in 1857, at a rate of 275 tones/year (1719 bbl). This is one year ahead of William's well at Oil Springs in Ontario and two years before Drake's discovery well in Pennsylvania. However, foreign travelers since the first half of the 16th century have mentioned the extraction of crude in the Romanian provinces of Moldavia and Wallachia. In 1900, Romania was the third largest oil producer of the world with a production of 0.3×106 tones/year (1.855×106 bbl). During 1953-1955 the oil output of Romania was around 9 to 10×106 tones/year (60.291×106 bbl), and in 1976 a maximum of oil output of 14.6×106 tones (91.219×106 bbl), was achieved.

Detailed mapping, using the publicly available data, was carried out, in order to estimate size and location of potential storage sites in Romania. All onshore options (i.e., deep saline aquifers, depleted hydrocarbon fields) where studied.

4.2 Capacity estimation in aquifers

When calculating capacity, several types of estimates can and often are made, depending on the nature and purpose of the assessment and they all lie across different regions of the resource pyramid (Bradshaw et all, 2006). This pyramid considers three technical and economic categories named Theoretical, Realistic and Viable Capacity. It is evident that our estimations falls at the base of the pyramid being the first of this sort ever carried out in Romania.

For the capcity calculations in saline formations we have used a volumetric ecuation recommended by many authors (RCSP, 2006, Bachu, 2007, etc):

As almost everywhere in the world the saline aquifers are poorly known. So in calculating their storage capacity we had to introduce several estimations (especially on reservoir thickness and porosity). The Romanian sedimentary basins potentially containing saline formations have been combined in 4 big zones (Moesian platform and S. Carpatians foredeep, Moldavian platform and E.Carpathians foredeep, Transilvanian basin and Pannonian basin). Out of their total surface areas, the surface with sedimentary cover thinner than 800 m have been eliminated from calculations as such areas are not suitable for CO2 storage. The efficiency factor considered is only 2 % as was recommended by CO2 Geocapacity studies. The results are presented synthetically in table below.

4.3 Capacity estimation in hydrocarbon fields

The CO_2 storage capacity in depleted or declining *hydrocarbon (oil and gas) fields* can be calculated either by a similar volumetric equation or by a production-based equation if acceptable records of volume of hydrocarbons produced are available. It is only necessary to apply an appropriate formation volume factor (B) to convert hydrocarbon volumes reported as production to subsurface volumes.

Romania has a history of 150 years of oil industry. It is estimated that during such a long period of time, some 720 Mt of oil and 1122 Gm^3 have been extracted from its underground (Gilbert, 2007). Today it may be considered a "mature" oil and gas province with 70 - 80 percent of its resources already exploited. However, the percentage of hydrocarbons produced varies in various geological units (see below).

Our calculations were based on total oil and gas reserves in each region. It was assumed that in 20 - 30 years the majority of remaining hydrocarbons will be exploited and more fields will become depleted and hence available for CO_2 storage. On the other hand, the same time span of 20 - 30 years will probably be the period until the CO_2 storage will become a mature technology for disposing of the unwanted gas an such a tehnology will be employed on a large scale. Also the possibility of using EOR and EGR should be taken into consideration.

4.4 Capacity estimation in coal fields

The Romanian coal fields do not offer appropriate conditions for CO_2 storage.

Table 4.2.1 *Estimated CO_2 storage capacity in deep saline aquifers in Romania*

Zone	Surface area (km^2)	Reservoir geological formations	Estimated reservoir Thickness (m)	Estimated porosity	CO_2 storage capacity (Gt)
Moesian Platform and South Carpatians Foredeep	38.000	Pontian Meotian Sarmatian Cretaceous Triasic	70	0.20	5.2
Moldavian Platform and East Carpathians Foredeep	24.000	Sarmatian Tortonian	50	0.20	2.5
Transilvanian Depression	22.000	Buglovian Sarmatian Tortonian	200	0.20	8.8
Pannonian Depression	15.000	Pannonian Tortonian Cretaceous	70	0.20	2.1
Total					**18.6**

Efficiency factor = 2%

Table 4.3.1 *Estimated CO_2 storage capacity in oil and gas deposits in Romania*

Geological Units	Produced Mt oil	Produced Gm3gas	Produced estimated % oil	Produced estimated % gas	Total Mt oil	Total Gm3 gas	Gt CO2 capacity Oil d.	Gt CO2 capacity Gas d.
Pannonian depr.	47	25	80	85	57	29	0,03	0,07
Transilvanian depr.	-	772	-	85	-	908	-	2,27
Barlad Depression	1	2			1	6	-	-
N. Dobrogean Pro.	6	13			6	13	-	-
East. Carpathians	377	90	85	90	560	100	0,34	0,25
Getic Deprssion	120	125	70	65	156	192	0,09	0,48
Moesian Platform	169	95	75	70	211	136	0,13	0,34
Total	720	1122			981	1384	0,59	3,41

Formation volume factor: Oil 1,5, Gas 0,005, CO_2 density 0,5 **Total** **4,00**

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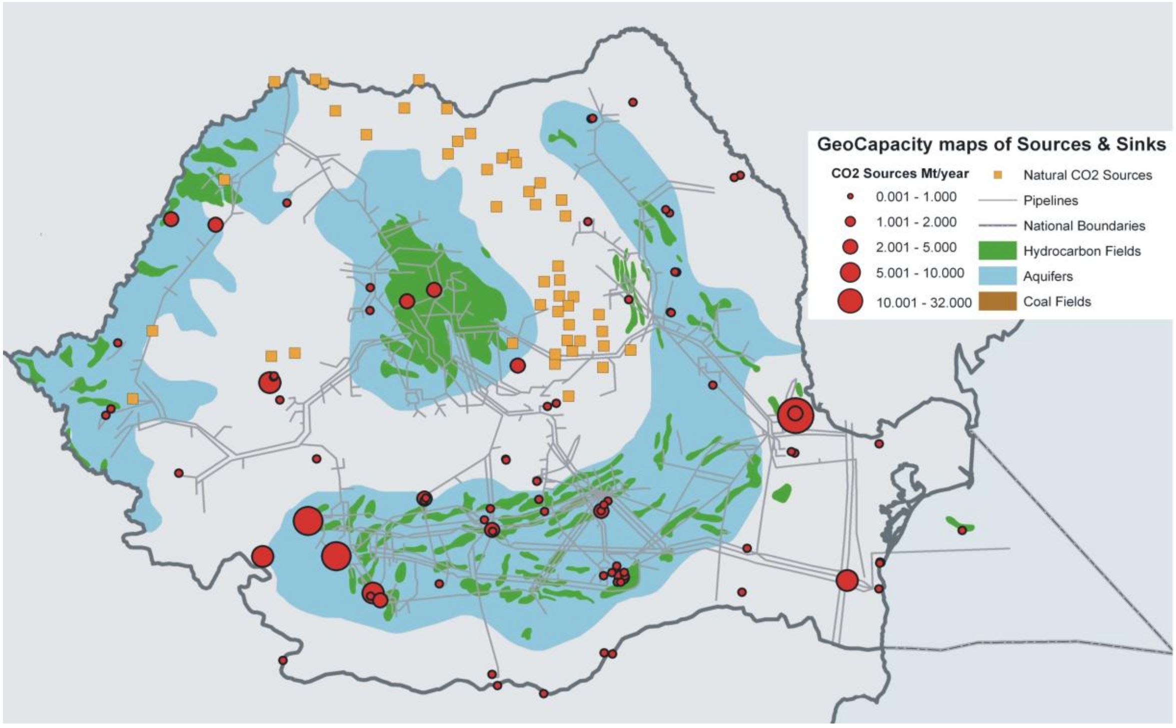

Fig.4.1 *Synthetic Map of CO_2 emissions, infrastructure and storage capacity in Romania (EU GeoCapacity project)*

Tables 4.1 *Conservative estimate of the storage capacity in Romania*.

CO_2 emissions	**Year(s)**	**Average CO_2 emissions (Mt)**
CO_2 emissions from large point sources in database	2007	67.3*
Total CO_2 emissions	**2007**	**74.4****

Note:
* Sum of verified CO_2 emissions generated in 2007 by EU ETS installations, which emitted more than 100.000t CO_2/year and may be suitable for implementing CCS technologies
** The total amount of allowances for EU ETS installation (NAP 2007)

CO_2 storage capacity	**Pyramid class**	**Estimate in database [Gt]**	**Conservative estimate [Gt]**
Storage capacity in aquifers	Theoretical	18600*	7500**
Storage capacity in hydrocarbon fields	Theoretical	4000*	1500**
Storage capacity in coal fields	-	-	-
Total storage capacity estimate	**Theoretical**	**22600***	**9000****

Note:
After estimation of the CO2 storage capacity at the scale of regional basins*, taking into consideration the available data related to the geological formations, it was possible to make a conservative estimation**.

5. GETICA CCS Demo Project

The "***Romanian CCS Demo Project***" will be implemented *to the Unit No. 6 (250 MWe net)*, from the existing power plant SC CE Turceni SA which is under ongoing retrofitting process (deadline and commercial operation – 2012).

The CO_2 capture efficiency will be **in excess of 85,0 %,** representing an annual quantity of stored CO_2 of **more than 1,5 million tonnes/year**.
The project location will be in the so called **"Development Region no 4 - South West Oltenia, county Gorj"**.

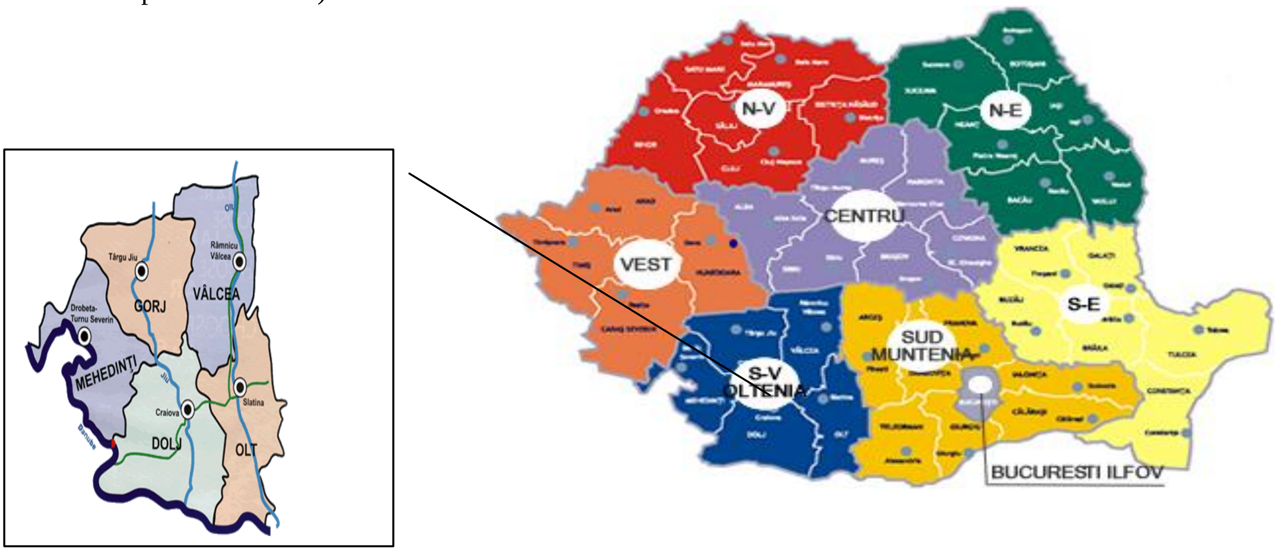

Figure 5.1 *Project location at national level*

The ***"GETICA CCS Demo Project"*** has finalized the ***feasibility study,*** with the intention to become a representative demo project in the Central and Eastern European region.

The "***GETICA CCS Demo Project***" will be implemented **in a power plant – base load**, **one of the strategic electricity suppliers to Romanian National Energy System - Turceni PP.**

Turceni PP and the adjacent lignite mines are part of SC Complexul Energetic SA, a state owned company originally built with 7 units of 330 MW. Currently the power plant operates 4 to 6 units, depending on the market request. The long term investment strategy is showing that just 4 units will continue to be operated.

The Unit No. 6 of 330 MW will be retrofitted in the next 3 years. As shown in the figure below the financial package is already closed.

The bidding process for the EPC selection is ongoing; it is expected that on the end of 2010 the EPC for retrofitting of the unit to be decided. The commissioning of the Unit no. 6 of 330 MW retrofitted will be at the end of 2012.

In the same time the SO_2 emission limit value will be achieved, due to fact that a flue gases desulfurisation system (FGD) will be installed by Austrian Energy & Environment based on the JBIC loan. At the end of 2012 the FGD system will be operational and the value of SO_2 emissions will be lower than the value proposed by the new industrial emissions Directive (changing the LCP Directive – Directive 2000/80/EC).

In Turceni PP will be installed a new system to evacuate and deposit the ash and slag (dense fluid) in order to respect the request of the Waste Directive (Directive 1999/31/EC). ISPE developed the design for the technical solution and owns the patent of the system to prepare, transport and evacuate to the landfill the ash & slag in fluid dense.

The Unit no. 6 will operate at least 15 years after retrofitting and will have all the installations needed to comply with the provisions of environmental legislation.

The facts described above were an important criteria in selecting Unit No. 6 to be the Romanian CCS demo project, because this unit will be in 2015 in operation. A new power unit in Romania has uncertainties to be ready and commercial operated before 2015, mostly because of the reduced financing possibilities during the actual economic and financial crisis.

As a part of the Feasibility Study, an analysis of the two alternatives for postcombustion: chilled ammonia and advanced amine will be presented, with the outcome of selecting the proper post combustion capture technology for the "***GETICA CCS Demo Project***".

The integration of the capture system into the existing power plant will be define in the Feasibility Study, in order to find the technical and economic solution in ensuring the utilities needed like steam, water, power and others.

For the "***GETICA CCS Demo Project"***, the CO_2 transportation system will be **onshore pipeline**, on existing natural gas routes, for getting the easiest procedure to obtain the required permits, and to realize the works.

In the area there are other 3 power plants using local lignite: Rovinari PP (1300 MWe), Craiova II PP (300 MWe) and Isalnita PP (600 MWe). For the future it can be considered **a CO_2 transportation network** if the existing power plants will decide to implement the CCS technology as a viable alternative to buying CO_2 allowances under EU ETS (Directive 2009/29/EC).

As indicative values, the estimative distances between the location of Turceni PP and the possible available CO_2 storage sites is around 50 Km.

Based on the data available at this time (interpreted seismic lines and some well logs from the area), on the geological knowledge of this area (structural map at the base of Teriary deposits), on the distribution of the main faults at the regional scale, including the area around Turceni site as well as additional geological informations about the investigation area (stratigraphy, lithology, sedimentary systems, tectonic evolution, etc, 11 possible storage sites have been identified (represented on Figure 5.2 below).

The selection of these 11 sites took into consideration the areal distribution of reservoirs, their thickness from Sarmatian and Meotian formations, the presence of cap rocks (seals), and the possibilities to form structural and lithological traps.

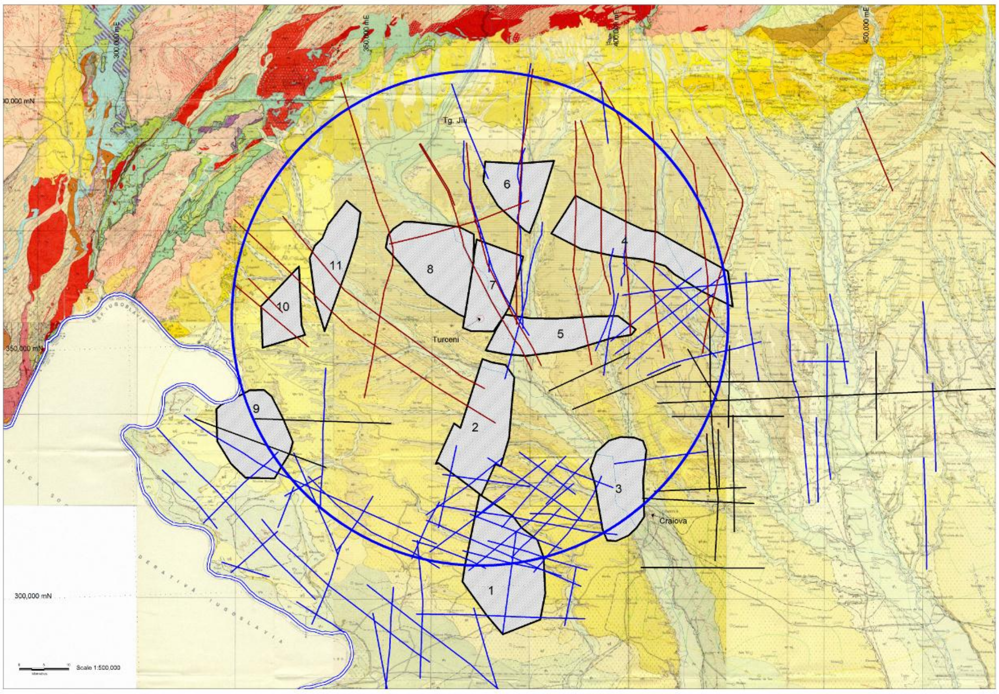

Figure 5.2 - *Preliminary selection of 11 sites*

As can be observed on the Figure above, most of the data currently available to the project focuses on the Southern part of the investigation area.

Therefore, as will be done in the Feasibility Study, the next and immediate actions to be addressed are to collect additional subsurface data which will allow for a better and more balanced coverage of the investigation area.

Once this is completed, from 8 -11 potential storage sites will be analized in the Feasibility study, finally will be define two proper storage sites for the "***Romanian CCS Demo Project"*** .

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