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Feasibility Study Overview Report

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PUBLIC REPORT

GETICA CCS

GETICA CCS DEMO PROJECT

Romania

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EXECUTIVE SUMMARY

The Getica CO_2 Capture and Storage (CCS) Demo Project aims to demonstrate the application of large-scale integrated CCS to an existing coal-fired power plant in Romania's South West Development Region. The Project's planned start-up date is December 2015.

The Project is officially sustained by the Prime Minister of Romania, coordinated by the Ministry of Economy, Trade and the Business Environment (METBE) and supported by the Global CCS Institute. It will be implemented by a new Project Company, in which the initial shareholders will be three existing State-owned companies; CE Oltenia SA, SNTGN Transgaz SA and SNGN Romgaz SA.

The Feasibility Study for the CCS chain (capture, transport, storage) was performed by a consortium comprising the Institute for Studies and Power Engineering (ISPE) – Romania (with support from INTETECH Consultancy – UK), Alstom Carbon Capture – Germany, GeoEcoMar – Romania, and Schlumberger Carbon Services – France.

The key findings from the Feasibility Study are presented below.

Carbon dioxide (CO_2) Capture

The CO_2 Capture Plant (CCP) will be retrofitted to the 330 MW Unit No. 6 of the existing six units in the Turceni power plant. Unit No. 6 is fuelled by local lignite equipped with wet flue gas desulphurisation (WFGD) and a dense slurry installation for ash and slag discharge. The CCP will treat a flue gas stream equivalent to 250 MWe of net electrical output, with a minimum targeted CO_2 capture rate of 85% from the flue gas stream. Around 1.3 Mtpa CO_2 will be captured by the CCP, resulting in a reduction of net power output of approximately 30% (275 MW reduced to 193 MW).

Since the Getica CCS demo project is planned for operation by the end of 2015, the technology selection was limited to the Chilled Ammonia Process (CAP) and the Advanced Amine Process (AAP), given their likely commercial availability at a scale applicable to this project. Based on various criteria, CAP was chosen as the post-combustion capture (PCC) technology for Getica. Key benefits of applying the CAP technology include:

- the existing electrostatic precipitator (EP) and WFGD are sufficient to enable CO_2 capture;
- the stability of the ammonium solution is not affected by oxygen or acidic trace components present in the flue gases;
- the environmental impacts are relatively small, given there are no degradation products, and no complex chemical compounds;
- the opportunity to utilise existing infrastructure associated with pre-existing use of ammonia at the plant;
- availability and cost effectiveness of ammonia supply; and
- lower operating costs compared to AAP with potential economic benefit from the liquid ammonium sulphates by-product.

CO_2 Pipeline

The Feasibility Study evaluated two storage options (Zone 5 and Zone 1), with two corresponding CO_2 transport pipeline routes. The CO_2 will be transported through a new onshore, underground pipeline with a nominal diameter of 350 mm (14 inch). The distance from the CCP to either of the two storage options is approximately 40 km. The CO_2 will be transported in dense phase, as this has been determined to be the most cost effective solution for long distance transportation. The pipeline design pressure-temperature envelope is: 0-140 bar and 0-50ºC. The pipeline operating range is 80-120 bar and 0-40ºC.

Key considerations for the pipeline routing include the terrain features, the population density in the area, the archaeological sites in the vicinity and environmental impacts.

CO_2 Storage

The selection of possible storage sites was made within a 50 km radius of the Turceni power plant (the emission source), within the Getic Depression. Sites were assessed based on key selection criteria; properties of the reservoir rocks (e.g. porosities and permeabilities), reservoir depth, and the existence of a suitable seal formation above the reservoirs.

Following preliminary selection of seven sites, a more detailed analysis of the data found that the most (potentially) suitable storage sites are Zone 5 and Zone 1 (both deep saline aquifers).

Storage characterisation will be completed and finalised during the Appraisal (Phase 2) of the project. The key objectives of the Appraisal phase are to fill the gap in knowledge identified during the performance and risk assessment work and to complete the site characterisation for the selection of a single site to be further developed. The Appraisal strategy is based on the assumption that Zone 5 is more promising as a CO_2 storage site than Zone 1.

CCS Costs and Financing

The total estimated capital cost for the Getica CCS Demo Project has been determined in the Feasibility Study, with an accuracy of ±20%. The breakdown of these investment costs is presented in Table ES-1.

Table ES-1 Investment costs

Component	Weight of total estimated cost (%)
Capture (compression component is 2.5% of total Capture cost)	60
Transport	4
Storage	14
Owner's costs	2
Development costs	19
Public awareness, communication and knowledge sharing	1
TOTAL	**100**

The operating costs, based on the Feasibility Study, are presented in Table ES-2.

Table ES-2 Operating costs

Component	Weight in annual OPEX (%)
Capture	90
Transport	2
Storage	8
TOTAL	**100**

Wherever possible, the investment costs for the Getica CCS Demo Project will be covered by direct funding (grants). Direct funding opportunities exist given the demonstrative nature of the project and the European Union's objective of advancing CCS toward commercial operation.

A detailed investigation of the possible financing sources at European level was undertaken, in order to assess which best fits the Project needs, in terms of time compatibility and level of funding. Further details on funding can be found in the Financial Scenarios Report for the Getica CCS Demo Project.

Project Risks

An initial risk assessment was performed during the Feasibility Study stage for the Getica CCS Demo Project. A preliminary risk register and risk matrix were developed. Of the 69 risks identified, 18 were classified as critical to the CCS project requiring near-term mitigation measures. These risks were related to uncertainties associated with:

- overall costs of the project;
- by-product management;
- the capture technology, and potential technical issues associated with the scale-up from pilot to demonstration phase;
- landowner approvals; and
- the performance of the CO_2 storage site in terms of injectivity and containment.

Next Steps

Based on the Feasibility Study findings, the major activities to be undertaken during the next front end engineering and design (FEED) phase of the Getica CCS Demo project are:

- FEED for capture;
- FEED for transport; and
- storage characterisation .

The objectives of the FEED phase are to explore the CCS project components at a greater level of technical detail and to reach a ±10% accuracy of the investment cost estimates (compared to the ±20% accuracy of the Feasibility Study phase estimates). This will involve acquiring and processing new geological data for the complete characterisation of the storage regime in Zone 5 (geological data acquisition (2D/3D seismic, wells) and modelling). This stage will determine the suitability of the selected storage solution and will provide the technical background needed to apply for the storage permit.

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ABBREVIATIONS

%wt	percentage (by weight)
2D	two-dimensional
3D	three-dimensional
AAP	advanced amine process
ACC	ALSTOM Carbon Capture GmbH
ANPM	The Romanian National Agency of Environmental Protection
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
CAP	chilled ammonia process
CAPEX	capital expenses
CO_2	carbon dioxide
CCP	CO_2 Capture Plant
CCS	CO_2 capture and storage
€	Euro (currency)
EA	Environmental Agreement
EGR	enhanced gas recovery
EHR	enhanced hydrocarbon recovery
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EP	electrostatic precipitator
EPC	Engineering, Procurement and Construction
EOR	enhanced oil recovery
ETS	Emission Trading Scheme
EU	European Union
FEED	Front End Engineering and Design
FID	final investment decision
FP7	EU 7th Framework Project
FS	Feasibility Study
GCCSI	Global CCS Institute
GHG	greenhouse gas
GR	gamma ray
Gt	gigatonnes (x10^9 tonnes)
HSE	health, safety and environment
ISO	International Organisation for Standardisation
ISPE	Institute for Studies and Power Engineering
kg/h	kilograms per hour
km	kilometre
kPa	kilopascals
kPa(a)	kilopascals (atmospheric)
m	metres
m^3	cubic metres
mD	millidarcy
MEA	monoethanolamine
MEF	Ministry of Environment and Forests
METBE	Ministry of Economy, Trade and the Business Environment
mm	millimetre
MoU	Memorandum of Understanding
MPF	Ministry of Public Finance
Mt	million tonnes
Mtpa	million tonnes per annum
MW	megawatt
MWe	megawatt (electric)
NAMR	National Agency for Mineral Resources
NER	New Entrants Reserve
N/G	net/gross ratio
NGO	non-government organisation
NOx	nitrous oxides
O&M	operations and maintenance
OPEX	operational expenditure
PC	Project Company
PCC	post-combustion capture
PM	particulate matter
PP	power plant
ppmv	parts per million by volume
PSL	product specification level
R&D	research and development
SO_2	sulphur dioxide
tpa	tonnes per annum
UK	United Kingdom
WFGD	wet flue gas desulphurisation

1 BACKGROUND

1.1 The Drivers for CCS in Romania

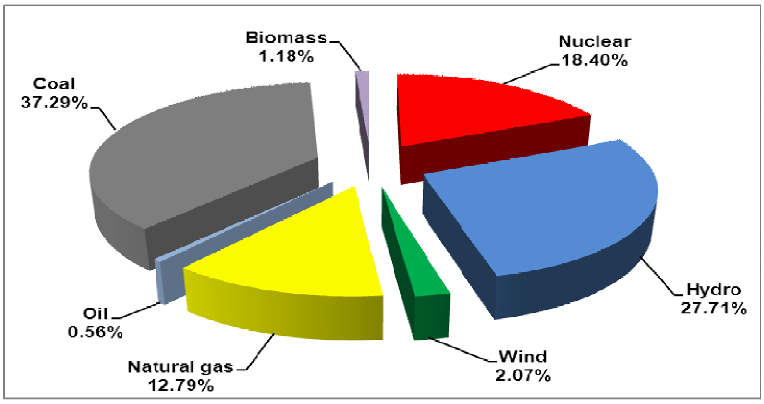
Key drivers for a carbon capture and storage (CCS) demonstration project in Romania include:

- the need to maintain coal as an energy source to support national energy security;
- the fact the energy sector accounts for a large portion of greenhouse gas (GHG) emissions in Romania (66.44% in 2009 (ANPM, 2011)); and
- Romania being identified at a preliminarily level as having high carbon dioxide (CO_2) storage potential.

1.1.1 Romania's Energy Portfolio

As presented in Figure 1-1, Romania meets its energy demand through a wide range of fossil fuel, nuclear and renewable power generation options.

Figure 1-1 The structure of the power produced in Romania in 2011



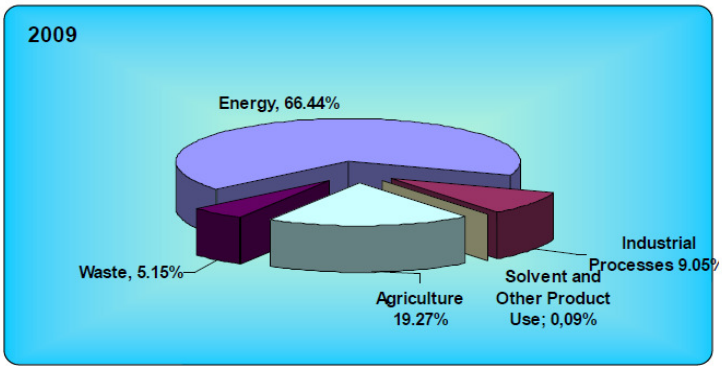
Source: ANRE Annual Report, 2011

Continued operation of existing coal-fired power plants is important to Romania's energy security, given coal is currently its primary energy source.

1.1.2 Romania's CO_2 Emissions Portfolio

In 2009, 66.44% of Romania's total GHG emissions were from the energy sector (ANPM, 2011). The nation's emissions by sector are shown in Figure 1-2 below.

Figure 1-2 Sectoral GHG emissions in 2009

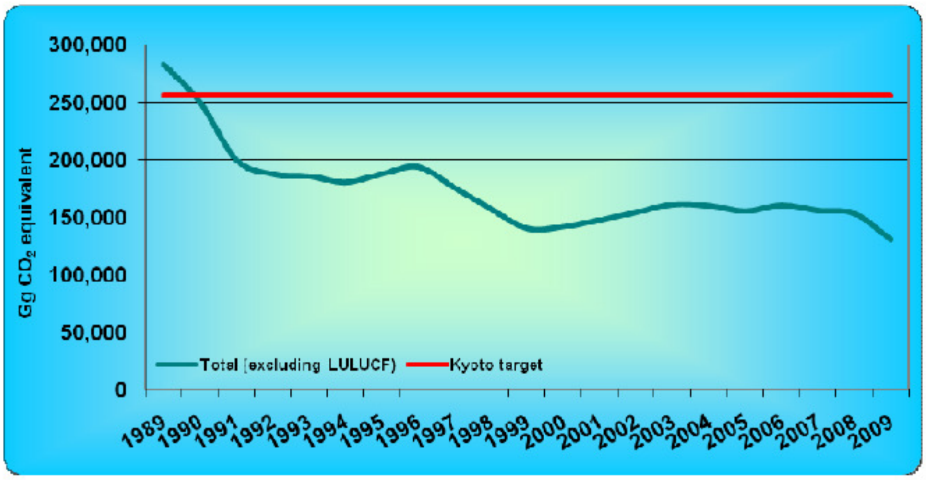


Source: ANPM, 2011

The annual GHG emissions for 1989-2009 are shown in Figure 1-3. Key features include:

- the period 1989-2009 being characterised by a process of transition to a market economy, including economic restructure;
- the first nuclear reactor becoming operational at the Cernavoda power plant in 1996;
- an increase in emissions from 1999 due to revitilisation of the economy; and
- a significant decrease in emissions in 2009 (from 2008) due to the economic crisis.

Figure 1-3 Total GHG emissions, 1989 – 2009, in CO_2 equivalent



Source: (ANPM, 2011)

1.1.3 CO_2 Storage Potential in Romania

The CO_2 storage potential in Romania has been identified as relatively high. The total estimated storage capacity for Romania is 18.6 Gt in deep saline aquifers and 4.0 Gt in depleted hydrocarbon fields (source: EU GeoCapacity project, WP2 Report – Storage capacity).

The estimate of the storage capacity in deep saline aquifers has been based on the identification and calculation of CO_2 storage potential of regional Romanian deep aquifers. The CO_2 storage capacity assessment in depleted hydrocarbon fields is based on the notion that most of the remaining hydrocarbons will be extracted from the current fields under exploitation in 20-30 years, and that the resulting depleted fields will be available for CO_2 storage. The potential for enhanced oil recovery (EOR) and enhanced gas recovery (EGR) were also taken into consideration when assessing the CO_2 storage capacity.

Romania has a long history of hydrocarbon production and was an early leader in the application of geophysical methods for exploration and field development. The first oil production was officially recorded in Romania in 1857 at a rate of 225 tpa. In 1900, Romania was the third largest oil producer in the world with 300,000 tpa.

Romania also has a long history in natural gas storage, linking back to the first attempts to enhance the production of gas in Sibiu County in 1961 through injection of natural gas. To this day, the capacity for underground storage of natural gas has been continuously developed by the establishment of new gas deposits. As at 2010, there were six operational deposits, with a total capacity of 2,760 million m^3. This could be a useful analogue for potential CO_2 storage.

1.2 Government Support for the Project

The Romanian CCS Initiative has a solid regulatory background and several Governmental actions have underpinned the Getica CCS Demo Project. These are summarised in Table 1-1.

Table 1-1 Romanian Governmental Actions

July 2009	Release of the “Action Plan to prepare Romania for the Energy-Climate Change European Union (EU) legislative package implementation”, co-initiated by several ministries including the Ministry of Economy, Trade and the Business Environment (METBE), Ministry of Environment and Forests (MEF), Ministry of Public Finance (MPF), and signed by the Prime Minister.
Early 2010	Commenced Romania’s preparation for transposition of the EU CCS Directive into national legislation. The MEF, in charge of this task, established a Working Group to undertake this task.
February 2010	Release of the “Action Plan for implementing a Demo Project regarding the Carbon Capture and Storage in Romania” initiated by the METBE and signed by the Prime Minister.
April 2010	The METBE launched the national call for CCS project proposals to CO_2 emissions-intensive industries in Romania. A national selection process followed.
May 2010	The Getica CCS Demo Project was selected as the Romanian CCS project from the energy industry to be put forward as part of the New Entrants Reserve (NER300) Programme. At this point, sufficient support was provided by the METBE for activities needed to present a valid CCS project application to the NER300 Programme. The development of the Feasibility Study commenced.
August, 2010	METBE launched the National CCS Research and Development (R&D) Program.
	METBE established the CCS Demo Project Inter-Ministerial Steering Committee through the Order no. 1508.
November 2010	Launch of the first NER300 call prompts completion of the application documentation.
2011	Transposition of the EU CCS Directive into Romanian legislation finalised (30 June 2011) – GEO no. 64/2011 - published in the Official Journal.
	Founding of the future CCS Project Company as the Romanian CCS Demo Project Sponsor.
	GETICA CCS Demo Project applied for funding under the NER300 Programme.

2 PROJECT OVERVIEW

The Getica CCS Demo Project is an integrated CCS demonstration project. It is officially sustained by the Prime Minister of Romania and coordinated by the METBE and supported by the Global CCS Institute.

2.1 Objective

The main objective of the Getica CCS Demo Project is to demonstrate the application of large-scale, integrated CCS to an existing coal-fired power plant.

2.2 Participants

The project will be implemented by a new Project Company, in which the initial shareholders will be three existing State owned companies:

- CE Oltenia SA;
- SNTGN Transgaz SA; and
- SNGN Romgaz SA.

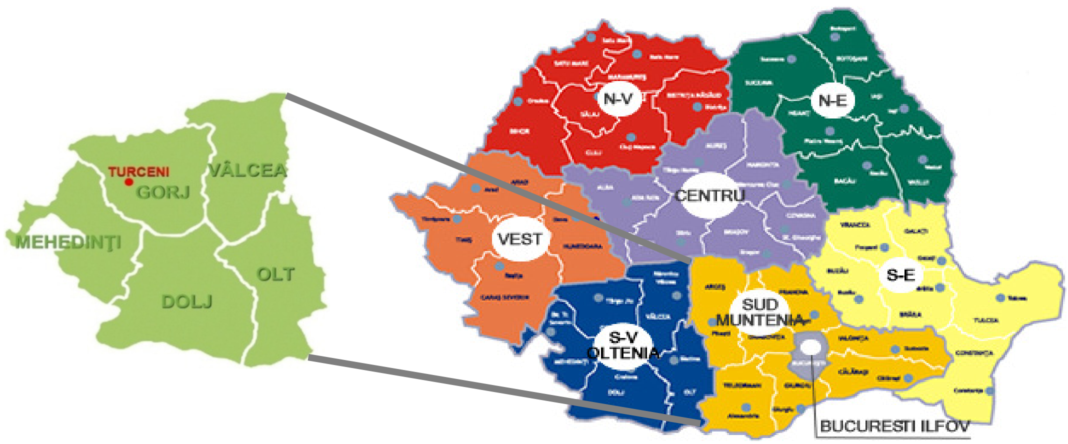
The Feasibility Study for the CCS chain (capture, transport, storage) has been performed by the following consortium:

- Institute for Studies and Power Engineering (ISPE) – Romania: project management, capture integration in the power plant and CO_2 transport development (the later with support from INTETECH Consultancy – UK);
- Alstom Carbon Capture – Germany: CO_2 Capture Plant (CCP) technology;
- GeoEcoMar – Romania: CO_2 geological storage; and
- Schlumberger Carbon Services – France: CO_2 geological storage support.

2.3 Project Specification

The Getica CCS Demo Project will be implemented in Gorj county, in Romania's South West Development Region. The South West Development Region comprises five counties: Dolj, Olt, Valcea, Mehedinti and Gorj (refer Figure 2-1).

Figure 2-1 Project location



Source: Ministry of Regional Development and Tourism

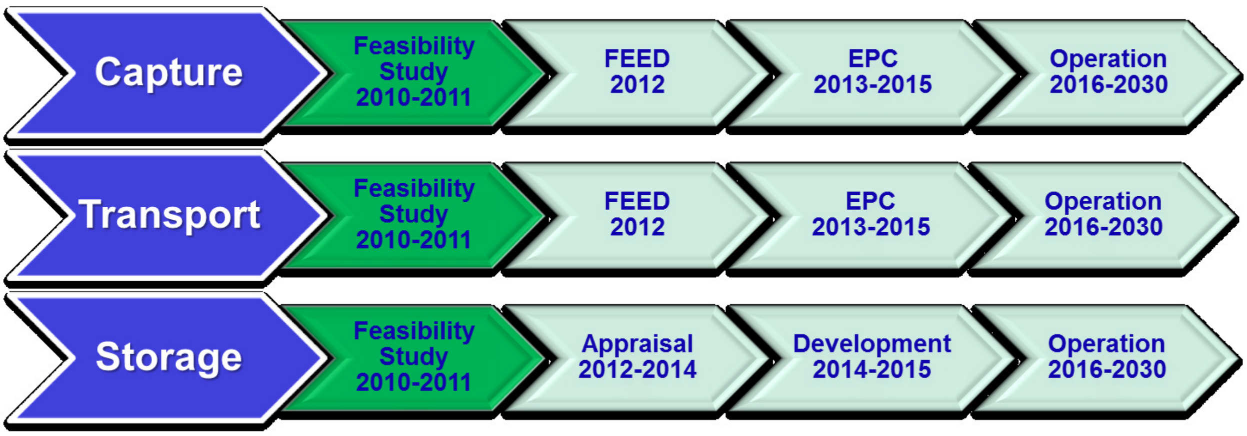
The Romanian CCS Demonstration Project comprises a full chain CCS system which plans to capture 1.5 million tonnes per annum (Mtpa) of CO_2 emissions from an existing 330 MW unit (No.6) of the Turceni Power Plant (PP). Turceni PP is a base-load plant and one of the strategic electricity suppliers to the Romanian National Power System. The power plant and the adjacent lignite mines are part of the Oltenia Energy Complex, a state owned company.

The CO_2 from the capture plant will be transported using (where possible) existing onshore natural gas pipelines and stored underground in onshore deep saline formations within a 50 km radius of the power plant. The prospective storage site is also situated in the South West Development Region.

2.4 Project Development Plan

The Getica project's planed start-up of operation is December 2015. The major phases up to operation are presented in Figure 2-2 below:

Figure 2-2 Getica CCS Demo Project key implementation phases



2.5 Current Status

At the time that this Feasibility Study Report was developed (April 2012), the Getica CCS Demo Project had successfully achieved the following milestones:

- selection of the first Romanian CCS demonstration project location (Turceni);
- Feasibility Study and Storage Assessment;
- application for the NER300 Programme first round funding; and
- signing of a Norwegian Financial Mechanism Memorandum of Understanding (MoU) between Norway and Romania, providing financial support of €40 million for the Getica CCS Demo Project.

Currently, the project is preparing for the Front End Engineering Design (FEED) kick-off. The grant funding from the Norwegian Financial Mechanism will be allocated to the execution of this stage.

2.6 Referenced / Associated Documents

The following documents have been previously as part of the development of the Getica CCS Demo Project (Table 2-1).

Table 2-1 List of Referenced / Associated Getica CCS Demo Project Documents

Release Date	Title / Description	Location
Dec 2011	Feasibility Study Report – CO_2 Capture	http://www.globalccsinstitute.com/publications/getica-ccs-demonstration-project-%E2%80%93-feasibility-study-report-%E2%80%93-co2-capture
Nov 2011	Permitting Report	http://www.globalccsinstitute.com/publications/getica-ccs-demo-project-%E2%80%93-permitting-report

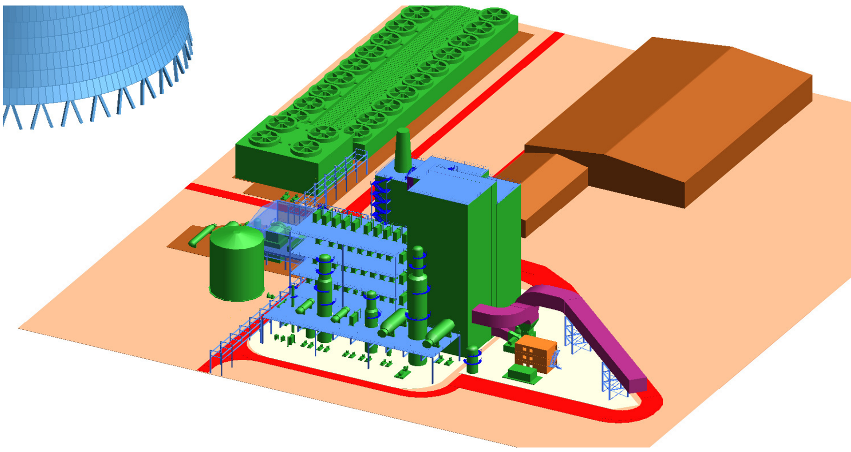
3 CAPTURE

This section provides an overview of the CO_2 capture component of the Getica CCS Demo Project. For a comprehensive description of the CCP and its integration with the Turceni PP, please see the CO_2 capture feasibility study report, published by the Global CCS Institute (refer Table 2-1).

The CO_2 capture plant will be retrofitted to the 330 MW Unit No. 6 of the existing six units in Turceni. Unit No. 6 is fuelled by local lignite equipped with wet flue gas desulphurisation (WFGD) and a dense slurry installation for ash and slag discharge. The power unit is currently being refurbished, with start-up expected prior to commissioning of the CCS project.

The CCP will treat a flue gas stream from Unit No. 6 equivalent to 250 MWe of net electrical output (sent out by the power plant, after the auxiliary load). The minimum targeted CO_2 capture rate is 85% from the flue gas stream. A representation of the CCP is presented in Figure 3-1.

Figure 3-1 Turceni CO_2 Capture Plant View



3.1 Capture Technology Options

The optimum post combustion CO_2 capture (PCC) technology selection should consider project-specific parameters including the project site, technical constraints and integration specifics. It should also take into consideration the stage of development and maturity of the PCC technologies and the expected development timeframes.

Since the Getica CCS demo project is planned for operation in 2016, the technology selection has been limited to the Chilled Ammonia Process (CAP) and the Advanced Amine Process (AAP), as these technologies are considered as being the most advanced in their development and closest to commercialisation at a scale applicable to this project.

The advantages of using an ammoniated solution as a CO_2 absorbent include:

- low heat of reaction;
- high CO_2 absorption rates;
- high pressure regeneration;
- low sensitivity to impurities; and
- low absorbent cost.

Advantages of the AAP compared to conventional monoethanolamine (MEA) scrubbing include:

- more energy efficient capture of CO_2;
- lower solvent degradation rates, leading to lower chemical consumption and lower production of effluents and waste;
- lower corrosivity, leading to less costly plants; and
- advanced and more flexible schemes, providing potential for further energy savings.

On 10 December 2010 a meeting took place at the Turceni power plant, with the participation of ISPE and the technology provider ALSTOM Carbon Capture GmbH (ACC). At this meeting, a decision was made to utilise the CAP technology.

3.2 Benefits and Limitations of the CAP for Turceni

The CAP is an emerging technology with encouraging prospects regarding performance and emissions based on extensive laboratory and pilot testing.

The CAP satisfies project-specific requirements and constraints, including the available land area for the capture plant and technical characteristics of the plant and utilities, for example:

- the existing EP and WFGD are sufficient to enable CO_2 capture, as the values of particulate matter (PM) and SO_2 in the flue gases are acceptable for the chemical process;
- the stability of the ammonium solution is not affected by oxygen or acidic trace components present in the flue gases; and
- the environmental impacts are relatively small, given there are no degradation products, and no complex chemical compounds.

The CAP also offers additional benefits for PCC at Turceni. These are described below.

Ammonia is already used in Turceni for the normal operation of the power plant. This presents an opportunity to utilise the existing infrastructure for the CAP Process. The operator of the power plant has long term experience with ammonia handling and management of its waste products. This will, therefore minimise the learning curve and the need for additional training for the existing operational staff. Further, the use of a chemical already in use at the plant will simplify the application and permitting process for the CCP.

For the ammonia make-up supply, the existing supply-chain may be utilised. Romania has suitable ammonia production facilities available, offering a low cost and readily available bulk solvent supply from the domestic market.

The CAP is economically attractive, particularly due to the existing use of ammonia on the Turceni site. The on-going operating costs for CAP are lower compared to AAP, due to the lower cost of ammonia make-up compared to amine solvents. A further economic benefit may be realised from the by-product consisting of liquid ammonium sulphates, which has commercial value as a fertiliser.

The assumption made in the Feasibility Study was that this by-product will be provided to a possible user of ammonium sulphate in Romania (preferably) or from the international market. If discussions with potential local users or buyers of the by-product are unsuccessful, a market analysis shall be conducted for the European Community market.

3.3 Capture Plant Product Properties

The key properties of the product stream from the CO_2 capture plant are presented in Table 3-1.

Table 3-1 CO_2 Product Properties from CCP

Parameter	Units	Value
Phase		Supercritical Fluid
Pressure	kPa(a)	12,000
Temperature	℃	30-40
Flow Rate	kg/h	238,000
Water content	%wt	< 50 ppmv
Carbon Dioxide	%wt	> 99.7% volume
Nitrogen + Argon	%wt	< 2,500 ppmv
Oxygen	%wt	< 50 ppmv
Ammonia	mg/Nm^3	< 150 ppmv
SO_2	mg/Nm^3	0
NO_x	mg/Nm^3	-
Particulate matter	mg/Nm^3	-

4 TRANSPORT

The Feasibility Study has evaluated two storage options (Zone No. 5 and Zone No. 1), with two corresponding CO_2 transport pipeline routes. Based on available data, Zone No. 5 appears to be the most suitable storage site. Zone No. 1 could still be an alternative storage site, which will be subject to further assessment and investigation. Options for CO_2 transport by pipeline to both sites have been considered in this Feasibility Study.

4.1 Technical Description

The CO_2 is being proposed to be transported through a new onshore, underground pipeline with a nominal diameter of 350 mm (14 inch). The distance from the CCP to either of the two storage options is approximately 40 km. The CO_2 will be transported in dense phase, as this has been determined to be the most cost effective solution for long distance transportation. The pipeline design pressure-temperature envelope is: 0-140 bar and 0-50ºC. The pipeline operating range is 80-120 bar and 0-40ºC.

The CO_2 pipeline start point is an outlet from the CCP dehydration and compression unit. The end point has been allocated in the area deemed most suitable for a booster station and the closest to the potential storage injection points. The booster station and CO_2 distribution header has been allocated as part of the project's storage component, and will be developed once the final injection locations are determined.

Within the Turceni PP site (approximately 1.6 km), the pipeline is proposed to run aboveground on new sleepers and the existing pipe rack. The remainder of the pipeline will be installed underground in a trench or by horizontal drilling, at a minimum depth of 1.2 m.

Pipeline steel will be in accordance with ISO 3183:2007 Grade L415 / API 5L Grade X60 to product specification level (PSL) 2. ASTM A333 grade 3 will be used where minimum temperatures are expected (one pipe joint either side of a valve, pipeline entry if low temperatures are expected in this pipe section due to filling procedures). ASTM A312 TP316L will be used for low temperature vent station piping, relief and safety valves.

Further material selection considerations and failure prevention approaches for the pipeline are presented in Appendix B.

Once commissioned, the pipeline will be constantly monitored and remotely controlled from the control room. The CO_2 transport control system will ensure process data acquisition, process control and data transmission to the transport network operating control centre, incidental leak detection, pipeline protection, emergency shut down and automatic closing of isolation valves.

4.2 Benefits and Constraints

Given the relatively close proximity of the CCP and storage sites, the CO_2 pipeline length is relatively short. This results in lower investment and operating costs.

However, the pipeline design had to consider several specific constraints. This includes terrain, population density, archaeological sites, relevant regulations and environmental considerations.

The pipeline will pass nearby populated areas (villages, roads, railways). Both potential pipeline routes traverse areas having a population density of 50-250 persons per square kilometre. Based on a preliminary risk and safety assessment, protection will be maximised primarily by installing the pipe underground, to reduce the likelihood of third party intervention. As a rule, a minimum clearance of 500 m from the existing villages and buildings has been considered when selecting the pipe route.

The pipeline will be installed in a hilly area, and some sections of the pipe route are subject to landslides. In compliance with Law no. *575/2001* on the approval of the *National Site Preparation Plan – Section V Hazard Zones,* the sites of the two routes investigated fall entirely within the zone with high landslide occurrence potential with high and very high slide likelihood.

To avoid the areas prone to landslides to the greatest extent possible, most of the pipeline route to Zone No. 5 (about 30 km) will be located in the major bed of Jilţu Creek and Motru River.

To avoid landslide occurrence and adverse impacts during pipeline operation, the Study recommendations are to:

- apply a crosswise approach to lay down the CO_2 pipeline under the slide plan (within the known, identified or prone to slide zones);
- avoid locating the pipeline above or next to this plan;
- reinforce, protect and stabilise the bearing prism of the slides occurred or in progress (should its crossing be unavoidable); and
- use horizontal directional drilling to cross these zones (this technology is also recommended for the water, railway and road crossings).

Possible risks generated by coal mining activities (quarries and pits) in the area were also considered. Surface subsidence will have a negative impact on the CO_2 transport pipeline. As a result, it is vital that these subsidence and mining areas are avoided when selecting the pipeline route (regardless of whether the mines are operational or decommissioned).

The steep slopes along the route may require unconventional construction methods for the installation of the pipeline. Special construction procedures will be needed in order to stabilise the construction right-of-way work areas along the side slopes. Temporary additional space will be required along the route where greater access will be needed during construction. Particular attention will be paid to the need for special restraints or anchor requirements for the slope and the pipeline.

4.3 Transport System Characteristics

The key properties associated with the CO_2 pipeline are presented in Table 4-1.

Table 4-1 CO_2 Pipeline System Properties

Parameter	Units	Inlet Value	Outlet Value
Phase		Supercritical Fluid	Supercritical Fluid
Pressure	kPa(a)	12,000	9,000

Parameter	Units	Inlet Value	Outlet Value
Temperature	℃	30-40	10-30
Flow Rate	kg/h	238,000	238,000
Water content	%wt	< 50 ppmv	< 50 ppmv
Carbon Dioxide	%wt	> 99.7% volume	> 99.7% volume
Length	km	40	
Diameter	mm/inch	350/14	

5 STORAGE

5.1 Regional Geology

The assessment of possible storage sites has been conducted within a 50 km radius of the Turceni PP (the emission source), within the Getic Depression. The Getic Depression represents a sedimentary basin developed at the contact between the South Carpathians and the Moesian Platform (Sandulescu, 1984). The 50-100 km wide basin comprises more than 6 km of Uppermost Cretaceous to Tertiary sediments deposited in a poly phase tectonic regime. This regime is described in greater detail in Appendix C.

5.2 Input Data

The main database for the storage part of the Feasibility Study comprised 241 existing 2D seismic lines and 107 well information packages. Most of the seismic lines were in digital format, but a few were on paper. Most of the wells were deep wells (almost entire Sarmatian sequence drilled), but some of them intercepted only the upper part of the Sarmatian formation.

Most of the data used in the Feasibility Study assessment has been acquired from the major Romanian oil and gas companies: OMV Petrom, Rompetrol and Romgaz, or from the major geophysical survey company – Prospectiuni.

Publically available literature and data have also been used, including: statistics on population (National Institute of Statistics), archaeological sites (Cultural Heritage Institute), and protected areas (Ministry of Environment and Forests).

The reports for the well integrity analysis were acquired in different stages. This presented the greatest challenge in terms of data acquisition for the Study. The first step involved developing an inventory of all the relevant pre-existing wells from the storage sites using old seismic plans from Prospectiuni, as well as situation plans and databases from the oil and gas companies that have exploration blocks in the area. Locating well reports for all the mapped wells was the most difficult task as many of them were old abandoned wells drilled before 1990.

5.3 Site Selection Methodology

The CO_2 storage site selection was based on assessment of all available geological and geophysical data (wells, seismic lines, gravimetric and magnetic maps, outcrops, geological cross sections).

Based on this information, the key selection criteria were:

- properties of the reservoir rocks (e.g. porosities and permeabilities);
- reservoir depth (with key objective of reducing economic costs);
- the existence of a suitable seal formation above the reservoirs.

5.4 Key Findings and Results

Aquifers in the tertiary formations have been identified as potentially suitable for CO_2 storage. These types of formations are located at depths suitable to develop a CO_2 storage project (i.e. greater than 800 m and no more than 3,000 m).

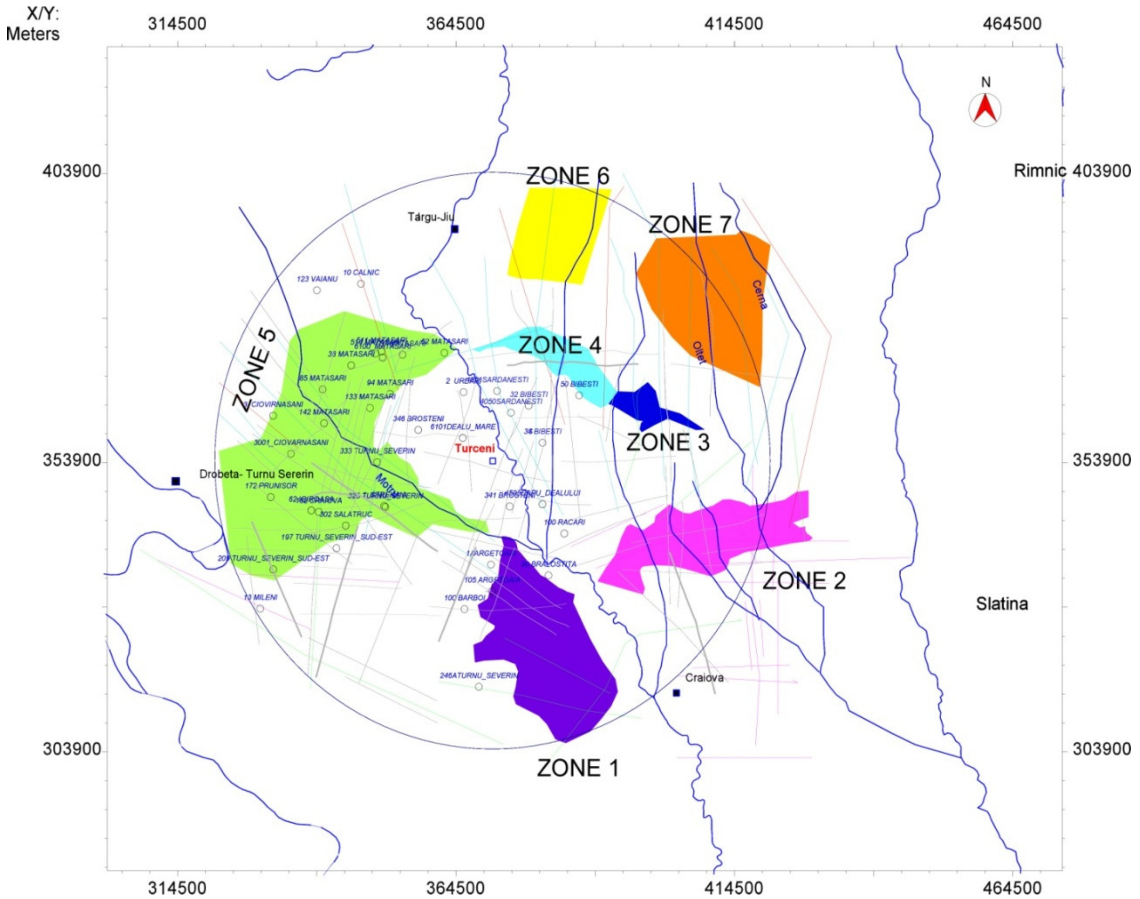
The tertiary formations have also generally been better studied over the years in the process of oil and gas exploration and exploitation (which facilitated the data collection for the Project).

Seven potential CO_2 storage sites have been identified based on the following data:

- interpreted seismic lines and well logs from the area;
- the geological knowledge of this area (structural map at the base of Tertiary deposits);
- the distribution of the main faults at the regional scale; and
- additional geological information about the investigation area (stratigraphy, lithology, sedimentary systems, tectonic evolution)

These seven prospective sites are shown in Figure 5-1.

Figure 5-1 Location of the Seven Potential CO_2 Storage Sites



Key features of the potential storage sites against the selection criteria are presented below.

5.4.1 Properties of the Reservoir Rocks

The Tertiary deposits are mainly siliciclastic comprising sandstones, conglomerates and sands altering with shale. According to outcrops, well and seismic data, the sandstones and conglomerates have good reservoir qualities. The porosities and permeabilities of the reservoir formations are relatively good, with average porosity of 14% and permeabilities varying from 50-100 mD.

Although the older geological formations developed under the Tertiary deposits are proven to have good reservoir properties, these were not taken into consideration. This is due to their development below 3,000-4,000 m, that would considerably increase storage costs.

Further analysis of the geological data concluded that the Sarmatian sequence was the best geological sedimentary sequence from the Tertiary sedimentary column for CO_2 storage.

5.4.2 Depth of the Reservoirs

The analysis concentrated mainly in zones where the reservoir depths are between 1,000 and 3,000 m. The development of the Tertiary sequences was controlled by the existence of an important Pre-Tertiary erosional unconformity which created a complex paleorelief. The base Tertiary map shows a general tendency to deepen northwards from 0 m to more than 5,000 m.

5.4.3 Existence of a Suitable Seal Formation

A proper seal formation above the reservoirs with good lateral continuity, good containment properties and considerable thickness was identified.

The total thickness and the Net/Gross (N/G) ratios of the sedimentary sequences covering the reservoir intervals were evaluated for every well in the analysed area. The N/G values show that the entire sedimentary sequence above the reservoir Sarmatian deposits is composed mainly of shale and is a very good seal for the Sarmatian reservoir.

The presence of the seal in the study area is supported by the presence of several oil and gas fields located in the eastern part of the area. Almost all these fields have Sarmatian reservoir rocks and the sedimentary sequence from surface to top Sarmatian as seal.

An average of the above N/G values (0.43) has been taken into consideration to evaluate the bulk volume of the reservoir rock from the study area.

5.4.4 Shortlisting of Potential CO_2 Storage Sites

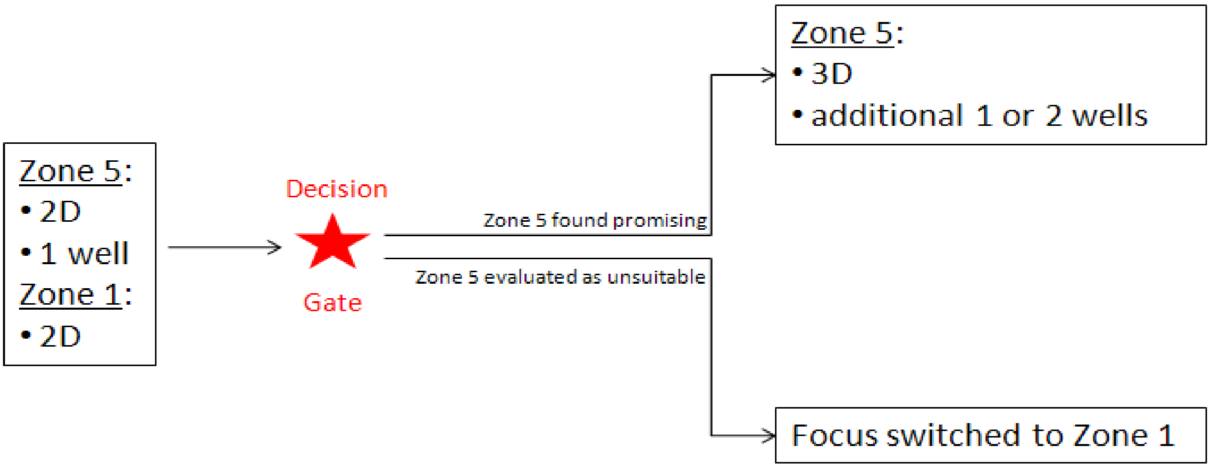
Following the preliminary selection of the seven sites, a more detailed analysis found that the most (potentially) suitable storage sites are Zone 5 and Zone 1 (both deep saline aquifers). Both reservoirs are made of several Sarmatian sequences composed from course sediments.

Static and dynamic modelling performed for each of the sites lead to an initial characterisation of their associated storage complexes. The dynamic simulations identified a storage capacity of around 100 million tonnes of CO_2. This capacity is sufficient to store the total amount of CO_2 emitted by Turceni PP and would also be sufficient for use by future CCS projects in the region.

This storage characterisation will be completed and finalised during the Appraisal (Phase 2) of the project. The key objectives of the Appraisal phase are to fill the gap in knowledge identified during the performance and risk assessment work and to complete the site characterisation for the selection of a single site to be further developed. Table 5-1 provides the proposed data acquisition for the appraisal wells.

The Appraisal strategy is based on the assumption that Zone 5 is more promising as a CO_2 storage site than Zone 1. Therefore, the strategy has been tailored to investigate Zone 5 as the primary target and Zone 1 as a backup, as shown in Figure 5-2 below.

Figure 5-2 Appraisal Strategy Overview



The next Appraisal phase of the project aims to:

- prove the existence and quality of the caprock;
- provide data on the overburden (presence of a secondary caprock, of shallow potable aquifers);
- acquire local reservoir petrophysical, geomechanical and geochemical data to confirm the characteristics of the reservoir;
- identify promising zones for injection from a structural point of view;
- prove the containment performance of the zones identified above;
- provide a detailed mapping of the lateral and vertical extent of all the faults either bounding or located within the zone, with a special focus of the bounding faults for fault stability and conductivity (lateral and vertical);
- show that faults found to extend above the caprock (and secondary caprock if found to be present) are vertically sealing;
- show that if they are going to “see” CO_2, that the bounding faults are laterally sealing; and
- provide a map of the reservoir heterogeneities.

The data acquisition program for the appraisal wells is presented in Table 5-1.

Table 5-1 Proposed data acquisition program for appraisal wells

<table>
<tr><th></th><th></th><th></th><th>Logging</th><th>Coring</th><th>Well Testing</th></tr>
<tr><td rowspan="3">Overburden</td><td></td><td></td><td rowspan="3">Sonic (BHC/LSS), Density & Neutron, Resistivity, Natural Gamma Ray (GR),
Nuclear magnetic resonance,
Advance sonic imaging platform and Formation imaging when/if caprock is detected, Caliper, VSP, Azimuthal cement and corrosion evaluation</td><td>Cuttings carefully monitored to look for possible caprock</td><td></td></tr>
<tr><td>Potential secondary caprock in overburden</td><td>Caprock</td><td>Sidewall core sampling when caprock is encountered for lithology descriptions and geomechanical testing</td><td>MiniFrac</td></tr>
<tr><td></td><td></td><td>Cuttings carefully monitored to look for possible caprock</td><td></td></tr>
<tr><td rowspan="2">Sarmatian</td><td>Above reservoir top sequence</td><td>Caprock</td><td rowspan="2">Density & Neutron, Resistivity, Natural Gamma Ray (GR), Nuclear magnetic resonance, Advance sonic imaging platform and Formation imaging, Elemental Spectroscopy, Caliper, VSP, Azimuthal cement and corrosion evaluation</td><td>Several conventional cores in the top, middle and lower sections</td><td>Extended Leak Off tests
MinifFrac</td></tr>
<tr><td>Reservoir sequences</td><td>Reservoir</td><td>Several conventional cores in the top, middle and lower sections</td><td>Pressure measurements to establish a pore pressure profile Formation fluid sampling

DST well production/injection testing</td></tr>
</table>

5.5 CO_2 Storage Characteristics

Based on the results of the injection simulations performed, a preliminary injection strategy (similar for both candidates) has been proposed. This involves a relatively large number of injector wells, compression of the CO_2 stream at the storage site and deep monitoring wells. The 3D boundaries of a target geological volume have also been presented for each of the two sites. The storage site and storage complex will be defined after the appraisal when the uncertainties currently associated with the subsurface have been significantly lowered.

A summary of the storage investigation for the Feasibility Study is presented in Table 5-2.

Table 5-2 CO_2 Storage Characteristics

Parameter	Units	Value
Sites identified		7
Sites selected		2

Parameter	Units	Value
Dynamic storage capacity (estimated for each of the selected sites)	million tonnes	100
Maximum distance from Turceni power plant	km	50
Depth (min/max)	m	1,000/3,000
Existing data used: - 2D seismic lines - Well information		 241 107
Average porosity	%	14
Average permeability	mD	50-100
Average Net/Gross ratio (N/G)		0.43

Preliminary risk and performance assessments were conducted on the two candidate storage sites (Zones 1 and 5). The assessment of the technical storage risk is presented in Section 7.1.1.

An appropriate design of the storage site (in the EU sense of the term, i.e. including the injection infrastructure) will contribute significantly to reducing the likelihood of the technical risks.

This design will include considerations such as:

- positioning the injectors at an appropriate distance from identified faults (larger than the expected extent of the CO_2 plume) will reduce the risk of CO_2 leakage through these faults, if not eliminate it (a risk of brine leakage will however still exist);
- considering the distance between the injectors and the existing wells in a similar way, presenting potential well integrity issues;
- introducing back-up injectors to limit the impact of injectivity risks by allowing the continued injection of the entire flow rate, even when one injector is shut down. An oversize design of the injectors could also provide the same benefits;
- design the injectors themselves with the objective of minimising the likelihood of all well integrity risks by:
    - selecting appropriate corrosion resistant materials for casing and completion;
    - selecting appropriate cement system; and
    - ensuring maximum well bore stability during the well construction (e.g. mud system, drilling practices).

6 HEALTH, SAFETY AND ENVIRONMENTAL IMPACT

A preliminary environmental assessment has been undertaken for each project phase (construction, operation and decommissioning). This is based on the information available at the feasibility study stage, in order to provide an early indication of the potential environmental impacts and suitable mitigation measures.

The complete environmental assessment will be performed during the Environmental Impact Assessment (EIA) process. This will involve reassessment of the potential environmental effects and the mitigation measures. The mitigation measures for the construction and operation phases will be presented in the Environmental Agreement (EA) granted for each component of the CCS chain.

The EIA for the CO_2 storage site will have also the role to provide baseline data for the monitoring activities. During the EIA, several studies and assessments will be conducted, such as water quality assessment, soil studies, air quality assessment.

The EA will be published as part of a wide ranging consultation programme which will inform the local community, the regulators and other stakeholders of the proposed development.

The EA will be part of the application for obtaining the Construction Permits for the Project.

For the CO_2 storage site, at the end of the construction/development phase, the static and dynamic models will be updated based on the data acquired during the injection tests.

During the operation phase, the static and dynamic models will be recalibrated based on operational and monitoring data. The environmental works performed during the operation phase will focus on leak detection (sampling and geochemical analysis, soil gas, vegetation stress, etc.) and quantification (if necessary) and on the health, safety and environmental (HSE) impact (CO_2 concentration in the air; water sampling/analysis, soils acidity studies, surface deformation assessment and ecosystems surveys).

The monitoring for the operation phase will be continuous and it will continue in the other two last phases of the project: closure and post closure. The models will be recalibrated in these two phases, based on the injection history and operational and monitoring data to ensure that the CO_2 will be permanently stored and that the predictive models will apply.

More details are presented in the ***Permitting Report*** of the Getica CCS Demo Project (refer Section 2.6).

7 RISK MANAGEMENT

7.1 Overall Risks to the CCS Project

An initial risk assessment was performed during the Feasibility Study stage for the Getica CCS Demo Project. A preliminary risk register and risk matrix were developed.

A systematic identification of risks was undertaken, taking into account the FEED, Engineering, Procurement and Construction (EPC), operation and post-operation phases. The risk assessment has included all of the potential technical and non-technical risks associated with CO_2 capture, transport and storage, including surface facilities and existing wells in the storage site area. These risks could significantly impact the CCS project in areas such as performance (technical, schedule, financial) and constraints to be met (HSE, public acceptance, compliance with regulations), for example.

Of the 69 risks assessed, 18 were classed as critical to the CCS project requiring near-term mitigation measures. These risks were related to uncertainties associated with:

- overall costs of the project;
- by-product management;
- the capture technology, and potential technical issues associated with the scale-up from pilot to demonstration phase;
- landowner approvals; and
- the performance of the CO_2 storage site in terms of containment and injectivity.

Although the results of this first round risk assessment show there are some potentially high risks, these can be reduced by relatively simple mitigation actions such as:

- more effective communication;
- acquiring more accurate, site-specific storage data;
- performing additional laboratory tests on the data collected; and
- conducting further modelling and simulations on pipelines and geological storage.

The residual risk estimation shows that the risk levels could be significantly reduced.

Other (non-technical) risks have been identified, such as insufficient funding, liability risks, possible conflicts of interests with the oil and gas industry, HSE risks and public acceptance related issues. However, issues such as the health risk on local population or public acceptance have been indirectly taken into consideration through the focus put on the containment performance factor. The possible conflicts of interest with the oil and gas industry will need to be addressed in detail to define its impact on the project development and must be evaluated when the proper procedures for granting the storage authorisation will be elaborated by the National Agency for Mineral Resources (NAMR), the Competent Authority for storage.

Since this is the exploratory phase of the project, there are currently some gaps in the level of understanding of the project. These gaps create uncertainty in the risk ratings. Quantitative risk assessment will need to be performed on some risks, mainly in the technical area. This will not be appropriate before project definition of the system and its sub-systems is obtained. The uncertainties can, and will be reduced by gathering more data and performing various rounds of modelling, simulations, and risk assessments.

As a consequence, the results of this initial risk assessment are not final and will be updated periodically as more data becomes available. It is essential to consider it as a dynamic process and to update the assessment periodically to reflect new data and/or changes.

7.1.1 Assessment of Technical Storage Risk

In general for CCS projects, storage is perceived to have the greatest uncertainty. This section considers storage risks in more detail. Preliminary risk and performance assessments were conducted on the two candidate storage sites (Zones 1 and 5). These showed that, based on current available data, subsurface storage of CO_2 could be possible in either of them. However, the preliminary evaluation of the storage technical performance indicators identified a relatively low injectivity, requiring a relatively large number of injector wells. Containment risks have also been flagged, such as the presence of faults, fracture corridors and a considerable number of existing wells. These risks will be evaluated further in subsequent project phases so that appropriate prevention and mitigation actions are taken.

A preliminary analysis of the critical risks associated with technical hazards was conducted to identify the major concerns regarding the two candidate storage sites. The critical hazards identified are presented in Table 7-1.

Table 7-1 Critical Hazards Relating to CO_2 Storage

Element	Hazard	Main Performance Factor impacted
Reservoir	Insufficient lateral extent of pinch outs	Containment
Caprock	Unidentified conductive faults crossing caprock	Containment
Caprock	Unidentified fracture corridors crossing caprock	Containment
Caprock	Permeability under estimated	Containment
Wells	Existing P&A wells leaking	Containment
Faults	Unidentified faults within the reservoir not laterally transmissive	Capacity, Injectivity
Faults	Bounding fault not sealing vertically or laterally	Containment
Reservoir	Permeability lower than expected	Injectivity
Reservoir	Porosity lower than expected	Capacity
Reservoir	Plugging due to salting out around well	Injectivity

Most of the critical hazards are related to the sites' containment performance, with faults being a primary concern. The presence of a large number of existing wells within the lateral boundaries of the site has also been considered as a potential threat to the safety of the storage.

It should be noted that the criticality of the containment risks associated to these hazards is currently perceived as high due to the lack of data. A reduction in this criticality is expected at the end of the appraisal phase, once more data has been acquired and subsequent studies have been completed. As a result, a much better representation of the geological model and potential technical risks will be obtained. This includes a work program that encompasses storage site definition, geological and reservoir modelling, seismic data, and after obtaining the complete results from the laboratory work and associated analyses of samples from all wells on site. It is expected that further characterisation work, conducted during Phase 2 of the project (appraisal), will significantly reduce the uncertainties associated with many of the technical hazards currently considered as critical.

The same applies to hazards related to the reservoir properties (permeability, porosity, associated heterogeneities) for which estimates are based on data from neighbouring structures.

Possible prevention/mitigation measures have been identified and classified according to the categories: “site characterisation/appraisal”, “monitoring”, “site design” and “operational plan”.

Selected monitoring technologies, integrated in an overall monitoring plan will contribute to the prevention and mitigation of technical risks associated with the storage site.

The storage operational plan is composed of several elements, with associated risk prevention and mitigation measures:

- Monitoring activities;
- Maintenance activities: in accordance with the maintenance plan and the data obtained through wellbore monitoring (corrosion and cement logs), maintenance activities will be conducted on the injection infrastructure, and in particular on the injectors, in order to minimise the occurrence of associated risks. Workover operations, such as replacement of completion components, cement squeeze, acid treatment or even fracturing of the near wellbore area can all be considered in view of either preventing well integrity or injectivity risks or provide remediation measures when they have occurred.
- The operational plan will actually contain the emergency response plan and all the remediation measures to be deployed and implemented in the case of occurrence of undesired events.

8 COST AND FUNDING

The costs for the Getica CCS Demo Project are presented in terms of investment and operating costs. Both include each of the components of the CCS chain – capture, transport and storage. They also include a knowledge sharing component.

The components included in the investment costs from the Getica CCS Demo Project Feasibility Study are presented in Table 8-1, and carry a +/-20% level of accuracy. The following key elements have been considered for the investment costs: capital equipment, sites infrastructure, studies, engineering and design, installation and commissioning, permitting, taxes, project management, knowledge sharing (Communication Strategy), contingency and owner's costs.

Table 8-1 Investment costs

Component	Weight of total estimated cost (%)
Capture (compression component is 2.5% of total Capture cost)	60
Transport	4
Storage	14
Owner's costs	2
Development costs	19
Public awareness, communication and knowledge sharing	1
TOTAL	**100**

The development costs (around €148 million of total investment costs) include:

- FEED and detailed design;
- studies (e.g. risk analysis);
- permits, authorisations, taxes, legal quotas;
- consultancy and tendering process organisation;
- site surveys (geotechnical, geological, topographical etc, seismic 2D and 3D acquisition and processing, coring and sampling);
- appraisal wells; and
- expenses for project management.

The contingencies applied for each of the capture, transport and storage investment costs are 10% for capture, 10% for transport and 15% for storage.

The operating costs based on the Feasibility Study for the Getica CCS Demo Project are presented in Table 8-2.

Table 8-2 Operating costs

Component	Weight in annual OPEX (%)
Capture	90
Transport	2
Storage	8
TOTAL	**100**

The operating costs across the CCS chain include:

- for CO_2 capture and compression, fixed and variable O&M, utilities, staff costs, knowledge sharing, and contingency. Utilities costs (electricity and steam, water, other) represent on average 82% of the total operating costs for capture. Out of the utilities costs, the cost of CO_2 compression is on average 14%.
- for CO_2 transport, fixed and variable O&M, utilities, staff costs, knowledge sharing, contingency; and
- for CO_2 storage, fixed and variable O&M (including maintenance, micro-seismicity and environmental monitoring), utilities, staff costs, insurance, knowledge sharing and contingency.

Wherever possible, the investment costs for the Getica CCS Demo Project will be covered by direct funding (grants). Direct funding opportunities exist given the demonstrative nature of the project and the EU's objective of advancing CCS towards commercial operation.

A detailed investigation of possible financing sources at European level was undertaken in order to assess which best fits the Project needs, in terms of time compatibility and level of funding. The potential financing sources are summarised below.

- Potential financing sources for the investment period are:
  - NER 300;
  - Norwegian Financial Mechanism;
  - EU ETS incomes from auctions;
  - National Public Sources;
  - EU 7th Framework Project (FP7);
  - Green Investment Scheme;
  - EIB loan; and
  - Equity.
- Potential financing sources for the operation period are:
  - NER 300;
  - EU ETS incomes from auctions;
  - National incentive scheme; and
  - Fee for CCS service.

As previously highlighted, the Financial Scenarios Report provides for further cost and funding details (refer Section 2.6).

9 PROJECT PLANNING AND NEXT STEPS

9.1 Challenges to Project Development

During the early stages of CCS project development, storage site characterisation is relatively intensive and typically presents a key constraint to the project. There is a risk associated with commencing the EPC phase for the Capture and Transport components prior to the validation and final investment decision (FID) of the storage site, requiring careful consideration and risk mitigation.

Any EPC contracts entered into prior to the storage being finalised need to be entered into under specific limiting conditions, in order to minimise the expenditure on the Capture and Transport. An example of such a limitation could be the commencement of procurement and construction being conditional on the certification of the storage site.

By using such measures, the expenditure will only be limited to the Detailed Engineering for Capture and Transport, without engaging in major equipment purchasing.

In the event that the Storage Appraisal extends for a longer period than initially planned, this can have a significant impact on the scheduled start-up for the entire project.

Another potential source of delay for the Getica CCS Demo Project is the availability of funding. As stated in Section 8, the strategy is to maximise funding from grants. In so doing, the project is exposed to external factors outside the project's control. Any delays in the timing of the funding will have a negative impact on the project.

9.2 Next Steps

Based on the Feasibility Study findings, the major activities to be undertaken during the next FEED phase of the Getica CCS Demo project are:

- FEED for capture;
- FEED for transport; and
- Storage characterisation.

The objectives of the FEED phase are:

- to explore the CCS project components at a greater level of technical detail;
- to reach a ±10% accuracy of the investment cost estimates, compared to the ±20% accuracy of the Feasibility Study phase estimates; and
- to acquire and process new geological data for the complete characterisation of the storage regime in Zone 5 (geological data acquisition (2D/3D seismic, wells) and modelling). This stage will determine the suitability of the selected storage solution and will provide the technical background needed to apply for the storage permit.

The start-up date for December 2015 will be re-assessed during the FEED phase. This milestone date is related to the NER300 funding constraints, where funded projects must be in operation within 4 years from award.

Important aspects of implementation of the first CCS project in Romania include knowledge sharing, capacity building and awareness campaigns. Such campaigns are part of the Getica project's communication strategy and have been in place since 2008. For a complete list of past and planned events on CCS in Romania please see *Appendix A* of this report.

10 CONCLUSIONS AND LESSONS LEARNED

The technical and financial outcomes of the Feasibility Study for the Getica CCS Demo Project are summarised in Table 10-1.

Table 10-1 Relevant Performance and Cost Figures from Feasibility Study

Performance				Costs				
Net power output before CCS	Net power output after CCS	CO_2 captured per annum	Total CO_2 captured	Capture plant integration	Capture plant	Transport	Storage	Total
(MW)		(Mtpa)	(Mt)	(%)				
275	193	1.3	20	3	72	5	20	100

The key outcomes of the Feasibility Study are:

- selection of the Chilled Ammonia PCC technology for CO_2 capture;
- optimisation of the thermal integration of the CCP into the power plant with resulting performance profile;
- preliminary design for the 40 km, 350 mm CO_2 pipeline to either of two storage options;
- a shortlist of two possible onshore storage sites (Zone 5 or 1) and the development of the Basis of Design for the Appraisal wells construction and evaluation;
- a cost estimate for investment and operation of the Getica CCS Demo Project;
- identification of sources of direct funding (grants);
- assessment of preliminary environmental impacts of the CCS Project; and
- identification of the risks to the CCS project during the FEED, EPC, operation and post-operation phases.

The key lesson learned during the Feasibility Study resulted from the storage assessment process. Namely, there was a high degree of effort needed to acquire the existing geological data for the potential storage area. This is due to the Getica project targeting deep saline aquifer formations in an area where several oil and gas companies have conducted prospecting campaigns in the past.

Further, the data collection process itself (data in various formats from different companies) is time consuming. Depending on the source of information, procedures and protocols had to be followed, such as engaging the oil and gas national authority, consolidation of data in a satisfactory database, and the digitalisation of the data in a common usable format.

Based on ISPE's experience, the acquisition of initial data (2D/3D seismic, well data) for future CCS projects globally can be grouped into the following categories:

- no existing geological prospecting data;
- geological data available from a single source; and
- geological data available from multiple sources.

The advantages and disadvantages for each of these categories are presented in Appendix D. The second scenario is considered the optimal scenario (geological data is available from a single source and that source is the developer of the CCS project). It is the scenario that provides an acceptable balance between cost, time and risks during the assessment and characterisation phases.

The successful implementation of the Getica CCS Demo Project will contribute to the continued operation of power plants running on local lignite, contributing to the security of supply, not only in Romania, but also in Central – Eastern Europe.

The first CCS project in Romania creates an opportunity for future applications of the technology to other power producers in the region (over 4,000 MW) on local lignite and other major industrial CO_2 emitters (metallurgical, refinery, chemical, cement, etc.).

The appraisal activities to be performed within the Getica project onshore storage system will be valuable for future CO_2 storage activities in the area. Based on the knowledge generated by Getica, there may be potential for future EHR developments in the region.

There is also a high potential to develop the CCS transport and storage infrastructure for the industrial CO_2 emitters in the region, at country and cross-border levels. The value of the data to be acquired during the storage characterisation extends beyond the Getica project; as such data could be used for the potential further development of a storage hub in the area.

As a result of these factors, future CCS projects in the region will be able to leverage off lessons learned from the Getica project to help overcome barriers to CCS deployment.

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APPENDIX A – INFORMATION AND EDUCATION CAMPAIGNS

Date	Activity	Attendees categories
2008	First International workshop "Promoting CO_2 capture and storage in Romania" - Bucharest	• Governmental entities • International bodies • Research & Development • Education at university level • Business environment • International CCS community
2009	The International Conference on Energy and Environment CIEM 2009 hosted "CCS Round Table" - Bucharest	• Research & Development • Education at university level • International CCS community
2010	The Second International Conference "Promoting CO_2 capture and storage in Romania" - Bucharest	• Governmental entities – Regulatory bodies • Parliament representatives • Diplomatic environment • Research & Development • Business environment • International bodies • International CCS community • National media
2010	Regional Energy Forum FOREN 2010 hosted the international workshop on Carbon Capture and Storage – Neptun, Constanta county	• Governmental entities – Regulatory bodies • Research & Development • Education at university level • Business environment • International bodies • International CCS community • Local and national media
2010	Polytechnic University in Bucharest - Educational event organised within the CCS Round Table	• Education at university and Ph.D. applicant levels
2010	First national knowledge sharing event organised within the CCS National R&D Program - Tg. Jiu, Gorj county	• Governmental entities – Regulatory bodies • Local authorities • Civil society representatives – NGOs • Local community • Research & Development • Education at university level • Business environment – local

Date	Activity	Attendees categories
		industry
2010	Official announcement of the Romanian CCS Demo Project candidacy to NER300 - Brussels	• Governmental entities • Parliament representatives from Europe and Romania • Diplomatic environment • European Commission • International CCS community
March 2011	Climate change – impact and solutions – First educational event – Turceni, Gorj county	• Education at Elementary, Gymnasium and College levels
March 2011	CCS Projects in Europe – dialog with the diplomatic environment in Romania - Business Meeting – Bucharest	• Governmental entities – Regulatory bodies • Diplomatic environment • Research & Development • Business environment • International bodies • National media
April 2011	Getica CCS - Open Door Event –Turceni, Gorj county	• Governmental entities – Regulatory bodies • Parliament representatives • Local and regional authorities • Civil society representatives – NGOs • Local community • Research & Development • Education at university level • Business environment • Local and national media
April 2011	Kick off meeting organised for launching the Global CCS Institute's CCS regulatory test toolkit in Romania – Bucharest	• Governmental entities – Regulatory bodies • Business environment • International CCS community
May 2011	CCS 2020 – International Conference organised within the CCS National R&D Program – Bucharest	• Governmental entities – Regulatory bodies • Civil society representatives – NGOs • Research & Development • Education at university level • Business environment • International bodies • International CCS community

Date	Activity	Attendees categories
		• National media
June 2011	Getica CCS Demo Project was promoted among the young generation at the International Environment Day – Bucharest	• Governmental entities – Regulatory bodies • Civil society representatives – NGOs • Education at college level
June 2011	CO2 Transport & Storage, international live webcast event – Mediaş, Sibiu county	• Governmental entities – Regulatory bodies • Local and regional authorities • Research & Development • Business environment • International CCS community • Local and national media
July 2011	Workshop organised for the Romanian CCS stakeholders for the Getica CCS Demo Project regulatory toolkit test exercise overview – Poiana Braşov, Braşov county	• Governmental entities – Regulatory bodies • Local authorities from the targeted area • Civil society representatives – NGOs • Business environment • Financing institutions • International CCS community • Local and national media
Oct. 2011	Kick off meeting organised for finalising the Global CCS Institute's CCS regulatory test toolkit in Romania – Bucharest	• Governmental entities – Regulatory bodies • Business environment • International CCS community
Nov. 2011	International CCS Round Table organised within the "CCS National R&D Program" and hosted by the International Conference on Energy and Environment - CIEM 2011 – Bucharest	• Governmental entities – Regulatory bodies • Research & Development • Education at university level • International bodies • International CCS community • National media
Dec. 2011	Research and Innovation International Workshop “Promoting CO_2 Capture and Geological Storage in Romania” – Bucharest	• Governmental entities • Research & Development • Education at university level • International CCS community
Jan.	International Workshop “CCS Romania – Lessons learned from the Global CCS	• Governmental entities

Date	Activity	Attendees categories
2012	Regulatory Toolkit" - Brussels	• Diplomatic environment • International CCS community • Business environment
March 2012	The 3rd International Conference "Promoting CO_2 Capture and Storage in Romania" – Craiova, Dolj county	• Governmental entities – Regional and local regulatory bodies • Local authorities • Research & Development • Business environment • International CCS community • NGOs • Local media
June 2012	WEC Central & Eastern Europe Energy Forum - FOREN 2012 – Neptun, Constanta county	• Governmental entities • Romanian Parliament • International bodies • Financing institutions • Business environment • Research & Development • Education at university level • Civil society representatives – NGOs • Local and national media
Sept. 2012	GETICA CCS Demo Project - CO_2 Geological Storage – Dr.Tr. Severin, Mehedinti county	• Governmental entities – Regional and local regulatory bodies • Local authorities • Research & Development • Business environment • International CCS community • Civil society representatives – NGOs • Local media
Nov. 2012	GETICA CCS Demo Project - optimum integration in power plant - Bucharest	• Governmental entities • Regulatory bodies • Business environment • Research & Development • Education at university level

APPENDIX B – PIPELINE MATERIAL SELECTION CONSIDERATIONS

The pipeline material selection has been based on design against fracture. Design against long-running fracture in pipelines is based on the ability to arrest running cracks, rather than avoiding crack initiation. Brittle fractures propagate at high speed, and much faster than decompression of the pipeline contents. Hence, the driving force for brittle fracture is essentially the initial pressure in the pipeline and brittle fracture propagation is basically independent of the properties of the fluid in the pipeline. The design approach is considered to be adequate to avoid brittle fracture in the CO_2 pipeline.

The second possible type of fracture is a ductile fracture (shear fracture). If a defect exceeds the critical size for the material and stress level, a crack may propagate along the pipeline driven by the hoop stress and internal pressure. Ductile crack propagation is slower than that of brittle cracks, and the driving force for cracking may be reduced by decompression of the fluid and resulting reduction in hoop stress at the crack tip. The properties of CO_2 are such that the internal pressure during decompression remains at a higher level for longer than (for example) with methane.

The standard means of mitigating the risk of ductile crack propagation is to specify an adequate toughness, in terms of Charpy V-notch test values. If this is impractical, then various forms of mechanical crack arrestors may be used.

Internal corrosion can be mitigated by control of the water content and operational procedures to prevent a free water phase forming. Given the total maximum water level of 50 ppm (ppmv or mol ppm in gas phase) from the discharge of the capture compression unit, this limit is well below the water solubility limit in the normal operating conditions. Thus, by controlling the CO_2 stream water content at the capture plant output, the internal corrosion risk can be mitigated.

The risk of forming free water in the pipeline during normal operation is therefore low and, if it does occur during transient operation, the exposure time is likely to be limited. However, a minimal corrosion allowance of 2.24 mm has been applied to allow for any short-term upset conditions that may arise over the lifetime of the pipeline.

External corrosion of the buried pipeline will be mitigated by a combination of coating and cathodic protection. A three layer system, consisting of a fusion bonded epoxy FBE base layer, an adhesive layer and an outer polyolefin layer (polypropylene or polyethylene) with minimum service temperatures of -40℃, will be provided for pipe coating. Three layer systems are favoured for resistance to handling and shipping damage. Field welded joints will be coated with a high integrity system (multi-layer shrink sleeves).

APPENDIX C – DESCRIPTION OF POLY PHASE TECTONIC REGIME OF GETIC DEPRESSION

Following a general tectonic scheme, the evolution of the Getic Depression was characterised by Paleogene to Lower Early Miocene extension/transtension followed by large scale Middle to late Miocene contractional to transpressional deformations, the entire system being buried by 1 - 2 km of flat-lying Pliocene sediments, slightly deformed in the last, late Pliocene tectonic event (Dicea, 1996; Matenco, Bertotti, Dinu & Cloetingh, 1997; Rabagia & Fulop, 1994).

The Tertiary evolution of the Getic Depression is mainly characterised by major variations in sedimentary and structural patterns. A roughly S-ward thinning clastic wedge is observed, three main sedimentary cycles being defined in connection with the tectonic activity: the Uppermost Cretaceous - Paleogene cycle (characterised by molasses type sediments); the Miocene sedimentary cycle (mainly composed from clastic deposits, the basal coarse sediments being gradually replaced upward by finer sediments) and the Upper Sarmatian – Pliocene cycle (mainly characterised by up to 2,000 m clastic deposits covering the deformed part of the fore deep).

Rabagia and Matenco (1999) defined, after analysing an important number of seismic lines from the area, several deformations which control the development of different lithological and seismic sequences:

- *Pre-Middle Burdigalian deformations*, created two major normal fault systems with NE-SW trending and WNE-ESE trending which defined several tilted blocks;
- *Late Burdigalian – Badenian deformations* are represented by the reverse faults, which structurally define various uplifted areas along the fore deep. The deformation is mainly characterised by the formation of an imbricated thrust system with WNW – ESE strike;
- *Sarmatian – Early Pliocene deformations* are the most important tectonic event in the foredeep characterised by the formations of transpressional strike – slip duplexes and flower structures associated with the frontal thrusting of the fore deep upon the Moesian platform.

APPENDIX D – STORAGE DATA ACQUISITION CATEGORIES

Based on ISPE's experience, the acquisition of initial data (2D/3D seismic, well data) for future CCS projects globally can be grouped into the following categories:

1. *No existing geological prospecting data*
    a. Advantages: a fresh start, most probably only literature data available. The project will have a higher flexibility and the opportunity to develop a comprehensive data acquisition plan. Also no containment risks due to existing wells, thus no associated costs for wells rework/abandonment.
    b. Disadvantages: longer duration needed for the site characterisation, higher risks regarding the assessment outcomes. Higher costs for the characterisation phase.
2. *Geological data available – <u>single source</u>*
    a. Advantages: usually the data would already be in the possession of the project developer. This would be the best case and would determine the minimum costs and the shortest time for the site assessment phase.
    b. Disadvantages: only if the data owner is not the storage developer. Even so, we can only foresee minor setbacks in this situation: the project developer has to acquire the data, meaning additional costs and time. Certainly the cost would be lower than acquiring new data.
3. *Geological data available – <u>multiple sources</u>*
    a. Advantages: we expect that the available data volume in this scenario would be higher, due to the fact that more than one company has prospected in the same area in the past. Based on the existing data, we consider that the additional prospecting needed for the completion of the site characterisation is lower than in the case of the first two scenarios. This would translate into lower costs and time needed for the second phase of the project – the characterisation.
    b. Disadvantages: acquiring the existing data will be more time and resources consuming than scenario 2 above. The containment risks would also be higher than the first two scenarios, if the assumption that more data is available is being considered. This translates into a higher probability of more existing wells, thus a higher probability for wells rework related costs.