The Compostilla Project
OXYCFB300

Carbon Capture and Storage Demonstration Project
Knowledge Sharing FEED Report

OXYCFB300 Compostilla

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The Compostilla Project
OXYCFB300

endesa

GOBIERNO DE ESPAÑA
MINISTERIO DE INDUSTRIA, ENERGÍA Y TURISMO

FOSTER WHEELER

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The role of the power sector in 2050 decarbonisation is essential, as its emissions account for over 35% of total EU emissions. Moreover, electricity has the potential of substituting other fuels on the demand side, thus contributing to the decarbonisation of the rest of the economy. Analyses from the European power sector show that decarbonisation in the EU is possible under certain conditions. But only a *portfolio* of solutions will achieve this goal. This includes energy efficiency, increase in renewable energy and CO_2 Capture and Storage (CCS). Indeed CCS could reduce annual CO_2 emissions by 0.6-1.7 billion tonnes in the EU and by 9-16 billion tonnes worldwide by 2050.

As a safe and efficient method of capturing and storing billions of tonnes of CO_2, CCS therefore represents the bridge to a truly sustainable energy system. It will enable Europe to grow its economy, enjoy a secure energy supply and meet its CO_2 reduction targets. CO_2 concentrations are already rising at over 2 ppm a year and it is estimated that delaying the implementation of CCS by just 6 years would mean CO2 concentrations increasing by around 10 ppm by 2020.

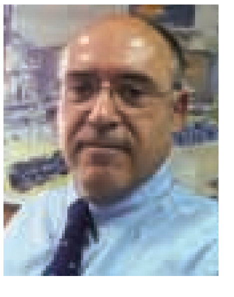
Therefore, wide-scale availability of CCS after 2030 is needed.

This knowledge Sharing FEED Report is the result of a Front End Engineering and Design (FEED) of OXYCFB300 Compostilla CCS Project undertaken by Endesa Generacion S.A, FWEOy and CIUDEN following the award of a Grant Agreement with the European Commission in April 2010 under the EEPR Program.

This FEED has been delivered by a team of more than 1000 experts. These experts comprised many different disciplines from Mechanical, Civil and Electrical Engineers to Geologists and also includes Lawyers, Accountants, Sociologists and other professionals. The FEED brought together and integrated expertise from several distinct industries: process plant, power generation and oil & gas. Finally, the FEED team included expertise from as far afield as Spain, Finland, Italy, Germany, Canada, USA, etc.

The Knowledge Sharing FEED Report will be publically available to CCS project developers through the European CCS Demonstration Project Network, to ensure the lessons learned from this FEED are disseminated as widely as possible to advance the roll-out of Carbon Capture and Storage in Europe. We hope you find this findings useful.

I would like to express our thanks to everyone involved in this project.



Martin Madrid Sanz
Head of Power Business Development
and OXYCFB300 Project Coordinator
ENDESA Generación S.A

Compostilla OXYCFB300 Project is a clear example of how we were able to adapt to the changes that arose, without forgetting the objectives and commitments and at the same time achieving the planned goals.

Energy stays at the basis of the constant evolution and economic development of the countries in the world. Every day we use more energy in the search of a better life quality, new services and products, but this higher consumption, unfortunately, has negative consequences for the environment. In order to reduce pollution levels without sacrificing the needed energy consumption for the ongoing development, a few essential aspects need to be dealt with. On one hand, it is the energy efficiency, and on the other hand, emissions reduction and renewable energies.

Energy efficiency means we spend what we really need, without wasting resources, we consume in an intelligent manner while looking for the synergies to produce less waste and therefore less pollution. This goal requires a sustainable consumption, which in the field of energy was called energy sustainability. Unfortunately, this is not sufficient and we must look for alternatives that allow us to maintain our living standard, without affecting negatively the environment so that future generations can enjoy this world in the same way we do today.

In this respect, one measure taken by Governments of several countries consists of reaching agreements related to the reduction of the CO2 emission levels.

To meet these emission reduction agreements, several innovative developments are contemplated. One of them is the capture and storage of CO2 in Coal Power Plants. These innovative technologies will enable us in the near future to use our own natural resources, work with top notch, reliable and secure power generation technologies, without generating emissions or wastes into the atmosphere.

To achieve these objectives, it is needed to develop projects with multi-disciplinary teams, able to analyze and search for solutions to technological, regulatory and administrative obstacles that may arise in this type of challenge.

The professionals who make up these teams are able to generate the alternatives that will allow us to achieve successfully what at first sight seems to be a far away and complex goal. To develop any R&D and innovation projects, getting the right support is of essence. Support from Public Administrations, private sector companies, technologists and peers, as well as engagement from the social environment, will definitely clear the path towards the projects success and continuity.

In the development of this project, from its inception until the very last days, many things have changed, but we have always counted on committed, professional and motivated people.

OXYCFB300 Compostilla Project is a clear example of how we were able to adapt to the changes that arose throughout the project lifetime without forgetting the objectives and commitments, and at the same time achieving the planned goals. This first phase of the project was carried out by an integrated team, which counted on valuable partner companies. The whole team intense and big efforts lead to a rewarding project goal accomplishment.

The end of the FID stage was reached, validating the technological feasibility of CO2 capture using Oxy-combustion technology in spite of the economic and regulatory obstacles that condition the project.

This letter is a special acknowledgement for all persons and companies involved in the project. I hope we will meet again soon in a second phase, which I expect to be at a minimum as exciting and intense as it was this first one, in the OXYCFB300 Compostilla Project.

Pablo Gutiérrez Cerezales
OXYCFB300 Compostilla Project Manager
ENDESA Generacion S.A.

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INTRODUCTION

ENDESA Generación, under its power generation strategy and continuing with the conviction to remain a leader in innovation and to tackle climate change decided to promote a CCS integral Commercial Demonstration Project, including CO_2 capture, transport and storage, based on a circa 340 MWe gross Circulating Fluidised Bed (CFB) supercritical oxycombustion plant, with CO_2 storage in a saline aquifer.

In May 2010 ENDESA Generación signed an agreement with FOSTER WHEELER ENERGIA Oy and Ciuden for joint development of this Demonstration Project, called OXYCFB300. On that date European Commission (EC) awarded OXYCFB300 Project under EEPR (European Energy Program for Recovery) Program.

Since then, and even before that date, the Project has carried out the activities included in that agreement, among which are TDPs construction, both capture and transport, geological charachterization for CO_2 storage in two different sites and an extensive Front End, Engineering and Design (FEED) study of the full chain OXYCFB300 Project.

Experts of the three partners have been working in a multidisciplinary team, including mechanical, electrical and civil engineers, geologists, ecologists, lawyers, accountants and many other professionals. The result is this "Knowledge Sharing FEED Report" where our lessons learned and knowledge are detailed. This report is available to everyone who is interested in the CCS development and we expect it will be helpful to develop future CCS commercial projects.

We would like to express our thanks to everyone who has been involved in the report development, as well as to EC for its strong support to CCS development and knowledge sharing.

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2. Project Framework
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7. Project Permitting
8. Project Implementation
9. Project Risk Analysis
10. FEED Conclusions

At the end of each chapter of this document there is a link which takes to a more detailed content. To access the information contained in that document, please follow the links.

In addition, to ease the information search, the reader can find at the end of the report a list of the chapters as well as a list of annexes produced to support the findings presented in this report.

KNOWLEDGE SHARING GOALS

As one of the objectives of the Project is to accelerate the deployment of CCS, it is necessary that the dissemination includes the three technical areas, capture, transport and storage. However, some detailed knowledge on technical size and performance is subject to IP Rights or competitive constraints.

The approach followed by the Beneficiaries offers outstanding opportunities to promote an early dissemination of relevant information to interested utilities in Europe and elsewhere.

The details of the technical knowledge that will be disseminated will be limited by the requirements of IP rights and trade secrets and a technology blocks approach will be considered. The following list is the general technical information, which will be published based on the FEED results and the results of the Technological Development Plant:

Estimated general performance of capture, transportation and storage:

- Gross and net power
- Gross and net efficiency of the plant
- Boiler efficiency
- Efficiency penalty due to CCS
- Consumption of feed stocks (fuel, oxygen, limestone etc.) and generated waste / by-product streams.
- CO2 capture rate
- CO2 stored
- Analysis and condition of CO2 stored
- Atmospheric emissions
- Water usage and waste water conditions
- General performance data for the main technology blocks of the plant at full load stable operation

A wide range of communication channels have been established to assure the adequate dissemination of the technology to each of the different interest groups and stakeholders. The definition of the different interest groups and stakeholders is in alignment with the ETP-ZEP (European Technology Platform for Zero Emissions Fossil Fuel Power Plants) proposal: contributors to the Network Programme, non-contributors, research institutes, government and the general public/NGOs.

The following methods have been used to disseminate information and knowledge:

- Regular reporting to public, government and EU including synthesized general knowledge.
- Public summary report.
- Scientific papers and conference proceedings.
- Website including public part.

Other specific efforts for knowledge sharing undertaken during the implementation of the Action include:

- Participation on technological platforms EU-ZEP and Spanish CO2 Technological Platform.
- Participation in ongoing FP7 CCS R&D projects.
- Participation in the IEA Greenhouse Gas R&D Programme (IEA-GHG).
- Participation of CIUDEN in the European Energy Research Alliance (an instrument of the SET-Plan), already effective
- Demonstrating and testing oxy-fuel combustion technologies and procedures on open-day visits in the CIUDEN TDP.
- Entry into the ECSSEL (European Carbon Dioxide Capture and Storage Laboratory Infrastructure) project under the ESFRI1 programme.
- Partnership with the Norwegian BIGCO2 National CCS R&D Platform coordinated by SINTEF.

LIST OF ACRONYMS	
AA	Administrative Authorization
AAI	*Autorización Ambiental Integrada*
ACTI	American Cooling Tower Institute
AEMET	*Agencia Estatal de Meteorología*
AL	Action Levels
ALARP	As Low As Reasonably Practicable
AMCA	Air Moving and Conditioning Association
ANSI	American National Standards Institute
API	American Petroleum Institute
ARI	Air Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ASU	Air Separation Unit
ATEX	*Atmósferas Explosivas*
AVT	All Volatile Treatment
AWS	American Welding Society
AWWA	American Water Works Association
B2B	Back to Back
BFB	Bubbling Fluidized Bed
BFD	Basis for Design
BHP	Bottom Hole Pressure
BIGCCS	Biomass Integrated Gasification Combined Cycle
BMS	Boiler Management System
BOD	Basis Of Design
BOP	Balance Of Plant
BPS	Boiler Protection System
CAC	*Captura y Almacenamiento de* CO_2
CAPEX	*CAPital EXpendidures*
CBL	Cement Bond Log
CCS	Carbon Capture and Storage
CCT	Clean Coal Technologies
CEDEX	*Centro de Estudios de Técnicas Aplicadas del Centro de Estudios y Experimentación de Obras Públicas*
CETC-O	CANMET Energy Technology Centre-Ottawa
CFB	Circulating Fluidised Bed
CHM-S	*Confederación Hidrográfica del Miño-Sil*
CICIND	Comité International des Cheminées Industrielles
CISOT	*Centro de Investigación Socio-Técnica*
CIUDEN	*Fundación Ciudad de la Energía*
CoD	Cross-over Duct
CP	Cathodic Protection
CPM	Computational Pipeline Monitoring
CPN	Critical Path Network
CPS	Cathodic Protection Stations
CPU	Compression and Purification Unit
CSF	Critical Success Factor
CSLF	Carbon Sequestration Leadership Forum
CTE	*Código Técnico de la Edificación*
CVN	Charpy V-Notch
CWT	Combined Water Treatment
D	Deliverable
DA	Deaerator
DC	Drains Cooler
DCA	Drain Cooler Approach
DCS	Distributed Control System
DG-TREN	Directorate-General for Transport and Energy
DIA	*Declaración de Impacto Ambiental*
DIN	Deutsches Institut Für Normung (German Standards Institution)
DoR	Division of Responsibilities
DoW	Description of Work
DSH	DeSuperHeater
DST	Drill-Stem Test
DTS	Distributed Temperature System
DUP	*Declaración de Utilidad Pública*
E&C	Engineering & Construction
EC	European Comission
ECSSEL	European Carbon Dioxide Capture and Storage Laboratory Infrastructure

eDGE	electronic Design Gate Evaluator
EEPR	European Energy Programme for Recovery
EF	Earliest Finish
EFC	Estimated Final Cost
EIC	Electrification, Instrumentation and Control
EIR	*Evaluación Integral de Riesgos*
EIS	Environmental Impact Study
EJMA	Expansion Joints Manufacturer Association
ELAN	Elemental Analysis
EN	European Standards
END	ENDESA
EPA	Environmental Protection Agency
EPG **ERT**	European Power Generation Electrical Resistivity Tomography
ES	Earliest Start
ESD	Emergency Shut Down
ETP	European Technology Platform
ETP-ZEP	Technology Platform for Zero Emission Fossil Fuel Power Plants
EUROC-ODES	European codes
EWRM	Enterprise Wide Risk Management
FEED	Front End Engineering and Design
FEM	*Federación Europea de Manutención*
FG	Functional Groups
FGCC	Flue Gas Cooler Condenser
FID	Final Investment Decision
FP7	Framework Programme 7
FPS	Fire Protection System
FWAG	Foster Wheeler AG
FWEOy	Foster Wheeler Energía Oy
FWEP	Foster Wheeler Energia Polska
FWES	Foster Wheeler Energia SL
FWNAP	Foster Wheeler North American Power
FWPGA	Foster Wheeler Power Group Asia
FWPS	Foster Wheeler Power Systems
GA	Grant Agreement

GCCSI	Global Carbon Capture and Storage Institute
GGHX	Gas-Gas Heat Exchanger
GHG	Greenhouse Gas
GHGT10	10th International Conference on Greenhouse Gas Technology
GICC	*Gasificación Integrada en Ciclo Combinado*
GOX	Gaseous Oxygen
GPG	Global Power Group
GSC	Gland Steam Condenser
H&M	Heat and Mass
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HEI	Heat Exchange Institute
HNBR	Hydrogenated Nitrile Rubber
HP	High Pressure
HP Eco	High-Pressure Economizer
HPH	High Pressure Heaters
HRA **HRC**	Heat Recovery Area Heat Recovery Cooler
HRS	Heat Recovery System
HSE	Health, Safety, and Environmental
HVAC	Heating, Ventilation and Air Conditioning
I/O	Input/Output
IBAs	Important Bird Areas
IC	Interpretation Centre
IDEA	*Instituto para la Diversificación y el Ahorro de la Energía*
IEA	Integrated Environmental Authorisation
IEA GHG	International Energy Agency Greenhouse Gases
IEC	International Electrotechnical Commission
IGV	Inlet Guide Vanes
IIW	International Institute of Welding
ILI	In Line Inspection
InSAR	Interferometric-Synthetic Aperture Radar
ISO	International Organisation for Standardisation
ITM	Ion Transport Membranes
ITPs	Inspection and Test Plans

KP	Kilometre Point
KPI	Key Performance Indicators
LBA	*Línea Base Ambiental*
LCOE	Levelized Cost of Electricity
LDS	Leak Detection System
LFM	Low Frequency Model
LICs	*Lugares de Importancia Comunitaria*
LIN	Liquid Nitrogen
LMAM	*Línea Mundial de Aguas Meteóricas*
LME	*Línea Meteorológica de España peninsular y Baleares*
LML	*Línea Meteórica Local*
LOX	Liquid Oxygen
LP	Low Pressure
LP Eco	Low-Pressure Economizer
LP-GOX	Low Pressure Gaseous Oxygen
LPH	Low Pressure Heaters
M	Milestone
MA	Municipal Area
MCR	*Modelo de Cuantificación de Riesgos*
MDT	Modular Dynamic Tester
MEM	Mechanical Earth Model
MFT	Modular Formation Tester
MICP	Mercury Injection Capillary Pressure
MITyC	*Ministerio de Industria, Turismo y Comercio*
Mº MA	*Ministerio de Medio Ambiente*
Mº MAyMRyM	*Ministerio de Medio Ambiente y Medio Rural y Marino*
MOC	Management Of Change
MoM	Minutes of Meeting
MoU	Memorandum of Understanding
MoPC	Management of Project Change
MP	Medium Pressure
MSCV	Main Stop-Control Valves
MSS	Manufacturers Standardisation Society
MT	MagnetoTelluric
MTD	*Mejores Técnicas Disponibles*

MTE	*Modelo Técnico Económico*
MV	Medium Voltage
MVA	Monitoring, Verification and Accounting
NACE	National Association of Corrosion Engineers
NAS-DAQ	National Association of Securities Dealers Automated Quotation
NFPA	National Fire Protection Association
NHIW	Non-Hazardous Industrial Waste
NHUW	Non Hazardous Urban Waste
OCC2	2nd Oxyfuel Combustion Conference
OPEX	OPerating EXpenses
OSHA	Occupational Safety & Health Administration
OT	Oxygenated Treatment
OXY-CFB	Oxy-Circulating Fluid Bed
P&IDs	Process and Instrumentation Diagrams
PBR	Polished Bore Receptacle
PC	Pulverised Coal
PCI	Protección Contra Incendios
PCU	Process Control Units
PE	Polyethylene
PE	*Proyecto de Ejecución*
PEM	*Puesta En Marcha*
PEP	Project Execution Plan
PFD	Process Flow Diagrams
PISCO$_2$	Plot for Injection in Soils with CO_2
PO **POF** **POX**	Primary Oxidant Primaty One Fan Partial Oxidation
PPE	Personnel Protective Equipment
PSD	Particle Size Distribution
PTA	*Planta de Tratamiento de Aguas*
PTV	*Planta de Tratamiento de Vertidos*
QRA	Qualitative Risk Analysis
QRA	Quantity Risk Assessment
R&D	Research & Development
RAMP	Risk Assessment and Monitoring Plan
RBA	*Recursos de Base Accesible*

RCE	Risk Control Effectiveness
RdT	*Red de Transporte*
REE	*Red Eléctrica de España*
REN	*Red de Espacios Naturales*
RES	Reservoir Evaluation System
RFCS	Request For Comments
REVIP	*Red Española de Vigilancia de Isótopos en la Precipitación*
RFG	Recirculated Flue Gas
RFQ	Request For Quotation
RH	Reheating
SCAH	Steam Coil Air Heater
SCAL	Special Core Analysis
SCD	*Sistema de Control Distribuido*
SC-OTU	Super Critical-One Through
SH	Super Heating
SHE	Safety Health Environment
SIS	Safety Instrumented System
SIS	Safety Instrumented System
SLDs	Single Line Diagrams
SNCR	Selective Non-Catalytic Reduction
SMACNA	Sheet Metal and Air Conditioning contractors National Association
SMES	Superconducting Magnetic Energy Storage
SO	Secondary Oxidant
SP	Set Point
SPF	SmartPlant Foundation
SPI	Society of Plastics Industry
SRF	Screening and Ranking Framework
SSPC	Steel Structure Painting Council
SSSV	SubSurface Safety Valve
SSTT	*Servicio de Industria, Turismo y Comercio*
ST	Steam Turbine
T/D	Time to Depth
TAO	Transmission Asset Owner
TCM	Two-Curve Method
TDP	Technological Development Plant
TDS	*Total de Sales Disueltas*
TEMA	Tubular Exchangers Manufacturers Association
TIR	*Tasa Interna de Retorno*
TN	*Tiro Natural*
TN FG	*Tiro natural con evacuación de humos*
TNS	*Tiro natural asistido*
TRD	Technisches Regelwerk fuer Dampferzeuger
TRS	Tubular Running Services
TSA	Temperature Swing Adsorption
TTD	Terminal Temperature Difference
UCP	*Unidad de Control de Proceso*
UNE	Una Norma Española (Spanish Standards)
UPS	Uninterruptible Power System
V&V	Verification and Validation
VAN	*Valor Actual Neto*
VDI	Verein Deutscher Ingenieure
VDRL	Vendor Document Requirements List
VDU	Video Display Units
VGB	Technische Vereinigung der Grosskraftwerkbetreik
VIPs	Value Improving Practices
VLE	Vapor-Liquid Equilibriums
VSA	Vacuum Swing Absorption
VSP	Vertical Seismic Profiles
WBS	Work Breakdown Structure
WD TNS	*Wet dry con tiro natural asistido*
WFGD	Wet Flue Gas Desulphurisation
WHT	Wellhead Temperature
WOP	Worley Parsons
WP	Work Package
WTP	Waste Treatment Plant
WWTP	Waste Water Treatment Plant
ZEP	Zero Emission Fossil
ZEPAS	*Zonas de Especial Interés para las Aves (Special Interest Areas for Birds)*

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1

Executive Summary

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1.1 INTRODUCTION

1.1.1 EU CCS Demonstration Programme

CO_2 Capture and Storage (CCS) is recognised as a critical technology for combating climate change within a portfolio of technologies, including greater energy efficiency and renewable energy.

The EU, which is responsible for around 11% of global GHG emissions today, has put in place binding legislation to reduce its emissions to 20% below 1990 levels by 2020. For the longer term, the EU has committed to cut its emissions to 80-95% below 1990 levels by 2050, as part of the action that will be required from the developed world.

The EU adopted in 2009 its CCS Directive as part of a package of climate and energy measures, establishing a legal framework for CO_2 storage and EU funding for up to 12 CCS demonstration projects – supported by the launch of the European CCS Demonstration Project Network and European Industrial Initiative on CCS.

The EU agreed to set aside 300 million emission unit allowances (EUAs) from the New Entrance Reserve (NER 300) to demonstrate CCS and innovative renewable energy technologies. The EU also launched an EU Energy Programme for Recovery (EEPR) in which €1 billion was set aside for CCS demonstration projects in Poland, Germany, the Netherlands, Spain, Italy and the UK.

The OXYCFB300 Project applied to EEPR program in July 2009 and the EC communicated in October 2009 that the Project was awarded. In May 2010 the Project partners (ENDESA, CIUDEN and FOSTER WHEELER) signed a Grant Agreement with the EC, establishing the scope of the Project and the conditions of the award, and also a Description of the Work (Annex I GA, DoW) was agreed between the beneficiaries.

1.1.2 Technology Development Stage: FEED Objectives

The OXYCFB300 Compostilla Project is a Carbon Capture and Storage (CCS) integral commercial demonstration project, including CO_2 capture, transport and storage.

The Project is based on a 300 MWe Circulating Fluidised Bed (CFB) supercritical oxycombustion plant, with CO_2 storage in a deep saline formation. This technology will be tested first on a new 30 MWth Technology Development Plant (TDP) sited in Cubillos del Sil, close to ENDESA's Compostilla Power Station in the Northwest of Spain, in which it will be scaled to demonstration size (300 MWe).

The Project has been divided into two distinct phases to significantly reduce the economic and technical risks of this cutting edge CCS demonstration Project:

- **Phase I.** Technological Development (2009-2013)
- **Phase II.** Construction of the Demo Project infrastructure (2013-2016)

1.2 FEED STUDY

As established in DoW Task 1.7, a Front-End Engineering Design (FEED) study ought to be carried out based on the preliminary feasibility Project studies.

The **aims** of the FEED work include:

- Analysis of state-of-the-art in CCS technologies, in the three areas: capture (oxyfuel technology in CFB boiler, air separation equipment and CO_2 purification and compression), transport (singular transport studies of anthropogenic CO_2) and injection and storage of CO_2.
- Performing of feasibility studies and analysis of the available design options.
- Overall analysis of the project issues, identification of the main needs, environmental constraints, legal requirements, identification of dependencies and integration of the three areas.
- Once technologies and major equipment have been selected, the corresponding FEEDs have been developed detailed enough to obtain an economic estimate.
- Development of the documentation for permit applications and analysis of operational risks. Integral Risks Assessment supports Final Investment Decision (FID) of Phase II.
- Preparation of technical specifications to obtain quotations and carrying out the OXYCFB300 commercial demonstration plant budget with a deviation of 10%.

FEED engineering has been developed by ENDESA in collaboration with its partners in the project, based on their knowledge as power generation company and feasibility studies prior EEPR that were conducted with FOSTER WHEELER for Compostilla Project OXYCFB300.

FEED starting point was June 2010 and it was performed during 36 months.

This document summarizes all the engineering studies and considerations developed during the Project FEED. From the original conceptual idea, FEED engineering works have yielded a functional and technically feasible power plant, which successfully integrates oxycombustion technology with a state-of-the-art ultrasupercritical regenerative power cycle and with an innovative CO_2 purification and compression process, integrated with a transport line that conducts the CO_2 at dense phase to the final CO_2 geologic sequestration site, for an operational life of 25 years.

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2

OXYCFB300 Framework

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2.1 PROJECT OVERVIEW

The OXYCFB300 Compostilla Project Basis

ENDESA Generación, under its power generation strategy and continuing with the conviction to remain a leader in innovation and to tackle climate change decided to promote a CCS integral Commercial Demonstration Project, including CO_2 capture, transport and storage, based on a circa 340 MWe gross Circulating Fluidised Bed (CFB) supercritical oxy combustion plant, with CO_2 storage in a saline aquifer. The main target of this Demo project is to validate, at commercial plant size, a CO_2 Capture and Storage (CCS) technology that will allow the renovation of the existing fossil thermal plants from 2020, using a wide range of domestic coals, as well as imported fuels (coals, pet coke), and biomass. The foreseen plant´s location is ENDESA`s Compostilla Power Plant, in the northwest of Spain.

Figure 2.1 Location of the capture site of the OXYCFB300 Compostilla Project

To guarantee the success of the project, ENDESA signed cooperation agreements with FOSTER WHEELER ENERGIA SL (FWES) and CIUDEN to participate in the scale-up validation program as well as for the future construction of the Commercial Demo Plant. FWES and ENDESA GENERACIÓN signed on October 2007 an agreement for joint development of the OXY-CFB with indigenous coals, including all the validation steps. A feasibility study of the future OXY-CFB demo powerplant was carried out during 2008. In this proposal the technology provider is the Finland based FOSTER WHEELER ENERGIA Oy, that is the responsible of the basic design of CFB units within the FOSTER WHEELER Global Power Group.

In October 2009, the project (ENDESA, CIUDEN, FWEOy) was awarded by the European Commission (EC) under the EEPR (European Energy Program for Recovery) Program with a contribution of a maximum of 180 M€, equivalent to the 80% of the total eligible costs estimated for the Phase-I of the project. The overall project schedule was divided in two phases: Phase I-Technology Development (2009-2013) (hereinafter, the “Action”), and Phase II-Construction of the Demo Project Infrastructure including capture transport and storage concepts (2013- 2016) (the Phase II-Construction of the Demo Project Infrastructure). The activities included in the EEPR Action are to be carried out during Phase I-Technology Development. By March of 2013, the Final Investment Decision (FID) process of the integrated project has been started and the FID is expected by the end of 2013.

A key role in this development has been assumed by CIUDEN who constructed an Integrated CCS Technology Development Plant (TDP) with EEPR funds in Compostilla featuring a 30MWth Oxy-Circulating Fluid Bed (Oxy-CFB) using the same technology to be incorporated by the commercial scale demo plant (Demo Plant). In that regard, CIUDEN made an agreement with FOSTER WHEELER ENERGÍA, S.L. (“FWES”), company of Foster Wheeler Global Power Group, for the supply by FWES of an Oxy- CFB boiler for the TDP.

In parallel with these capture activities, ENDESA started different geological surveys for a possible CO_2 storage site in the vicinity of Compostilla (Duero Site). To reduce the risks of the project associated with the storage site, and as a second alternative, ENDESA also worked in another area close to Teruel Power Plant (Andorra Site), where it was carried out the geological characterization of an alternative saline aquifer. The studies developed revealed that Teruel geological structure is not technically nor economically feasible to withstand a CO_2 reservoir in the size needed for the Project or for any other commercial application of CO_2 storage for large scale powerplants.

EEPR (European Energy Programme for Recovery)

The European Energy Programme for Recovery (EEPR) provides financial support to selected highly strategic projects in the energy sector. By co-financing these projects, the programme helps the European Union to progress towards its energy and climate policy objectives: security and diversification of energy supply; completion and smooth operation of the internal energy market; and reduction of greenhouse gas emissions. At the same time, by sustaining capital expenditure in the real economy, the programme aims at stimulating economic activity and promoting growth and job creation.

The EEPR was set up in the wider context of the global effort undertaken at EU level to face the financial crisis that erupted in 2008 and to stimulate economic recovery. Since then, an even more severe crisis is sweeping Europe and therefore policies to stimulate recovery remain highly necessary. Given the complexity and the magnitude of the crisis, no single policy initiative or spending programme can be expected to deliver economic recovery on its own. However, in this difficult context, the EEPR has been and continues to be a useful tool that allows progress in a number of key investment projects, which without public EU funding would be at risk of being delayed, downsized or cancelled.

The OXYCFB300 Project applied to EEPR Program in July 2009. In October 2009 EC communicated to the OXYCFB300 Project that it was awarded and finally, in May 2010 the three partners signed a Grant Agreement (GA) with the EC which established the scope of the OXYCFB300 Project and conditions of the award. One of the requirements of EC to sign the GA was the signing of a DoW (Description of Work) between the partners involved. This DoW included the scope of the Action and described the activities to be developed by each partner.

Within the general framework of the EEPR, the CCS programme makes a significant contribution to the general objective of European energy policy to deliver secure, competitive and sustainable energy supplies.

Investing in CCS technologies at such an early stage of their development offers the EU the opportunity to be a global leader in CCS commercialization. CCS also offers the potential to help considerably in meeting our sustainable energy targets for 2020 and beyond.

CCS projects supported by the EEPR aim to:

- Help demonstrate the entire CCS-value chain technology by 2015;
- Contribute to lowering the manufacturing and operational costs in the second generation technology;
- Accelerate the development and implementation of regulatory and permitting schemes.

OXYCFB300 Compostilla Project EEPR Beneficiarles

ENDESA, part of the Italian group Enel, is the leading Spanish electric utility and the largest private electricity multinational in Latin America holding a strong position in other energy sectors such as coal mining, gas, cogeneration and renewable energies. ENDESA Generacion has a long tradition in producing electricity from coal, and has been working very actively on Clean Coal Technologies (CCT) and CO_2 Capture and Storage (CCS) over the last six years.

CIUDEN is a technological development institution created in 2006 by the Spanish Administration. CIUDEN's main objectives are the research, development and demonstration of efficient, cost effective and reliable advanced CCT and CCS technologies. CIUDEN aims to support and promote international cooperation so as to enhance European competitiveness through strategic research partnerships with industry, SMEs, Universities and research institutions.

Foster Wheeler Energia Oy (FWEOy) is a Finland based operating company of Foster Wheeler AG (FWAG) well known at international level for its energy production systems based on the Circulating Fluidised Bed technology (CFB).

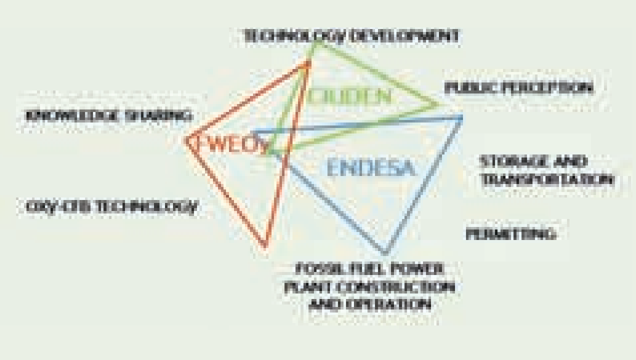

Figure 2. 2 Role of partners

2.2 OXYCFB300 SCHEDULE

Initially, the OXYCFB300 Compostilla project EEPR Action had an estimated duration of 42 months (mid 2009-2013), but in November 2012 EC extended the duration until October 2013 due to the delays caused in TDP tests and in storage programmed activities.

To reduce the risks associated with any new technology, the strategy of the Beneficiaries has been to complete under the EEPR Action, the Phase I-Technology Development. This period allows filling the knowledge gaps in the three technical areas and consolidating a more reliable integrated concept.

The strategy followed is schemed in the picture below:

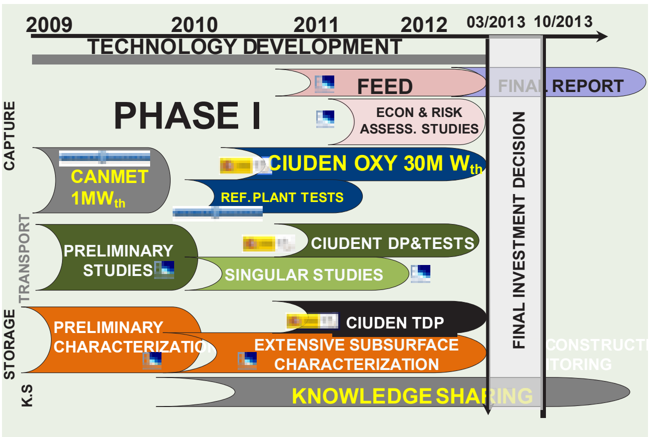

Figure 2. 3 Action strategy

The activities in the Action Work Plan by area have been:

Capture

- Characterization of the design fuels and limestone in air and oxy-fuel conditions in a lab-scale plant of around 1MWt at CANMET in Canada.
- Construction of a Technological Development Plant (TDP) in the CIUDEN facilities and perform validation tests at CIUDEN oxy-circulating fluidized bed boiler 1:30 scale.
- Develop a test program in the air reference plant (Lagisza CFB).
- Development of operating modes and control strategies of the fully integrated Technology Development Plant.
- Develop models for optimising the final design for oxy-combustion.
- Economic and Risk Assessment studies.
- Development of a Front-End Engineering Design (FEED) for the demo plant.

Some of these activities are partially covered and funded by the FP7 project "FLEXI-BURN CFB".

Transport

- Preliminary studies.
- Singular studies that will cover research gaps regarding CO_2 transportation for OXY-CFB-300 composition and operating conditions.
- Construction of a Technological Development Plant (TDP) in the CIUDEN facilities and perform tests in CIUDEN pilot plant, with improvement of the knowledge of CO_2 transport performance based on long-term experimental tests with real CO_2 streams produced by the TDP.
- Economic and Risk Assessment studies.
- Development of a Front-End Engineering Design (FEED) for the demo plant.

Storage

The storage area includes the complete characterization of the site and evaluation as a feasible CO_2 storage site. Tasks include the following items:

- Sites Assessment, including the development of a homogeneous three-dimensional static geological earth model based on the data collected in previous steps.
- Preliminary Characterization of the subsurface structures, through a magnetoteluric campaign, 2D seismic survey, well and drilling, and logging campaign. Update and upgrade geological models.
- Extensive subsurface characterization, through new drilling of wells, logging campaign and 3-D seismic survey that will provide the necessary information to feed a three-dimensional model and finish the characterization of the site.
- Economic and Risk Assessment studies.
- Monitoring and risk management. Definition and assessment of risks for defining monitoring program.
- Identification and characterization of a Pilot Plant for long-term storage of CO_2.
- Development of algorithms that allow the simulation of the processes that will take place within the reservoir and in the seal during the storage process.

In parallel, two very important interrelated activities were begun:

- Permitting process: To avoid delays in the construction phase, different permitting processes must proceed according to the general schedule presented in point 1.2.3. (Fig. 1).
- Public acceptance and communication planning. To guarantee the success of the proposal, communication planning was launched from the very first stages of the Action.

By March and economical boundary conditions of the project. By By March 2013 the Final Investment Decision (FID) process of the integrated project was started, based on all the knowledge and results obtained in the Phase I-Technology Development and the final permitting, financial and economical boundary conditions of the project. By that date the three areas, capture, transport and storage, had converged with positive results. Additionally all the CCS regulatory boundaries must be established and confirmed by the relevant regulatory bodies. The FID will be completed by the end of the Action (foreseen October 2013).

If the FID is positive, the Phase II of the Project will be executed. The duration of the construction of all infrastructures of the Project (Phase II) is estimated in 56 months.

2.3 PROJECT ORGANIZATION

2.3.1 Action Detailed

The Project is organized in seven work packages (WP):

- WP0: "Coordination and management".
- WP1: "CO_2 Capture".
- WP2: "CO_2 Transport".
- WP3: "CO_2 Storage".
- WP4: "Permitting".
- WP5: "Public perception".
- WP6: "Knowledge sharing".

2.3.2 Action Implementation

Management structure and procedures

The regulation of the management of the Action, financial arrangements and partners' rights and obligations are the contents of the agreements completed and to be completed among the Beneficiaries.

The management framework is shown below:

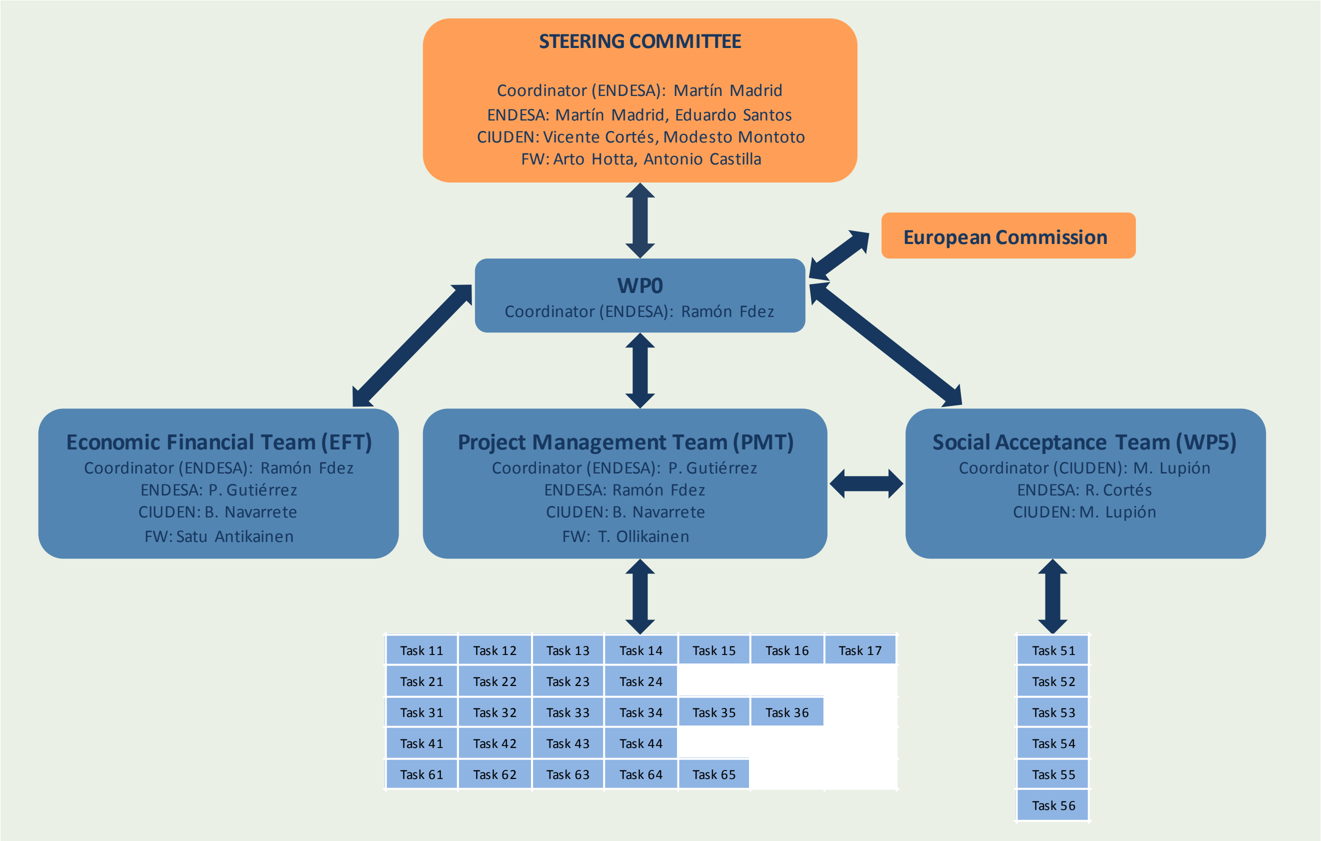

Figure 2.4 Management structure (as agreed between the Partners at the beginning of the Action)

The Steering Committee is responsible for the Beneficiaries strategy and leadership. The Steering Committee is formed by representatives of the three Beneficiaries. The coordination is responsibility of ENDESA.

The Coordinator is responsible for maintaining an overview of the Action and supervisory role in order to guarantee the conformation between the contract, technical contributions and final results. The Coordinator manages the implementation of the Action according to the directions and decisions delivered by the Steering Committee. The Coordinator consolidates the Action planning, progress reports, and budgetary overviews, as well as, coordinates the communication among workpackages. Two supporting teams help to the Coordinator in these activities: a planning and management team, and an economical and financial team. The Coordinator also assures the relations and contacts with the European Commission.

Monitoring and verification procedures

In order to manage the Action and ensure the final objectives and the adequate quality of the work, continuous monitoring has been carried out. Periodically, Steering Committee official meetings have been held all along the action to manage the Project. Other Project teams, including the Project Management Team and the Economical and Financial Team met frequently for coordinating the action. Specific purposed technical meetings between the partners were also held in the close-up range.

The Beneficiaries produced different reports throughout Action's life. These reports were used by the Steering Committee to take decisions about the Action and supply recommendations to WP leaders.

Activity technical reports have been generated every six months and reported to the European Community. Management and financial reports were generated every twelve months and also reported to the European Community, including the explanation of the use of the resources, the financial statements with the costs incurred by the three partners and a summary financial report and audited costs certificates.

The Compostilla Project
OXYCFB300

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3

FEED Project Management

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3.1 FEED ORGANIZATION

3.1.1 Technology Development Stage: FEED Objectives

Before the widespread deployment of a technology on a commercial scale, it must be subjected to different stages of escalation. Thus, it is checked and validated the process from a lower level to a higher level of development, evaluating in this escalation the potential deployment at higher levels. When results meet the expected requirements, they will be used to implement design improvements in the next stage, reducing the technical risk and economic investment, being otherwise the next inversion stage abandoned.

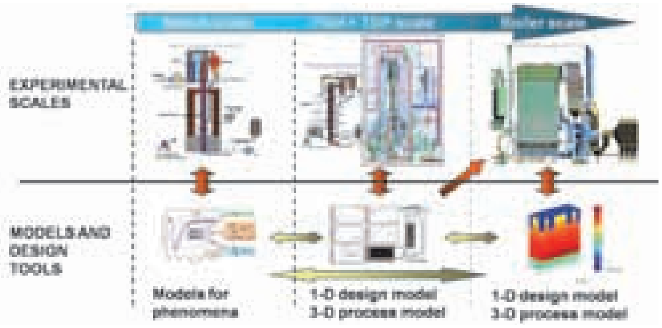

Figure 3.1 Technological development phases.

Thus, the scaling stages of the OXYCFB300 Project are:

- Laboratory scale: where it is studied: the combustion, flue gas composition, ash and slag produced, with different ranges of coals, oxidants and limestone.
- Pilot Scale: Simulates at small-scale one electricity production plant, with the main equipment that would be implemented in the demo powerplant. This plant allows a detailed analysis of the different ways of operation and yields obtained.
- Construction commercial demonstration plant, where electricity is generated for sale to commercial size. The trial period will be longer than a mature technology, but it will be made compatible in its final stages with the starting of the commercial operation of the Plant.

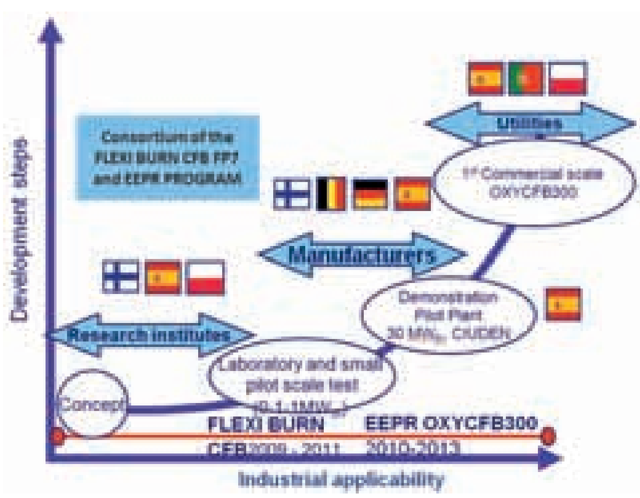

Figure 3.2 Road Map for OXYCFB300 Project.

To minimize the risks of the project it has been divided into two stages: the first one for the technology development and a second stage for the construction of the CCS commercial demonstration plant.

The CFB technology has been commercially demonstrated for conventional air firing but additional efforts to ensure the technological applicability to oxyfiring were required. For this purpose and within the framework of a powerful collaboration between the three partners of the project, an integrated Technological Development Plant (TDP) was constructed by CIUDEN during the EEPR program. This plant incorporates as the core unit a CFB boiler with the same technology of the future commercial demo plant, and at the same location where the OXY-CFB-300 capture plant is planned to be built.

Before the Decision Making (FID) about the construction of commercial demonstration project (Phase II), it was necessary to complete in this technological development phase (Stage I), all studies and works carried out in the three areas of capture, transport and storage, as well as all the necessary permits for the construction of the demonstration plant.

The description of the work committed to the EC under the program EEPR for Phase I of the Project Compostilla OXYCFB300 is defined in the document DOW Grant Agreement with the CE, Description of Works) and have been divided into different tasks and Deliverables.

The aims of the FEED work have been:

- Analysis of state-of-the-art in CCS technologies, in the three areas: capture (oxyfuel technology in CFB boiler, air separation equipment and CO_2 purification and compression), transport (singular transport studies of anthropogenic CO_2) and injection and storage of CO_2. Comparison of the available options in the market, mature enough to enable its commercial deployment with the required reliability. Study of the pros and cons, comparisons of performance, fuel consumption and costs, to define the best technical and economical solution to be developed in the FEED.
- Performing of feasibility studies and analysis of the available design options. Development of conceptual and basic engineering through a work of successive approximations and iterations and considering all the constraints of the project.
- Overall analysis of the project issues; identification of the main needs, environmental constraints and legal requirements; identification of dependencies and integration of the three areas (capture-transport-storage).
- Once technologies and major equipment have been selected, based on them and for each area separately (capture, transport and storage), the corresponding FEEDs have been developed detailed enough to obtain an economic estimate with a deviation of 10%. During the FEED design the following works have been made: mass and energy balances of the plant, water balances, flow diagrams and PI & Ds, description of major systems, study and optimization of layouts, load analysis and taking civil measurements,

single-wire schemes, study of the control architecture definition and design of the pipeline layout from the CO_2 emission and capture point to final storage, valve arrangement, injection engineering development and monitoring of wells for CO_2 final storage.

- The development of the engineering has enabled the development of the documentation for permit applications and analysis of operational risks using HAZID (Hazard Identification), HAZOP (Hazard and Operational Risks) and QRA (Quantitative Risk Analysis).
- Preparation of technical specifications to obtain quotations and carrying out the OXYCFB300 commercial demonstration plant budget with a deviation of 10%.
- These quotations have been used, in addition to obtaining the commercial quotation and budget preparation, to gather additional technical information that would allow to progress in the developed FEED detail engineering. In case that FID is positive, the implementation phase of the commercial demonstration plant (Phase II) will be commenced.

3.1.2 Development Organization FEED

FEED engineering has been developed by ENDESA in collaboration with its partners in the project, based on their knowledge as power generation company and feasibility studies prior EEPR that were conducted with FOSTER WHEELER for Compostilla Project OXY-CFB300.

During 2010-2013 ENDESA carried out Tasks related with FEED (Front-End Engineering Design) studies, involving suppliers and manufacturers during the design stage, in order to evaluate the technical, commercial and economical feasibility of the plant.

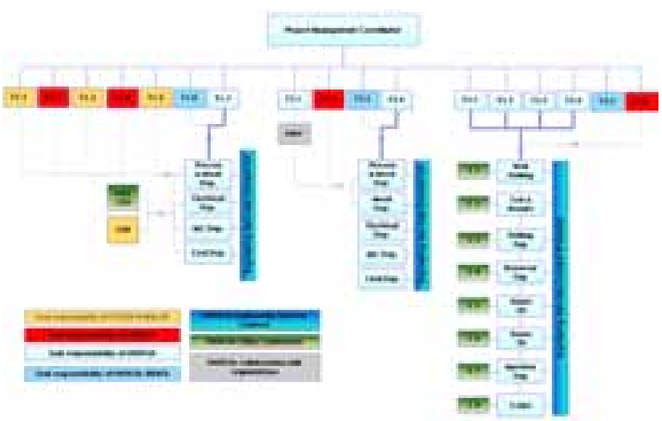

Figure 3.3 Task distribution.

Capture

TECNICAS REUNIDAS has provided support to ENDESA in the preparation of FEED engineering services for the 340 MW capture power plant. The design of the capture plant is conditioned by the requirements of the CFB boiler. Starting from the CFB boiler conceptual and basic engineering provided by FOSTER WHEELER and continuing with the CFB boiler FEED design developed in detail by FOSTER WHEELER, TÉCNICAS REUNIDAS together with ENDESA have developed thermal cycle engineering and integration with other equipment and capture plant components.

ASU and CPU are not usually present in conventional thermal power plants, and had to be developed as “first of a kind” on this scale for OXYCFB300 plant, especially the CPU. Being very specific technologies in commercial development phase, it was necessary for major advance and detail of FEED work, hiring FEED engineering to appropriate technologists to develop CPU and ASU.

The activities related to the technological development of the boiler, ASU and CPU have been developed and partially financed by the European Framework Programme FP7 (FLEXI BURN), coordinated by VTT and ENDESA, FOSTER WHEELER and CIUDEN as major partners.

In a first stage, the necessary inputs for the design of plants have been provided to technologists, so by these means a first conceptual design has been obtained. The first conceptual design gave a way to the next stage of integration and optimization with the rest of the plant and FEED design of all systems and equipment. Comprenhensive Requests For Quotation were released.

Thus, through successive approximations and iterations in consumption, performance, layout optimizations and improvements it has been achieved conceptual design of the plant composition and economic estimation with a deviation of less than 10%.

Transport

WORLEY PARSONS has supported ENDESA in transport FEED engineering, reviewing and updating singular studies made during this stage of technological development in collaboration with DNV: studies of materials and purity of CO_2, hydraulic studies, dynamic and CO_2 pipeline definite layout (HEYMO engineering). Risk monitoring and safety studies have also been developed (CO_2 leaks dispersion model).

Storage

WORLEY PARSONS has supported the team of experts and ENDESA`s Task Managers in carrying out the activities of Engineering, Front-End mode, Reservoir, Drilling, Injection engineering and Surface Facilities, in coordination with other project activities , for proper evaluation of the Zones described as sites under Geological Storage of Carbon Dioxide Bill. WP has been responsible for defining, specifying, selecting, planning, evaluating costs, timely delivery support, form and quality of the projects, contracts, services and campaigns associated with the Reservoir Engineering by third parties as SCHLUMBERGUER, WEATHERFORD, GEOSTOCK GESSAL, Halliburton and others in monitoring activities baseline surveys, 2D and 3D seismic, update static and dynamic models, magneto telluric campaigns and other tasks necessary for comprehensive evaluation of CO_2 storage for the Project.

Figure 3.4 Capture, transport and storage.

Figure 3.5 Results and input data to the final decision making (conceptual).

3.1.3 FEED Project Management

During the development phase of the technology several activities had to be performed in parallel to the FEED design, as some inputs or requirements provided the necessary results to develop new tasks needed for defining this phase and achieving the targets set in EEPR.

Tasks such as regular consultation meetings throughout the project with different administrations, development of documentation for obtaining permits, preparing information for public perception activities and dissemination of knowledge, implementation and support internal and external audits, various commercial work and organization of requests for proposals, establishment of partnership agreements and confidentiality agreements with technologists and definition activities to define legislative, regulatory and operational framework of Business Development Plant have required the participation of experts and coordinators of the various tasks that form the FEED.

Within the works developed in parallel to FEED engineering design is the Integral Risk Assessment for Compostilla Project OXYCFB300 supporting Final Investment Decision of Phase 2 of the project (construction plant CCS capture, transport and storage deep geologic CO_2 generated by a 340 MW oxyfuel plant).

Risk assessment as described in the description of works document (DOW), is an evaluation "complete and detailed" of risks "technological, financial, economic, regulatory, permitting, and social acceptance in relation to the investment decision to make ", so it is considered the ultimate result of the FEED work.

Endesa contracted DELOITTE consultant in October 2011 to develop specialized services to support the Integral Risk Assessment of Compostilla Project OXYCFB300, including market risk, business and regulatory risks, operational and integration risks (environmental, safety and health, quality and deadline).

These Works have taken as input technical risk studies (HAZID, HAZOP, QRA) developed by FEED engineering, as well as financial information that would enable ENDESA to develop the project.

Regarding social acceptance and public perception inputs, the project has carried out 4 major public engagement studies.

- Social perception of qualitative study in Hontomín (July, 2011)
- Compostilla project public perception study (February, 2012)
- CO_2 Storage Technologies Social acceptance in Sahagún (June, 2012)
- Psychosocial study (June, 2012)

Since the completion of the above mention studies, the project had continued participating in in local fairs and new informative meetings with town-halls. A specific section on the website dedicated to Sahagún social acceptance campaign is still active at the project website **www.compostillaproject.eu**

3.1.4 FEED Programme

Tasks Identification and General Description

After signature of the Grant Agreement with the European Commission in May 2010 and finishing all the Project Structure and Work Breakdown Structure in coordination with the Partners, in June 2010 Endesa proceeded to organize and develop FEED activities for the 3 main Workpackages comprised in the Description of Work.

Front-End Engineering Design plans were arranged for Workpackage 1 CO_2 Capture Task 1.7 "FEED", Workpackage 2 CO_2 Transport Task 2.4 "Engineering Bidding Process", and Workpackage 3 CO_2 Storage Task 3.3 "Extensive Subsurface Characterization". Therefore, the date of June 2010 is internally considered as the Starting Point (SP) milestone for the FEED implementation at capture, transport and storage areas of the Oxycfb300 Compostilla project. Since then, FEED activities took along over the years 2010, 2011, 2012 and roughly half 2013. Once finished FEED activities of all Workpackages, the Close Out milestone has been reached by the date.

Accordingly, as depicted above, the FEED schedule has been run in between the following dates:

- FEED Starting Point (SP): June 2010
- FEED Close Out (CO): June 2013 (partial close outs: for capture November 2012, for transport January 2013 and for Storage June 2013)
- FEED Performed Period: 36 months.

Baseline FEED schedules were defined and settled in June 2010, with the aim of accomplishing all the milestones in time for FID process start in June 2012. Several setbacks delayed gradually the Close Out milestone and thus the FID process start (for further detail see Critical Path). Performed actual FEED Programme (with real delays) is presented in this section.

Capture FEED Tasks

Capture FEED schedule was initially divided in two main blocks: CFB boiler FEED (primarly driven by FWEOy) and integration engineering FEED (primarly driven by Endesa). Both schedules had several links that were managed in common between Partners. In addition to this, CFB boiler FEED had vast connections with the test plan at Lagizsa plant, Canmet center and CIUDEN's capture TDP[1] facilities. Therefore, many activities performed in testing campaigns at the various facilities created a cascade of dependencies, in first degree by CFB boiler FEED and in second degree by the integration engineering FEED. In other words, any delay of the test plan had potential for relevant impacts on capture FEED schedule, especially if the CFB boiler design would have had suffered of major modifications due to tests results, which has not ocurred.

CFB boiler FEED activities started in June 2010 with the plant concept verification, standards and rules verification, and information for boiler design basis completion. Preliminary boiler design was completed by 1st quarter of 2011. After Canmet tests completion in late 2010 and definitive results, the boiler water – steam circuitry was partially updated in July 2011, in seek for higher efficiency and operational failures improvement. Also in July 2011, a preliminary version of the boiler PDMS 3D[2] model was issued. In February 2012, based on material studies, the re-heaters materials were upgraded. During 2011 and 2012, boiler island engineering was done to the extent deemed necessary for achieving the targets of the FEED, including layout and piping engineering, performance engineering, systems engineering, strength engineering, electrical & control engineering, construction engineering, commissioning engineering, technical specifications, materials lists, civil and HVAC engineering. Also a dynamic model of the boiler was developed, operational requirements were discussed and safety studies were handled (HAZOP/HAZID studies). In spite of all these works, finalizing of the CFB boiler FEED and boiler design verification was subject to completion of CIUDEN TDP oxycombustion tests and analysis of results, in early 2013.

Regarding integration engineering FEED, after planning and purchasing services, and once requirements were defined from first boiler design steps, kick-off was held in October 2010. Integration engineering works were divided in two stages: preFEED and FEED. PreFEED took from October 2010 to May 2011, finalizing with the preliminary technical specifications of the main packages (ASU, CPU, boiler island and turbine island). PreFEED stage focused on heat & mass balances iteration process, aiming to integrate boiler balances with turbine balances in order to define accurately the steam-water cycle. Basic engineering documents (inc. preliminary layouts, landscape & architectural studies, preliminary environmental studies, topography and geotechnical studies, preliminary lists of loads and equipment or preliminary battery limts) were developed also during the PreFEED.

Once PreFEED finished, in May 2011 a budgetary RFQ[3] to ASU, CPU, Power Island and Cooling Tower technologists was initiated, with the aim to obtain enough information to develop ASU & CPU integration (Task 1.3 "ASU & CPU technology development"). After several clarification meetings between Endesa, FWEOy and ASU/CPU technologists, by September 2011 it turned out that all the information available was insufficient. Then a new RFQ was started, but with the aim to purchase ASU & CPU engineering services from technologists. By January 2012, ASU FEED and CPU FEED were kicked-off. Both FEEDs boosted up ASU & CPU integration activities, thus allowing during early 2012 to develop new heat & mass balances for the whole plant and auxiliary systems (in both MCR[4] and partial loads, and in air and oxy modes). The new heat & mass balances comprised the updated boiler FEED design, turbine island balances from suppliers and tailor-made balances from the ASU & CPU FEED. Also during the ASU & CPU FEED, detail engineering, PDMS 3D models, safety studies, dynamic models, final specifications and investment estimates for ASU & CPU were developed.

1 Technological Development Plant

2 Plant Design Management System three dimensional model

3 Request For Quotation

4 Maximus Continuous Rating

During the 2nd half of 2011 and 1st half of 2012 detailed engineering of the integration FEED continued to all its extent, covering all the systems and areas of the future demo plant:

- Regarding process engineering, performance was updated and P&ID[5] diagrams and functional descriptions were issued for all systems. Water balances and auxiliary services balances were completed.
- Regarding mechanical engineering, general arrangements were developed for all indoor and outdoor areas and floors, and piping isometrics were developed for 8 inches or bigger pipes. BOP[6] equipment, pumps, fire fighting system, heat and ventilation systems, auxiliary fuel system, cooling tower internals, solids handling, ducts, pipes, package plants and other equipment were calculated and defined.
- Layout of capture plant was completed. Architectural, civil and structural drawings of all buildings were done, and all main foundations were calculated. Cooling tower calculations were completed. Outdoor areas were defined and final landscape and architectural study was issued.
- All the electrical single-wire diagrams were done for high voltage, medium voltage, duty current systems, safety voltage systems and uninterruptible power supply system; and typicals were developed for medium voltage. Grid calculations were developed for accurate definition of generator and main electrical equipment parameters.
- Lightning, conduits and trays, transformers and cables (high, medium and low voltage), control cables, motors, motor control centers, cabinets, gas insulated substation and other electrical equipment were calculated and defined.
- Control equipment, control architecture, control philosophy, instrumentation, valves, signals list and distributed control system requirements were defined.
- Bill of materials and bill of quantities were issued for all systems and areas.
- Health and safety studies were developed, including ATEX (explosive atmospheres), and HAZOP/HAZID studies for the whole capture plant.
- Environmental impact study was completed as well as complementary studies (emissions study, noise study, waste production study and others).

Technical and procurement specifications for the 18 procurement packages defined were issued; including civil works, site preparation works, mechanical erection, electrical and control erection, detailed engineering, supervision and commissioning for the construction phase.

Once detail engineering completed, in June 2012 binding RFQ were launched. Evaluation of all bids was completed by September 2012, allowing by this means an accurate estimate of the capture demo plant investment, accounting market status to the date.

During the last few months of FEED study, dynamic model was also fully completed for the whole capture plant.

As a result of all the FEED studies, roughly 2.500 documents were issued and updated to the last version. This number indicates the size and extent of the FEED studies performed.

Transport FEED Tasks

Transport FEED studies were constrained by the development of transport singular studies, namely PreFEED activities in the transport FEED Programme.

Singular studies were developed during 2010 and 2011. Once defined the first preliminary traces and hydraulic studies, which was done in late 2010, all the singular studies were run in parallel, although some overlap between them was necessary for developing transportation concepts. The preliminary studies were also a significant deadline for the first environmental study (initial document), that was accomplished on time for the permitting process in March 2011. Research made on materials and impurities, which required laboratory testing, increased the initial period estimated for all the singular studies but in time for the extended deadline due to delays on CIUDEN's transport TDP construction and testing, on the critical path. In parallel, dispersions models were adapted to the changes motivated by other studies. The only singular studies that continued during 2012 and beyond were the DNV's initiative Pipetrans phase 2, in which Endesa participates only as an associate, but this activity was not critical at all and has only contributed to the project with the first preliminary conclusions.

Once singular studies finalized in late 2011, FEED studies were commenced in November 2011, including both CO_2 pipeline and surface facilities at the location of injection. Basic design was updated as well as all the static and dynamic calculations. By November 2012, all the transport FEED was concluded, with all the detail engineering and the following main activities performed:

- All the process engineering
- All the main systems engineering
- All the auxiliary systems engineering
- Constructive project, including constructive method, materials, detailed layout drawings, list of affected land-owners and properties by the pipeline trace, crossings detailed drawings (rivers, roads, others)
- Location and detail engineering of switchgear valves
- Bill of quantities, bill of material and lists of all equipment, valves
- Monitoring, overpressure, crack arrestor, leak detection, corrosion protection, fire fighting and trap scrappers systems
- Environmental impact study including complementary studies (dispersion and leakage models)

[5] Piping and Instrumentation Diagram

[6] Balance of Plant

- Health and safety studies (including what-if, HAZOP and HAZID studies)
- Power supply, electrical systems, lightening, instrumentation, and controlling
- Technical and procurement specifications for the 3 main procurement packages defined were issued; and RFQ for investment estimate released and concluded.

Although transport FEED was concluded in November 2011, deliverable submit to the European Commission EEPR Programme (D2.1 "know how on design criteria, materials selection and safety issues for captured CO_2 transport by pipeline") was delayed to include CIUDEN's transport TDP conclusions and finally delivered in January 2012.

Storage FEED Tasks

Storage FEED tasks were highly constrained by Preliminary and Extensive Subsurface Characterization studies (Tasks 3.2 and 3.3 on DOW).

During 2010, activities were focused mainly on completing and reviewing previous works (2D seismic surveys, magnetoteluric surveys, hydro geological studies, existing wells and surveys reinterpretation, first geological models and soforth). At the end of 2010, all storage characterization plan was set and the screening and appraisal strategy was audited and verified independently by specialized services provided by Schlumberger Carbon Services.

During 2011, preliminary and extensive subsurface characterization campaigns were deployed, with the aim of completing the lack of data, parameters and information needed for completing the geological models:

Duero 3D seismic survey was released in June 2011. Due to social opposition at site, the campaing finalization was delayed from December 2011 to June 2012.

In late 2011, after the required engineering, permitting and procurement, drilling campaing of characterization wells at Duero site was released. 4 wells were drilled (3 with oil industry technology and a complementary one with mining technology). Little overlaps between wells were possible during this campaign due to the availability within budget of only one oil drilling rig with the required capacity to reach 2,000+ meters depths. Once each well drilled, site tests (injection, capacity, permeability, pressure), laboratory tests on core samples and data processing were performed. This massive campaign took one year long until late 2012.

As a result of what explained above, and considering that both all wells and 3D seismic were needed for completing the geological static and dynamic models, only in late 2012 the static and dynamic models were completely updated. Later on during 1st semester of 2013, all the information gathered has allowed to finalize the reservoir engineering, the injection and monitoring engineering, the risk analysis, all the specifications for the construction phase and the FEED engineering for the storage reservoir.

Critical Path

Critical paths are diverse and certainly not just a single one in such a complex programme. All the EEPR technological development activities performed during 2010, 2011, 2012 and early 2013 converged on a single clear and rigid-fixed milestone, the Final Investment Decision (FID) process start, scheduled for 1st April 2013 (accomplished). Close Out (CO) internal milestone for all the FEED activities is scheduled for June 2013 (accomplished). Between the Close Out (CO) and the Starting Point (SP) of all FEED activities, the main critical paths identified during management of the project and FEED Programme were the following:

- Regarding Work Package 1 CO_2 capture FEED studies, critical path went through the oxycfb combustion technology demonstration and validation. CFB boiler design and integration engineering during FEED were run in parallel, and directly connected to tests plan results (Canmet, Lagisza and CIUDEN's capture TDP), especially during the boiler design validation in early 2013.
- Regarding Work Package 2 CO_2 transport FEED studies, critical path went through the development of singular studies during 2011, in order to allow completing all the FEED studies during 2012. Nevertheless, CIUDEN's transport TDP construction and tests plan delays finally had impact on the critical path during late 2012, delaying final conclusions on transport know-how until January 2013.
- Regarding storage reservoir, critical path went through the site assessment and storage geological characterization activities, and later on through the reservoir assessment and FEED engineering. Delays on field campaigns (3D seismic survey due to social opposition and characterization wells drilling) had relevant impact on the delays of the project.

The most significant mitigation measures taken for avoiding or mitigating delays on the critical path were the following:

WP [7]	DELAYS MITIGATION	PARTICIPANTE	PURPOSE
WP1 capt. FEED	Contract ASU & CPU dedicated FEEDs by technologists	Lack of information during Apr-Sep 2011 for thermal cycle integration of ASU and CPU	ASU & CPU FEEDs performed during 1st semester 2012 in time for all the capture FEED studies
WP1 capt. FEED	Decoupling of boiler and capture FEED from tests plan results	Delays on tests plan due to delays on capture TDP construction and commissioning	Boiler FEED and capture FEED studies developed in parallel without significant modifications after results, avoiding greater chain delays
WP2 trans. FEED	Speed-up preliminary alternative traces (From Mar-13 to Apr-12)	Faster development of permitting process	Administrative delays in permitting cancelled the expected positive effect (see next item)
WP2 trans. FEED	Early deliver of initial document for starting permitting process earlier than scheduled (Jun-11 vs Oct-11)	Obtain objections to the project in an early stage of design	Administrative delay of the Environmental Board surpassed float (8 months vs. 3 months max. legal period)
WP2 trans. FEED	Decoupling of transport FEED from tests plan results	Delays on tests plan due to delays on transport TDP construction and commissioning	Transport FEED studies developed in parallel without significant modifications after results, avoiding greater chain delays
WP3 stor. FEED	Contract specialized audit services to validate characterization plan and screening and appraisal strategy	Doubts on fit for purpose characterization plan	Avoid delays due to wrong planning and strategy
WP3 stor. FEED	Communication plan roll-out in the Duero-Sahagún site area	Avoid 3D seismic campaign paralization (Jul11)	3D adquisition campaign restarted in Nov-11 after public engangement sessions and agreements signatures completion with land owners
WP3 stor. FEED	Speed up plan for Duero site characterization wells	Delays on drilling campaign	Higher delays avoided. Prioritization of results needed for modeling
WP3 stor. FEED	Abandon Monegrillo-Ebro site campaign after first negative 'no-go' results	Quick evaluation of the impact of first negative results on Monegrillo-Ebro site appraisal	Focus resources on Duero campaign for higher speed up and delays recover
WP3 stor. FEED	Progressive update of geomodels from field data	Right integration of schedules and essays heuristics (drilling, site tests, laboratory tests, data processing and modeling contracts)	Avoid greater chain delays
WP3 stor. FEED	Develop generic FEED specifications	Lack of information for each injection and monitoring well	Development of generic injection and monitoring wells specifications for CAPEX/OPEX preliminary estimation in Nov-12 (input required for risk analysis) prior to FEED finalizing
Annual Review Meeting	29th September 2011	ENDESA, CIUDEN, FWEOy	Review of the 2nd Interim Report with the EC
Technical Meeting	29th September 2011	ENDESA, FWEOy, others	Meetings on technical and planning issues of Flexiburn work packages
Technical Meeting	lOth November 2011	ENDESA, FWEOy, others	Dynamic simulation model (APROS tool)
Technical Meeting	16th November 2011	ENDESA, FWEOy	Oxy-CFB boiler design issues, ASU & CPU integration issues, design interactions with auxiliary systems and technical status of the project
Technical Meeting	27th March 2012	ENDESA, FWEOy	Detailed Oxy-CFB boiler engineering and FEED issues
Technical Audit	26th April 2012	ENDESA, CIUDEN, FWEOy	Technical audit of the project by the EC
Technical Meeting	12th June 2012	ENDESA, FWEOy	Boiler FEED finalizing
Technical Meeting	12th June 2012	ENDESA, FWEOy, others	ASU & CPU FEED finalizing

Table 3.1 Delays mitigation measures taken.

[7] Work Package

Next table shows original planned dates (as established on the DOW) and actual achieved dates for the deliverables that were connected to FEED Programme activities placed on the critical path of the project. Delays on these dates show evolution of the FEED schedule:

DELIVERABLE	ORIGINAL DATE	ACTUAL DATE ARCHIEVED
D1.1 CANMET tests characterization	sep-10	nov-10
D1.2 TDP completed and ready to carry out the test program	jun-11	dec-11
D1.3 Tests results evaluation. Know-how on oxy-firing in CFB	dec-11	dec-12
D1.4 Operating modes and control strategies of the integrated TDP	may-12	jan-13
D1.5 Final Oxy-CFB integrated Plant Assessment for Demo project construction	may-12	feb-13
D1.6 Capture economic and risk assessment analysis final conclusions	may-12	dec-12
D1.7 FEED	nov-11 & may-12	nov-11 & nov-12
D2.1 Know-How on design criteria, materials selection and safety issues for captured CO2 transport by pipeline	jan-12	dec-12
D2.2 Transport economic and risk assessment final conclusions	may-12	dec-12
D3.1 Homogeneous and heterogeneous static earth model	mar-12	jan-13
D3.2 Dynamic earth model	mar-12	jan-13
D3.3 Storage site availability report	may-12	jun-13
D3.4 Storage economic and risk assessment final conclusions	may-12	jun-13
D4.1 Documents for Demo Plant authorization request	mar-11	apr-11
D4.2 Documents for Demo Plant local permitting request	mar-12	sep-12
D4.3 Document for pipeline authorization request	nov-12	dec-12
D4.4 Documents for storage authorization request	nov-12	not yet archieved
D6.5 FEED final conclusions	dec-12	sep-13
M1.5 Final Investment Decision (FID) process start	may-12	apr-13

Table 3.2 Original planned dates and actual dates.

Floating Tasks

Next table shows details on task identified as floating (with possibility of delay without delaying critical path of the project) during the analysis of the FEED Programme and final results:

WP [8]	FLOATING TASK	APPROACH	RESULT
WP1 capt. FEED	Limestone tests at Canmet 1MWt	Extend limestone testing	Limestone tests extended to include different samples from a variety of sources near the site. Results improved without delays on critical path
WP1 capt. FEED	Lagisza plant 460MWe tests	Delayed due to operational troubles at PKE plant	No impact on critical path
WP1 capt. FEED	HV grid permitting activities	Not speeded up	No impact on critical path
WP1 capt. FEED	Dissemination activities at FP7 programme	Partially delayed	No impact on critical path
WP2 trans. FEED	DNV pipetrans phase II initiative	Delayed by coordinator DNV	No impact on critical path
WP2 trans. FEED	CIUDEN's TDP transport tests	Delays due to failures between commissioning	Float was surpassed and delayed critical path on transport FEED by 1 month
WP3 stor. FEED	Baseline reports	Extended campaign for better characterization	No impact on critical path

Table 3.3 Floating tasks.

[8] Work Package

The Compostilla Project

OXYCFB300

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4

FEED Design

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4.1 BACKGROUND

In 2007 Foster Wheeler and ENDESA Generación reached an agreement for the development of Oxy-fuel combustion technology in circulating fluidized beds, in which it was agreed to develop a feasibility study that would become the basis for the development of the CO_2 Capture and Storage demo plant concept, (CCS) OXYCFB300.

The feasibility study performed in 2008 was for a fictitious greenfield power plant of 500 MWe (gross) situated in Spain. Later on, this feasibility study was updated for 300 MWe (gross) size. Initially, specifications were provided for two different sites (Compostilla and Teruel Power Stations). It was later decided to use the Compostilla specifications, while performance estimates with other fuels and at alternate conditions may be carried out in subsequent studies.

Supercritical parameters were selected after considering that the steam cycle efficiency should be as high as possible owing to the energy spent on oxygen production and CO_2 capture. The involvement of industrial gas technologists was required for both realistic cost estimates and supporting technical data for the cryogenic Air Separation Unit (ASU) and CO_2 Compression & Purification Unit, (CPU).

Since the feasibility study, the concept evolved so that instead of studying air-fired CFB and oxy-fuel CFB separately, it was decided to study a dual firing concept. This means that the Flexi-Burn® CFB boiler (and plant in general) will be able to operate in air firing mode as well as in oxy-combustion mode without making modifications to it. It was assumed that oxy-fuel combustion with CCS would be the primary operation mode, while air firing would be needed for start-up and as back-up e.g. in case of the unavailability of CO_2 transport and storage facilities.

For storage development, ENDESA Generación has been working at preselected safe CO_2 storage sites in Spain from December 2005 to 2008. In this way, a screening and ranking framework (SRF) has been developed to evaluate potential geological carbon dioxide storage sites on the basis of capacity, health, safety, and environmental (HSE) risks arising from CO_2 leakage. Therefore, several technical and social-economic criteria were defined. Six different potential sites have been evaluated. Based on the results developed under previous projects, two possible saline aquifers were selected to store CO_2 from the OXY-CFB-300 plant, "Duero Site" and "Ebro Site".

Consequently, after the pre-selection works had been performed, administrative permits for the exploration of the two selected sites were authorized and the corresponding CO_2 storage exploration permits were granted. Legal administrative resolutions were issued for ENDESA Generación, S.A. from CASTILLA Y LEÓN and ARAGON regional governments in August, 2008. During 2009-2010; a number of tendering processes were organised to perform selection, pre-characterization and characterization tasks based on the previous results achieved.

4.2 FEED DEVELOPMENT

4.2.1 Site Data and Conditions

4.2.1.1 Site Conditions

ENVIRONMENTAL CONDITIONS	
Barometric pressure expected	948 mbar
Temperature	
Average (design teams)	12.6 °C
Absolute maximum (equipment structural design)	45 °C
Absolute minimum (equipment structural design)	-13 °C
Relative humidity (annual average)	66%

Table 4.1 Environmental conditions at the plant site

4.2.1.2 Fuel

Fuel included in the design

The following table shows the characteristics of the fuel mix on which the design and warranty of the boiler is based.

DESIGN MIX–COAL-PETCOKE (70/30% WEIGHT)		DESIGN
General (as received; percentages by weight)		
Carbon	%	61.03
Ash	%	22.73
Total humidity	%	8.19
Sulphur	%	2.57
Hydrogen	%	2.31
Oxygen	%	2.09
Nitrogen	%	1.08
LHV	MJ·kg-1	23,059
Ash Fusibility (in reducing atmosphere)		
Softening temperature	°C	> 1100

Table 4.2 Fuel composition according to plant design

Other fuels

In addition to the fuel included in the design, the boiler is capable of operating by burning only coal (anthracite with high percentage of ash). There is an entire range of coal types and coal blends / with different characteristics and calorific features.

Biomass may be included in the fuel mix: If required, the biomass shall consist only of wood pellets. The average properties shown in the table below are based on the analysis of a wood pellet sample. According to preliminary analyses, the allowable share of wood pellet co-firing with the design fuel blend shall be limited as follows:

- If the blend consists of anthracite and petcoke, the maximum share of wood pellets is 10 % (on LHV basis).
- If the blend consists of anthracite only, the maximum share of wood pellets is 20 % (on LHV basis).

Auxiliary Fuel

The plant uses light gas oil as auxiliary fuel, which will be used as:

- Fuel for the emergency diesel generators (to ensure the safe shutdown of the entire plant).
- Fuel to power the diesel pump of the fire-fighting water system.
- Fuel to feed the diesel fuel pump that sends water to the boiler during emergencies (plant "black-out").
- Fuel for start-ups.

Limestone

Limestone of high reactivity is preferred for sulphur oxide removal.

4.2.2 Process Systems Description

4.2.2.1 Generation and Capture Plant

A simplified process flow scheme of a power plant designed for both air-fired and oxygen-fired operation modes is shown below. It consists of an air separation unit (ASU), a high-efficiency steam cycle utilizing Foster Wheeler Flexi-Burn® CFB boiler technology and a CO_2 processing unit (CPU).

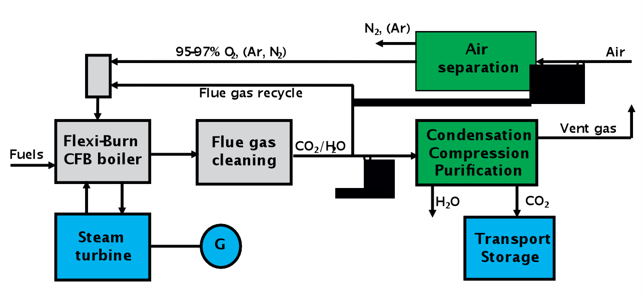


Figure 4.1 Schematic of a Flexi-Burn® CFB power plant

Among all the equipment included in the power plant, the oxy-fired CFB boiler will be the first-of-its-kind ever designed and erected. No large oxy-fired boiler has ever been operated and, within the OXYCFB300 power plant it will be responsible, not only for producing a stable steam flow that guarantees the expected electric power output, but also for producing a stable flue gas flow from which the CO_2 can be captured.

Acknowledging that the CFB boiler is the key component of the plant, the power cycle has been engineered to match its performances. By the following, both the boiler and the power cycle systems (including solid handling systems) are briefly presented.

Boiler Process Description

The OXYCFB300 plant CFB boiler has been designed for stable operation in air combustion and oxy- fuel combustion (O_2 rich combustion) within the specified load range and with smooth transitions between the two modes. However, only the later mode of operation is of interest from a CO_2 capture point of view since the flue gas flow is not rich enough in CO_2 when the boiler operates under standard air combustion. For oxy-fuel combustion, which is then the primary operation mode, low purity oxygen produced in the ASU is mixed with recycled flue gases, creating a N2-lean mixture that is used as oxidant in furnace combustion instead of air. The absence of nitrogen in the oxidant produces a flue gas stream with a high concentration of CO_2, largely easing its separation with equipment of reasonable size.. In the air firing mode, which serves to risk mitigation purposes but may also be applied during high load demand, the ASU and the CPU are out of service (or in stand-by) and the plant is operated like a conventional power plant, leading flue gases to the atmosphere.

The following figure provides a sketch of the boiler concept in a block-diagram manner, the equipment needed for air-operation being represented in light grey.

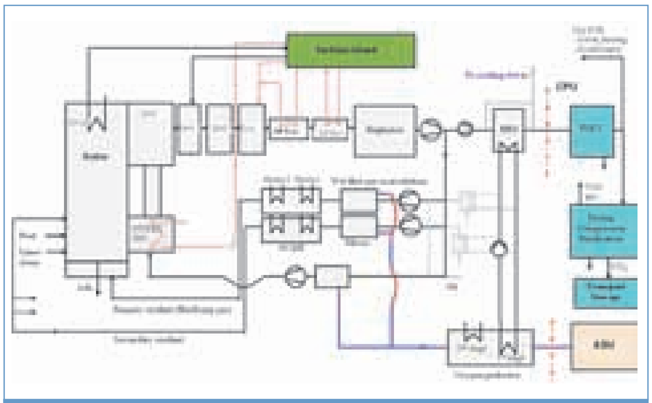


Figure 4.2 Block flow diagram of the current boiler concept (simplified)

The boiler has been conceived so as to maximize its efficiency when operating in oxy-mode. The design intends to recover as much waste heat from the flue gas as possible. To do so, the following specific equipment has been included in the design:

- A high-pressure economizer (HP Eco) is located after the conventional economizer in flue gas path. In the water-steam circuit it is located upstream of the normal economizer, in parallel with HP feedwater heaters. HP Eco is active regardless of operation mode.
- A low-pressure economizer (LP Eco) utilizes remaining flue gas heat and cools the gas to a temperature considered optimal for filtration and flue gas recirculation, approx. 160 °C in oxy mode. LP Eco heats up a mixture of condensate extracted upstream of the deaerator and low pressure feed water from feed water pump extraction. It is active regardless of the operation mode.
- A heat recovery system (HRS) consisting of a plastic tubular heat exchanger with water as the heat transfer medium and water-oxygen/water-air heat exchangers is used to transfer residual heat from the flue gas flow going to the CPU (in OXY-mode) to the incoming fesh oxidant stream (O_2 in oxy-mode and atmospheric air in air-mode). The HRS treats the whole exiting flue gas stream in oxy mode but only part of it in air mode. This is to save investment cost: a full size HRS would increase efficiency in air mode but not change it in oxy mode, which is defined as the main operation mode of the boiler.

In oxycombustion operation, downstream of the baghouse (upstream of the HRS) the flue gas flow is split and most of the flow is mixed with the incoming flow of low purity O_2 coming from the ASU and preheated against power cycle water in a dedicated exchanger. Two (2) oxidant streams are fed to the furnace: the primary and secondary oxidants. Both streams are heated against power cycle steam in dedicated steam coil air heaters (SCAH), thus further increasing boiler efficiency.

Boiler fan concept is illustrated in the following figure. Dual-purpose equipment (for air and oxy operation) has been chosen. For the RFG fans, the gas inlet is either from outside or from the recirculation gas take-off point, and in change-over periods the inlet gas can be a mixture of air and flue gas.

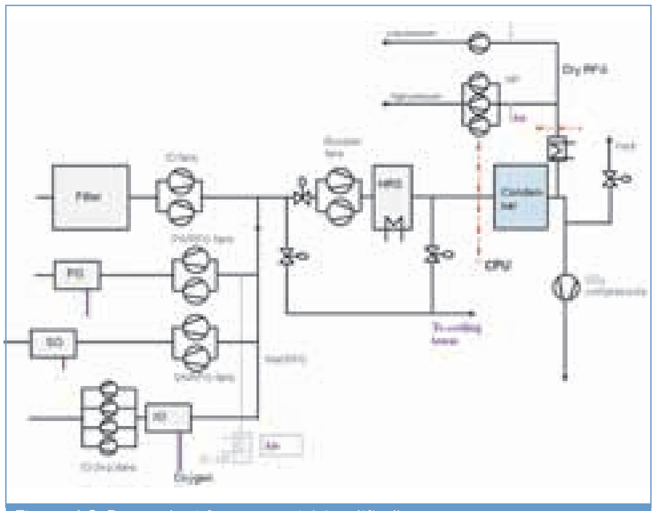


Figure 4.3 Powerplant fan concept (simplified)

The water and steam side design in based on the low mass flux BENSON once-through technology. This technology is ideal for CFB conditions as it utilizes vertical furnace tubes, opposed to spiral wound tubing used in many other once-through designs. For the CFB technology the vertical tubing is the normal arrangement in natural circulation designs and hence the similar design can now be used for supercritical, once-through boilers. The technology has been in commercial operation since 2009 (Lagisza, 460 Mwe). Additionally, five new boilers are under construction.

The heat fluxes in CFB and boilers are low and uniform compared to PC boilers and therefore the required water mass fluxes are rather low. The low heat fluxes allow also using normal smooth tubes in furnace walls with a mass flux of 550-650 kg/m^{2}s at full load. Due to low and uniform heat flux of the CFB furnace and the BENSON low mass flux technology, the fluid temperatures are very uniform after evaporator in different load conditions.

The following figure illustrates the current water/steam circuitry of the boiler. The feed water is pumped from the deaerator and divided in two parallel streams, one leading to conventional feedwater heaters using steam extracted from the turbine, while the other one leads to a HP economizer(a flue gas-water heat exchanger placed in the boiler flue gas stream). Next, the parallel feed water streams are combined into one that enters the boiler at a temperature of 290 °C for preheating in a bare tube economizer. Thereafter water is taken to water-cooled hanger tubes and the enclosure walls of the INTREX fluidized bed heat exchangers, and finally to distribution headers of the evaporator (furnace) walls. The water is heated in the evaporator wall tubes and eventually converted to superheated steam before the evaporator outlet.

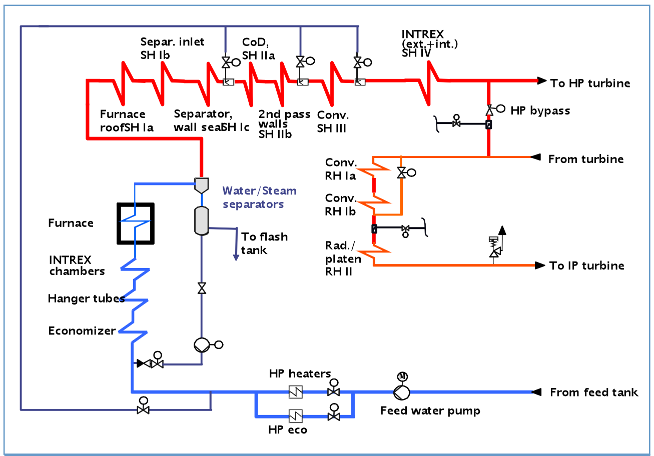


Figure 4.4 Water-steam circuitry.

Dry steam from the evaporator is led to the furnace roof, which is the first part of superheating system. After the furnace roof, steam is taken to the four steam-cooled solids separators, which are formed of gas tight membrane walls covered with a thin refractory lining with high heat conductivity. The first water spray desuperheater is located after the separator. Next, steam flows to walls of the cross-over duct (CoD) and convection pass, followed by the second water spray desuperheater. The third stage of superheating occurs in tube coils of the convective superheater, and the third effective water spray is located after the SH III stage. The fourth and final superheating stage occurs in totally four INTREX superheaters at one side of the furnace below the separators.

The main steam temperature is controlled with feed water sprays as well as by adjusting fuel feeding and feedwater flow. Steam, after the high-pressure turbine, is brought back to the boiler for reheating. Part of the cold RH steam is extracted for the SCAH units to preheat the PO and SO streams. The first stage reheater located in the convection pass and divided into two sections (Ia and Ib) is equipped with a steam side bypass, which is used for reheat steam temperature control. At higher loads part of the reheat steam bypasses the RH I, which reduces the heat pick-up and hence the inlet steam temperature to RH II is decreased. With this patented reheat steam control method spray control is normally not required on the reheat side, and therefore the related decrease in plant efficiency is avoided. Final reheating (RH II) is performed in platen type panels hung from the top of the furnace.

Steam/Water Cycle

The power generation steam cycle consists of a three (3) pressure, condensing-type steam turbines, a surface condenser, motor driven feedwater pumps, condensate pumps, complete set of condensate and feedwater preheaters, a deaerator and all the associated instrumentation, control, piping, valves, auxiliary equipment needed.

The steam turbine has seven steam extractions; down flow exhaust connected to a surface condenser, and is connected to a generator for power generation at 50 HZ. It is capable of operation in fixed, sliding or modified sliding pressure modes, with sub or supercritical steam conditions.

As introduced previously, the steam cycle is largely interconnected with the boiler. Waste heat is transferred from boiler flue gas flow to power cycle water in LP and HP economizers, while some steam is drawn from the power cycle to preheat boiler oxidant in the SCAH. The LP and HP economizers are installed in parallel with condensate/feedwater heaters, thus minimizing the steam extracted from the turbine to preheat power cycle water.

The steam cycle is designed and optimized for the 100% load Oxy mode operation. The main steam cycle systems are the following:

- Steam and bypass system
- Condensate system
- Feedwater system
- Steam extraction system
- Heater drains system
- Circulating water system

Solids Handling Systems

The OXYCFB300 power plant will need extensive infrastructure for the management of all the solids involved in the combustion process. The new plant will take advantage of part of the already existing fuel equipment (coal yard and associated equipment) but new systems have been engineered and will have to be erected to handle most of the solids needed and produced in the boiler.

The solids handling systems are the following:

- Coal transport, handling and boiler feeding system
- Limestone handling and feeding system
- Fly ash handling system
- Bottom ash handling system
- Pneumatic Transport

Power Cycle Auxiliary Systems

Apart from the main systems described in the previous section, the plant has a number of auxiliary systems that support the steam/water power cycle, provide the ASU and the CPU with the utilities they need and that are, thus, required for the correct operation of the whole plant:

- Auxiliary cooling water systems
- Auxiliary steam system
- Steam turbine drains system
- Plant drains system
- Condenser vacuum system
- Demineralised water system
- Raw water system
- Distillate oil system
- Fire Protection System (FPS)
- HVAC system
- Gas storage and distribution system
- Compressed air system
- Service water storage and distribution system
- Potable water storage and distribution system
- Sampling system
- Chemical dosing system

CPU Process Description

CPU process is split between a chemical section and a cryogenic distillation section. In the chemical equipment, water, mercury and all acidic components are eliminated from the flue gas flow. Then, in the cryogenic section the CO_2 is condensed and purified by not-condensing the very low condensing temperature gases (Ar, N_2 and O_2). The following figure presents a simplified process scheme.

To summarize, the recommended CPU configuration is as follows:

- 1 x 100% flue gas condenser with associated level control, water recirculation and water cooling heat exchangers (cooling by process condensate and cooling water from the power cycle)
- 1 x 100% contaminant removal scrubber with associated level control, water recirculation and heat exchangers

- Process condensate collection drums with associated level control and 2 x 100% pumps
- Seal/transport gas heater
- 2 x 50% raw CO_2 compressors with associated intercoolers
- 2 x 100% water absorbers with associated regeneration equipment
- Regenerant agent (incondensables from cold box) heater
- 1 x 100% mercury removal absorber
- Filtration system
- 1 x 100% cryogenic cold box including the distillation columns, heat exchangers, air expanders and cryogenic pumps
- Expanders
- 2 x 50% Product CO_2 compressors and associated aftercoolers
- Vent valves and associated silencers
- Drain tanks and associated drain pumps

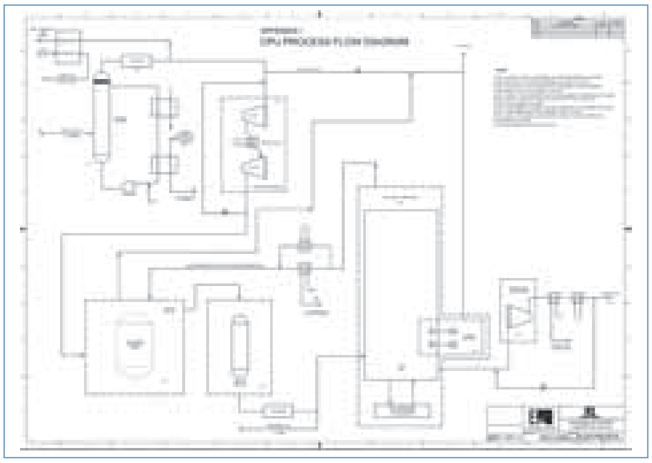


Figure 4.5 OXYCFB300 CPU simplified process scheme

CPU Main features

The main goal is providing enough capacity to purify and compress all flue gases coming out from boiler during its normal operation. To do so, at least rotating equipment should be redundant so that a single failure may still allow proper boiler operation.

- Ramping capacity: CPU load change rate, during the whole load change period of the boiler, shall be a minimum of 4% per minute.
- CPU-Boiler synchronization: the CO_2 Compression and Purification Unit has been designed according to a "CPU follows" philosophy. That means that CPU operation depends on the gas flow exhausted from the boiler. CPU rapid-response vent capacity shall be installed to prevent boiler fans from tripping. Moreover, CPU start up time from ambient temperature (hot start-up) shall be minimised to avoid CO_2 venting.
- CPU turndown (in terms of boiler load): 120% to 40% MCR boiler load. The Wet Gas Scrubbing section and its ancillaries have to be designed to handle a 120% of the MCR boiler load to withstand overfiring phenomena. In order to improve the CPU economy and OXYCFB300 Generation and Capture Plant efficiency and auxiliary power consumption, it has been decided to design all equipment downstream the Wet Gas Scrubbing section for 100% Boiler MCR flue gases handling.
- CPU Integration: OXYCFB300 Generation and Capture Power Plant has been designed to maximize its efficiency. CPU technologists and Developer have designed a revolutionary CPU plant adapted to oxycombustion market, searching for the most advantageous synergies between the power cycle and the CO_2 Purification and Compression Unit. It has resulted in heat recovery studies involving thermal integration.
- Thermal integration: minimizing thermal losses from compression processes.
- Adsorption bed regeneration: regenerative venting gases are preheated by a steam source from the power cycle.
- Gas expander feed stream is preheated by a steam source from the power cycle.

ASU Process Description

Oxidant gas with high concentration of O2 to be used in the boiler as comburent is produced by cryogenic distillation at the Air Separation Unit.

A simplified representation of the process is given in the following figure.

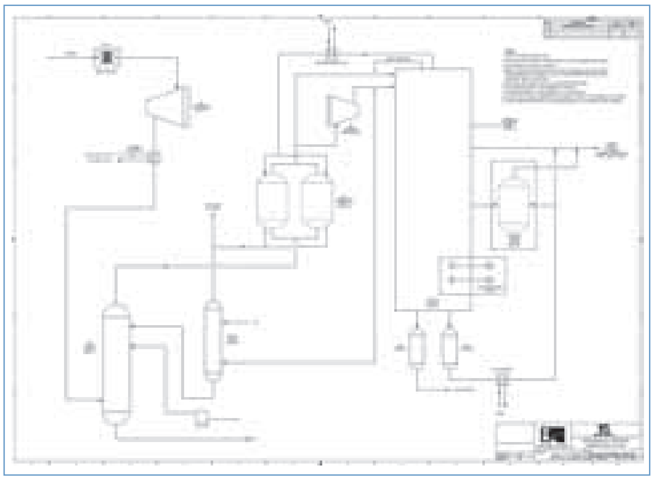


Figure 4.6 OXYCFB300 ASU simplified process scheme

The recommended ASU configuration after the FEED study is as follows:

- 2 x 50% air filters.
- 2 x 50% air compressors.
- 2 x 50% direct-contact air cooling columns.
- 1 x 100% water/nitrogen precooling tower.
- 4 x 50% alumina/zeolite based adsorption bed columns for air purification with associated regeneration heat exchangers.
- 1 x 100% cryogenic cold box including the distillation columns, heat exchangers, air expanders and cryogenic pumps.
- 1 x HP GOX buffer. Part of this liquid oxygen is vaporized continuously and sent to a gaseous buffer. The function of this gaseous buffer is:
  - Normal operation: Smooth normal pressure fluctuation. When the pressure in the LP oxygen pipe deviate from pressure fluc-

tuation normal range, the valve at buffer's outlet opens, and sends some oxygen from the buffer to the LP oxygen pipe, which helps maintain the pressure.
- Cold box interruption: Avoid any oxygen supply interruption during the start-up of the back-up vaporizer which typically takes less than 1 minute.

- LOX storage capacity ≃ 600 m^3; with associated vaporizing capacity
- The LOX storage tank net volume shall be enough for the following services:
  - LOX for temporary GOX unavailability: 3 h boiler 100% load.
  - ASU cold box has to be designed to refill LOX storage capacity in no more than 7 days at 100% MCR Boiler load (58.4 kg·s-1) ASU load GOX production rate.
  - LIN storage tank and associated vaporizing system: LIN storage capacity has to consider two (2) ASU start-up cooling events, one cold stand-by event (to cover 55h of cold stand-by) plus Boiler and Power Cycle needs plus CPU needs taking into account two (2) CPU start-up events. ASU cold box has to be designed to refill LIN storage capacity in no more than 7 days at 100% MCR Boiler load (58.4 kg·s-1) ASU load GOX production rate.

ASU Main Features

The main goal is providing a stable GOX supply while minimizing the power consumption at all operating loads. To do so, at least rotating equipment should be redundant so that a single failure may still allow boiler operation in oxycombustion mode.

- Ramping capacity: Oxygen consumption is expected to continuously oscillate with load variations. ASU to be configured. In order to avoid variations in GOX quality and pressure ASU to be designed with a ramp-up capacity of below or equal to (4% O_2 consumption)/minute.
- ASU-Boiler synchronization: ASU start-up times has been required as follows:
- Cold start-up time: 6 hours

The unit has to be kept in cold stand-by ("cold start-up conditions") for 55 hours @ ambient design temperature.

- Warm start-up time: 72 hours.
- ASU turndown (in terms of GOX production flowrate): 40% MCR boiler load (26.5 kg·s-1).
- ASU Integration: OXYCFB300 Generation and Capture Power Plant has been designed to maximize its efficiency. ASU technologists and Developer have designed a revolutionary ASU plant searching for the most advantageous synergies between the power cycle and the Air Separation Unit. It has resulted in heat recovery studies involving thermal integration.
- Thermal integration: minimizing thermal losses from compression processes.
- Adsorption bed regeneration: regenerative venting gases (mainly nitrogen) are preheated by a steam source from the power cycle.

Electrical Description

Single-Wire Diagram Description

Configuration

The configuration for the electrical project is shown in the one-line diagrams included at the end of this section. The generation plant is formed by the following:

- One electrical generator, 409 MVA, 16.5 kV, 50 Hz forming a turbine generator unit with a steam turbine.
- One Generator Step-up Transformer: 340/425 MVA, ONAN/ONAF, 223 ffl 10 x 1%/16.5 kV.
- Two Unit Auxiliary Transformers : 24/30 MVA (ONAN/ONAF), 16.5 ffl 2.5 ffl 5%/6.9 kV.
- One Spare Unit Auxiliary Transformer on standby: 24/30 MVA (ONAN/ONAF) 220 ffl 10 x 1%/6.9 kV.
- MV busbars associated to the auxiliary transformers.
- AC/DC LV systems.

The ASU plant shall include the following:

- One auxiliary transformer: 40/50 MVA, ONAN/ONAF, 220 ffl 10 x 1%/10 Kv. This transformer will be located near the GIS substation, outside the ASU area
- Medium voltage busbars.
- AC/DC LV systems.

The CPU plant shall include the following:

- One auxiliary transformer: 40/50 MVA, ONAN/ONAF, 220 ffl 10 x 1%/10 kV. This transformer will be located inside the CPU area
- Medium voltage busbars.
- AC/DC LV systems.

In addition, a GIS substation shall be installed close to the step-up transformer. The general electrical system of the OXYCFB300 plant shall carry out the following functions:

- Generate electrical power in the turbine generator and transmit it to the 220 kV, 50 Hz off-site network through the 220 kV substation.
- Supply electrical power to the auxiliary plant services and to the ASU and CPU plants to actuate the equipment, command, monitoring, control, protection, lighting and any other function that requires electrical power supply at the different stages of operation, such as: startup, operation and shutdown of the unit and the associated plants.

Electrical System

The electrical system shall be made up of the following main systems:

- High voltage system (ADA).
- Generating system (MK and BA).
- Generator Earthing System (BAW).
- Power transformer system (BAT and BBT).
- Medium voltage system (BBA).

- System of 400V power centres (BFA).
- Distribution centres, auxiliary services and lighting centres at 400/230 V (BLA, BLT, BNA, BNT).
- System of 400 V motor control centres (BJA).
- 125 Vdc system (BU).
- Vac UPS System at 230 V (BRA).
- Emergency power system at 400 V, 50 Hz, (BM).
- Lighting and power outlet system (BLA).
- Telephone and public address communication system (CY).
- Atmospheric surge protection system (BAW).
- Earthing system (BAW).
- Cathodic protection system (AXP).

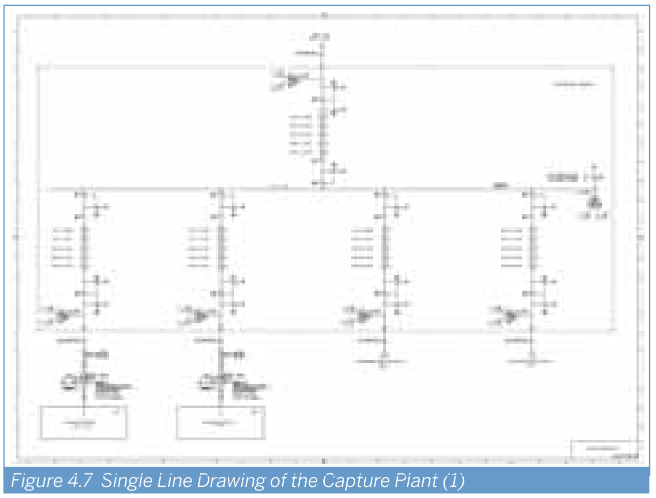


Figure 4.7 Single Line Drawing of the Capture Plant (1)

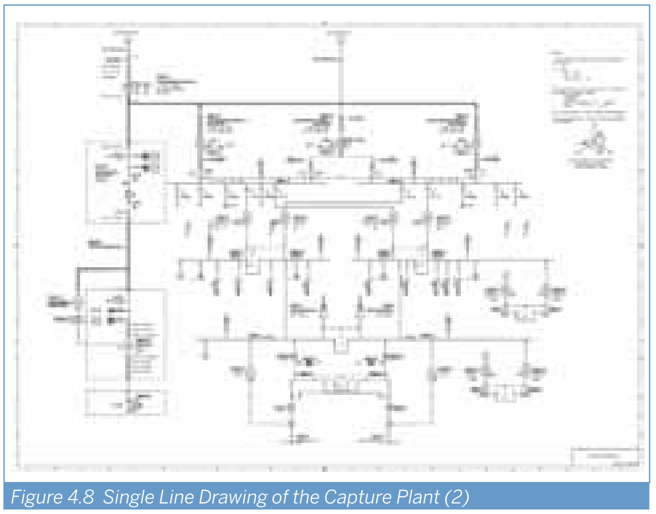


Figure 4.8 Single Line Drawing of the Capture Plant (2)

4.2.2.2 Piping and Onshore Facilities

The project consists of the design of a 14-inch pipeline to transport CO_2 in the dense phase to an underground injection site approximately 136 kilometres away. The pipeline originates at the CO_2 capture facilities at Compostilla, Municipality of Cubillos del Sil in the Province of Leon and ends at the injection facilities near the Municipality of Villaselán.

The pipeline routing developed during the conceptual design has been optimized by an on-the-ground survey selecting the best possible route with the least interference to the environment and habitats and at the same taking into consideration the constructability aspect of the project. This field routing included the preliminary selection of the block valve sites.

The injection facilities at the terminus of the pipeline consist of three (3) injection wells for which ENDESA has provided location coordinates. The injection facilities include a distribution manifold(s) with lateral lines to the individual wells. Alternative configurations will be developed for consideration to include in the final design.

The pipeline and injection facilities will not be manned on a 24 hour basis but will be remotely monitored and controlled from the power plant control room. Communication and local control will be provided at the block valve sites and injection facilities.

Basic Data

Origin and End Point

The CO_2 transport pipeline route originates at the flange of the CPU, inside the thermal power station in Compostilla, in the municipal limits of Cubillos de Sil (Leon).

Pressure

The design pressure is 220 Bar.

Diameter

The pipeline's outer diameter is 14" (355.6 mm).

Temperature

The temperatures considered to be the thresholds for the transported fluid are as follows:

- CO_2 temperatures at the pipe intake: Minimum: +30 ºC / Maximum: +50 ºC
- Design temperatures of the outside: Minimum: -20 ºC / Maximum: +60 ºC
- Design temperatures underground: Minimum: +10 ºC / Maximum: +20 ºC

Pipe roughness

An internal pipe roughness of 0.015 mm has been considered for the entire route of the pipeline. This corresponds to an unlined carbon steel pipe.

Length

The length overall of the pipeline is 135,499 lm.

Location of valve positions

To minimize the potential risks a break or fault in the pipeline could mean for goods, services and people, the entire length of the pipeline is subdivided by isolation valves. These valves permit the existence of leaktight compartments that help with this objective.

As a general rule for the location of these facilities, it is believed that they should be located away from existing or planned urban centres, as well as motorways, dual carriageways, other roads, railways and any roadway with significant traffic of vehicles and/or people.

The locations of the valve positions are as follows:

NAME	KP LOCATION	MUNICIPAL LIMIT	ACTUATION
POS.00	0,150	Cubillos del Sil	Motorised
POS.01	25,616	Folgoso de la Ribera	Motorised
POS.02	44,698	Villagatón	Motorised
POS.03	62,741	Turcia	Motorised
POS.04	85,626	Chozas de Abajo	Motorised
POS.05	111,818	Santas Martas	Motorised
POS.06	124,951	Valdepolo	Motorised
POS.07	135,486	Villamol	Motorised

Table 4.3 Location of valve positions

Location of pig launching and receiving trap positions

In order to enable post-construction cleanup and to facilitate inspection during the operation phase, pig launching and receiving traps able to launch or receive scrapers through the pipeline are used.

This project will use a 14"x18" launch trap located in the output terminal POS.00.

The associated reception trap will be located in the injection unit project, in a receiving terminal, whose scope is the subject of another project.

The auxiliary lines of pipes connected to the main body of the scraper trap will allow for:

- Launching or receiving the scrapers
- Drain any possible condensate
- Taking pressure readings

Auxiliary Facilities

The group of systems located along the pipeline for the proper operability and control of the fluid to be transported are defined as ancillary facility.

Mechanical and Geometrical Characteristics of the Metal Materials

All materials: piping for the line and for the positions, valves, insulating joints, fittings, flanges, etc.; to be welded will have their chemical composition limited so as to ensure the weldability of the metal.

Pipeline

The pipeline will be made of ∅14" high yield strength carbon steel, manufactured in accordance with the API 5L Specification and it will be of X-70 grade quality. The material selected has the following main mechanical characteristics:

- Minimum elastic limit Specified: 485 MPa
- Breakage load: 570 MPa

In addition, and in compliance with the regulations, the yield strength/tensile strength (Spanish acronyms LE/CR) ratio will always ≤ 0.85. The thickness selected in accordance with the calculations made is as follows:

DIAMETER (")	MATERIAL	THICKNESS (MM)
14	API-5L Gr. X-70	11.9

Table 4.4 Size, material and thickness selected for the pipeline

There may have been occasional increases in the thickness selected at some points of the route as a result of its construction particularities.

Valves

The combination of the mechanical characteristics of the valve material and its thickness will be equivalent to those of the line pipe where they are inserted. When required, the valves will be fitted with transition sleeves that will accommodate the differences between the mechanical properties of the valve and of the pipe.

Characteristics of Materials for Civil Works

Works of mass and reinforced concrete to be made as support or protection for the conduction will be made in accordance with the relevant standard technical drawings and the EHE-08 Instruction on Structural Concrete and Instruction RC-08. The type of concrete to be used in all cases will have the characteristic strength indicated on the standard technical drawings or in the Terms and Conditions.

The steel for the framework will be high adhesion with yield strength equal to or greater than 400 N/mm^2.

Coating

In order to isolate it from the corrosive media surrounding it, the pipeline will have an outer covering along its entire length which will provide passive protection. This will decrease the current intensity necessary for cathodic protection.

External Coating

The outside of the pipe will be covered in-factory with hot-applied extruded polyethylene in a thickness that depends on the areas of:

DIAMETER (“)	COATING TYPE THICKNESS (MM)	
	NORMAL	REINFORCED
< 14	2	4
14	2.5	5

Table 4.5 External coating standard thickness for the pipeline

On-site coating

The cold-applied coating, based on plastic tape, will be used for applying a coating to the following on-site: welded pipe joints, fittings, special parts, repairs to the pipe coating from damage during transport from the coating factory to the worksite, and the coating for the joint welds.

This has been adopted based on its lesser complexity when compared to other processes in terms of machinery used, and thus is more economical.The base material will be polyethylene and the application will be done using tape or heat shrink sleeves.

Before it is lowered into the trench, the set of coatings for the pipe will withstand a 20 kV test with no faults detected.

Burial Depth of the Pipe

Under normal pipeline laying conditions, the minimum depth considered in the project for laying the pipe is 1.50 m. At crossovers with large rivers, streams or creeks, it is planned to reach a minimum burial depth of between 1.50 and 2.50 m. This may be greater, depending on the individual undercutting studies. At crossovers with railways, the minimum overload with respect to the pipe’s upper generatrix will be 2.50 m. In addition, at crossovers with motorways, dual carriageways, roads and roadways, the pipeline will be installed at a minimum of 2.00.

Instrumentation and communications

The instrumentation installed in the pipeline can be described, essentially, based on the type of positions for this project: output terminal and positions with a pipe isolating valve. These different types of positions include the following associated instrumentation.

The following instrumentation can be found in the starting/ending terminal:

- Pressure gauges (PI)
- Pressure indicating transmitters (PIT)
- Thermowells (TW), temperature sensing elements (TE) and
- Temperature transmitters (TIT)
- Actuators for the motorisation for the valves (MOV)
- Safety Valves (PSV)
- H_2O online analyser (AT)
- CO_2 and H_2S detectors 2 (AT)
- Corrosion Monitoring Kit (CT)
- Corrosion Coupons (CC)
- Pig passage detectors (XI)

The following instrumentation will be found at the main valves positions:

- Pressure gauges (PI)
- Pressure indicating transmitters (PIT)
- Contact temperature transmitters (TIT)
- Actuators for the motorisation for the valves (MOV)
- CO_2 and H_2S detectors 2 (AT)
- Intruder detection alarm

All instrumentation will be remotely controlled by the control system and the signals will be transmitted via the Communications System. An RTU (remote control) will be included in all positions and terminals. This will capture all the signals and be connected to the Control Room for the Transport System via fibre optics.

Cathodic Protection

An active protection system has been designed. It consists of attaching the structure to be protected (pipeline and facilities) to the negative pole of a DC source. This is a transformer/rectifier, whose positive pole is connected to the anode or dispersing bed.

The direct current exiting the rectifier through the positive pole –and considering the ground as electrolyte or conductor– penetrates the structure to be protected and is conducted through it to the negative pole. The result is a decrease in the potential of the structure relative to that of ground and, therefore, it is protected. Thus, the elements considered to be part of the cathodic protection system can be divided, for descriptive purposes, into two main groups:

- Cathodic Protection Stations (CPS)
- Fittings installed in the pipe

Electrical Connections

The valve positions need electrical power as they have remotely operated isolation valves located in them. In the case of this project, all the valve positions require an electrical supply. To meet the demand for power as established by the electrical company, the following transformers will be installed:

- Position POS-01, 50 KVA
- Position POS-02, 50 KVA
- Position POS-03, 50 KVA
- Position POS-04, 50 KVA
- Position POS-05, 50 KVA
- Position POS-06, 50 KVA

Power will be supplied to Position POS.00 from one of the company's existing panels.

Power will be supplied to Position POS.07 from a power line (covered under separate injection project).

Information relating to each of these facilities is included in the following table:

SUPPLY	INSTALLED POWER (W)	ESTIMATED POWER (W)	UPS POWER (W)	MUNICIPALITY	LENGTH
POS 00 (B.T.)	15,000	10,180	5,400	Cubillos del Sil	50
POS.01 (A.T.)	16,000	10,980	6,200	Folgoso de la Ribera	782
POS.02 (A.T.)	16,000	10,980	6,200	Villagatón	146
POS.03 (A.T.)	16,000	10,980	6,200	Turcia	2607
POS.04 (A.T.)	16,000	10,980	6,200	Chozas de Abajo	1330
POS.05 (A.T.)	16,000	10,980	6,200	Mansillas de las Mulas Santas Martas	2185
POS.06 (A.T.)	16,000	10,980	6,200	Burgo de Ranero Valdepolo	4589

Table 4.6 Medium and Low Voltage Electrical feeders for pipeline valve positions

Characterization Wells Locations

In order to better characterize the Duero basin, 5 new wells were drilled, SD-1, SD-2, SD-3, SD-4 and SDE-3 (Figure 4.12).

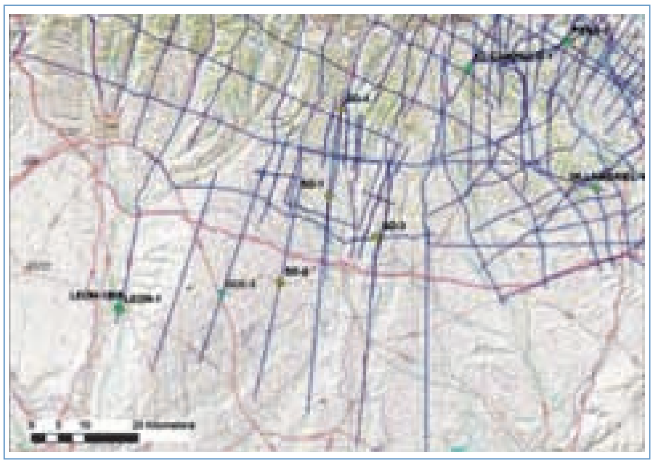


Figure 4.9 Duero Basin with old, existing wells (green well location: Leon-1, Leon-1BIS, Pena-1, El Campillo-1, Villameriel-1), and newly drilled wells (yellow and cyan well locations: SD-1, SD-2, SD-3, SD-4, SDE-3).

4.2.3 Storage Subsurface Characterization and Reservoir Engineering

4.2.3.1 Reservoir Characterization

This section describes the activities conducted in relation to the Reservoir Characterization report, as part of the storage FEED of OXY_CFB-300, to characterize the geology of the Duero storage site. Five tasks are reported here:

- Interpretation of well log data. For each of the appraisal wells, interpretation of petrophysical logs, image logs, sonic logs, pressure data and cement log data are reported, and conclusions are provided to recapitulate the findings across the various wells
- Interpretation of seismic data. Two interpretation phases were conducted according to the availability of the seismic surveys (old 2D surveys and new 2010 2D seismic were interpreted in Phase I, then integrated with 2011 2D and 2012 3D surveys and converted to depth domain in Phase II). The results in terms of the understanding of the structural geology and its potential impact on CO_2 storage are described
- Inversion of the new seismic surveys. Inversion was performed on the 2010, 2011 and 2012 seismic survey in order to obtain an acoustic impedance volume that could be used as a guide for the distribution of reservoir properties, notably porosity for static modelling
- Static reservoir modelling. This consisted in the integration of the previously described work: seismic interpretation was used to build a structural geological model; petrophysical log interpretation and inversion data were used to build a property model, including facies and petrophysical properties, which was finally used to obtain static volumetric estimates and analyse their uncertainty.
- Dynamic reservoir modelling

In terms of CO_2 storage, the following formations were identified in the beginning of the study as potential reservoirs and caprocks within the basin, mentioned from the top to the base of the geologic sequence:

- Tertiary formations as potential caprock
- Garumn formation as potential caprock
- Boñar carbonate formation as potential reservoir
- Utrillas sandstone formation as potential reservoir

The formation tops were chosen based on the mud log and log responses.

Seismic Interpretation

This section describes the seismic interpretation of the Duero basin that was carried out in the frame of the modelling of the Duero potential CO_2 storage site. This interpretation has consisted of two separate phases, according to the availability of the input data:

- Reinterpretation of old 2D seismic and interpretation of 2D survey acquired in 2010
- Interpretation of 2D survey acquired in 2011 and 3D survey acquired in 2012

Static Modelling

The static model has been built over a larger scale in order to include data from older wells, notably structural and facies data; however, priority has been given at all times to the data and conceptual understanding from the central part of the model, where the most recent, more dense and better quality data (esp. SD-1 to SD-4 wells; 3D seismic) provide better constraints to the modelling. As expected, uncertainty increases (and model accuracy may decrease) towards the edges of the model.

Figure 4.10 Static model (orange polygon). Seismic surveys are plotted in purple, old wells in green, new wells in yellow (deep wells) or blue (shallow wells); red polygons are ENDESA permit boundaries

Dynamic Modelling

An appraisal program and feasibility study is being carried out in the Duero basin to investigate its performance as a CO_2 storage site. Five appraisal wells; SD-1, SD-2, SD-3, SD-4 and SDE-3 were drilled to acquire data for reservoir characterisation. The dynamic data collected includes permeability, pressure, temperature gradient, water properties, rock compaction, capillary pressure, and relative permeability. CO_2 solubility data were also acquired to estimate the dissolution trapping.

The analysis of the dynamic data concludes that the Utrillas formation has good porosity and appears to have a good injectivity. A high injection rate was maintained in SD-3 DST-1. To the contrary, the Boñar formation appears to have very low permeability and does not seem to have sufficient injectivity to accommodate a commercial injection target. It could, however, help the containment by trapping some of the CO_2 injected into Utrillas.

The pressure gradient acquired in Utrillas and Boñar are close to hydrostatic gradient.

The dynamic data also confirms the Garumn potential as the primary seal due to its low permeability and the presence of massive claystone as its main facies. Low permeability was also observed in the Tertiary and thus it could act as a secondary seal.

Irreducible water saturation and residual CO_2 saturation were identified during the core flood simulation and this may improve the modelling large plume extent.

The dynamic model of the Duero syncline was constructed using the appraisal data. This model will be used as a mean of technical performance evaluation where injectivity, storage capacity, and containment will be defined.

The aim has been to construct a reservoir dynamic model to be used as one of the principal tools in the technical performance evaluations in the succeeding FEED Project.

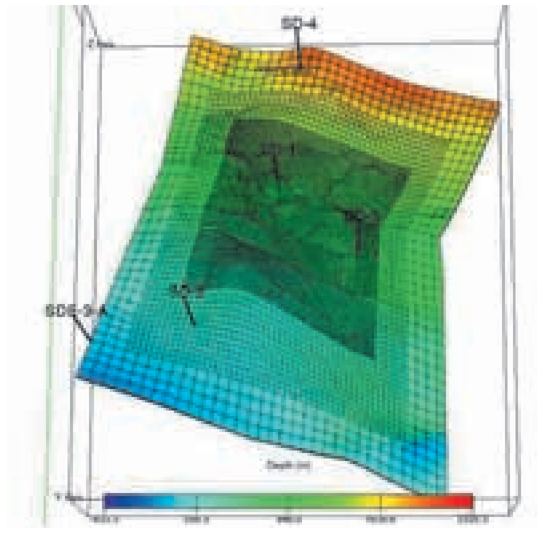


Figure 4.11 Dynamic model grid cells, top of Utrillas

4.2.3.2 Conclusions: Reservoir Viability

The appraisal program conducted, especially with the ambitious well data collection program and 3D seismic survey, allowed building an accurate and very well constrained geological model of the Duero basin. The correlation of five appraisal wells with the existing offset wells, thanks to detailed mud logging, core description, and image log interpretation, allowed defining a more realistic facies classification, with a 2-level hierarchical approach to describe the problematic transition between Utrillas and Boñar and to define lithofacies classes matching all well observations, which can be reliably used to constrain the rest of the modelling.

The results of the inversion of 2D and 3D seismic data provided a very valuable trend for the porosity distribution across the model, providing a constraint to the stochastic approach to populate the inter-well areas and fitting the conceptual geological model accurately. The acquisition of permeability data, together with the well test program and extensive laboratory analyses, allowed representative horizontal and vertical permeability distributions to be modelled, and provided a reasonable criterion to define net-to-gross ratios across the different formations.

Volumetric calculations confirmed the potential of the Duero basin in terms of CO_2 storage capacity, and uncertainty analyses showed a relatively small impact of the modelling parameters (porosity variogram parameters and fluvial facies modelling parameters) on capacity estimates, supporting the reliability of the base case static model for the subsequent phases of the characterization.

Dynamic data acquisition was carried out in the Duero basin for reservoir characterization purposes. Five appraisal wells; SD-1, SD-2, SD-3, SD-4 and SDE-3 were drilled to acquire data for reservoir characterisation. The dynamic data collected includes permeability, pressure, temperature gradient, water properties, rock compaction, capillary pressure, and relative permeability. CO_2 solubility data was also acquired to estimate the dissolution trapping.

The following conclusions could be withdrawn from the analysis of the dynamic data:

- The Utrillas formation has good storage property and appears to have a good injectivity.
- The Boñar formation appears to have a very low permeability and does not seem to have a sufficient injectivity to accommodate a commercial injection target. It could, however, help containment by trapping the CO_2 injected into the Utrillas.
- The Garumn formation does have the potential to act as the primary seal; it consists mainly of massive claystones with low permeability and high pore entry pressure.
- The Tertiary could act as a secondary seal. It consists of shaly sandstones with very low permeability.
- The pressure gradient acquired in the Utrillas and the Boñar formations are close to the hydrostatic gradient.
- The different pressure regime between the two formations could indicate that there is some level of discontinuity (partially or entirely) between the Utrillas and the Boñar and will be taken into account in the dynamic model by assigning two different equilibration regions.
- Irreducible water saturation and residual CO_2 saturation were identified during the core flood experiments and this may improvement of the knowledge about the large plume extent.

The dynamic model of the Duero syncline was constructed using the appraisal data. This model will be used as a means of technical performance evaluation where injectivity, storage capacity, and containment will be defined. A compositional simulator with Peng Robinson EOS will be used to model the CO_2 injection stream properties.

4.2.3.3 Generic Design of the Injectors and the Monitoring Wells

The injector wells have to able to ensure the best available technologies to operate under safety operating and environmental conditions.

PARAMETERS	ASSUMPTIONS	COMMENTS
Average flow rate during injection periods, per well	15kg/sec	This well flow rate corresponds to approx. 70 kg/s for 5 injectors' injector wells and 40% downtime.
Maximum instant flow rate during injection periods, per well	20kg/sec	This situation would happen, for instance, when injection has to be performed with only 4 wells instead of 5 (eg during shutdown periods for maintenance)
Expected Wellhead temperature (WHT)	0-20°c	
Maximum range of wellhead temperature (WHT)	-20°C + 50°C	We expect possible cooling of the wellhead during venting operations or during emergency shutdown leading to possible gas decompression in the wellbore
Expected wellhead pressure	75-110 bara[9]	

Table 4.7 General assumptions for the injector well

The injected fluid is supposed to have the following specifications, assuming third injecting parts.

COMPONENT	CONCENTRATION (% MOL)
CO_2	>95.5%
H_2O	<500 ppm
H_2S	<200 ppm
CO	2000 ppm
O_2	<4% vol
CH_4	<4% vol
N_2	<4% vol
Ar	<4% vol
H_2	<4% vol
SOx	100 ppm
NOx	100 ppm
Solid content	negligible[10]

Table 4.8 Specifications of the CO_2 composition.

[9] The numbers above were chosen to be in coherence with the results of the study "Pre-characterization Report OXYST-END-SID-IF-00041-01", (Endesa, 2012)

[10] Solid content is considered negligeable in that its concentration is considered below the threashold that would create erosional damage. This assumption is typically verified in Carbon steel hydrocarbon producing wells where water content is small, <500ppm or 0.5 bbl per 1000 bbl of oil and velocity speed in the tubing is maintained below 33ft/sec.

Given the specifications for water content (<500 ppm) and the operations conditions, it is foreseen that there would be no free water phase[11] in the well and the well metallurgy selection will be performed accordingly.

The injector well must have the minimum functional measurement capabilities for operating and controlling the injection under safety conditions:

- Continuous downhole pressure and temperature measurement as close as possible to the reservoir.
- Annulus pressure monitoring
- Continuous Distributed Temperature profile outside the injection tubing.

In addition to the assumptions already mentioned, we assume the following:

- The target life of the well completion and sensors should be 10 years
- The X-mas tree should include an Emergency Shutdown Valve (ESD)

The injector well, from a casing design perspective, is pretty typical and nothing unusual about the materials of the surface or intermediate casing strings is noted.

The liner however, which will be in contact with the injected CO_2, will need to be of a CRA material. Given the CO_2 composition, it's recommend Cr 25 with premium flush joint connections.

DEPTHS (M)	COMPLETION
	Casing
0 (-58)	Conductor: 20'' OD - 94 lb/ft H-40 BT&C set in a 26'' wellbore cemented to the surface
0 (-350)	Surface: 13-3/8'' OD -61 lb/ft J55 BT&C set in a 17-1/2'' wellbore cemented to surface
0 (-1445)	Intermediate: 9.625'' OD - 43.5 lb/ft N-80 BT&C set in a 12-1/4" wellbore cemented to surface
1336 (-1600)	Production liner: 7'' OD - 29 lb/ft N-80 set in a 8-1/2'' wellbore cemented to liner top
1600 (-1960)	Production liner: 7" OD - 29 lb/ft, 80 Ksi, 25 Cr with premium flush joint connections
	Injection zone
1700 (-1900)	Utrillas (Middle and Lower)
	Packer
1670 (-1685)	PBR with 4m seal assembly 7" 29 lb/ft Retainer production packer with a 3.25 (minimum) seal bore extension with 25 Cr wetted surfaces
	Injection String
0 (-1336)	4-1/2'' OD - 12.6 lb/ft, 80 Ksi, 25 Cr with premium connections from surface and a crossover form 4-1/2" to 4" tubing
1336 (-1670)	4'' OD - 11.6 lb/ft, 80 Ksi, 25 Cr with premium flush joint connections and a locator sub and seal assembly built on a 2-7/8" OD sub with 3.25" seal stacks (elastomer for CO2 service)
1685 (-1695)	2-7/8" OD - 25 Cr Pup joint
	Profiles
1444	X-N bottom of tailpipe
1567	X midway of tailpipe
1581	X above packer
1695	2-7/8" x 2.313" BX Nipple 25 Cr
1700	2-7/8" 25 Cr Wireline Entry Guide
	Gauges
1640	Pressure/Temperature Gauge: set in 4" ported sub in the tubing string with encapsulated conductor cable in a ¼" stainless steel line.
0 (-1640)	Pressure/temperature Line. ¼" stainless steel line with encapsulated conductor cable for P/T gauge
0 (-1640)	Distributed Temperature Sensing (DTS) fiber optic cable in a ¼" stainless steel line (if available, a unique HYBRID ¼" line covering DTS and Pressure/ T gauges is preferred).
	Valves and misc.
60	4-1/2" Subsurface safety valve with ¼" SS control line
	Cannon Clamp to strap the two ¼" SS lines to the tubing. Should be placed at minimum on every other joint of casing.
1345	Line hanger 7" x 9-5/8"

Table 4.9 Summary of completion specifications for injection wells

The monitoring wells will be positioned geographically so as to ensure that it will see CO_2 early in the life of the project (a few months after injection starts). It's goals are:

- to enable the monitoring of the pressure front in the target reservoir before and after the CO_2 arrives at the wellbore;
- to permit time lapse cased hole logging across the reservoir (ie, allow for the necessary access at the wellhead);
- to permit the monitoring of casing cementation quality across the reservoir and caprock, and casing corrosion for a well with similar geometry as an injector well ;
- to detect potential leakage of CO_2 along the wellbore in the 7" annulus by mean of a Distributed Temperature monitoring System (DTS);
- as an option, to permit the monitoring of possible passive microseismic events in the reservoir and the caprock (the MONITORING WELLS is therefore assumed to be located within the corresponding "listening" range of a CO_2 injector well).

MEASUREMENTS	COMMENTS
Distributed temperature system (DTS)	From Surface to reservoir
Down hole reservoir pressure and Temperature	At around 1000 - 1800m
7" casing pressure	
9 5/8 x 13 3/8 annulus pressure monitoring (optional)	
7" x 9 5/8 casing annulus monitoring (optional)	
Time lapse cased hole logging using up to 4 ½" OD logging tools including reservoir saturation logging, cementation logging, casing integrity logging	The goal here is to enable the time lapse access of a large range of wireline tools. It is accepted that those tools would be run only when the microseismic tubing is removed (see below)
Passive listening of microseismic events in the reservoir and the caprock	Optional – must be deployed on tubing inside the 7" OD casing

Table 4.10 List of expected measurements in the monitoring well

[7] For proof, see for instance (IEAGHG, 2010)

A surface casing of 13-3/8 inches will be run to 350m inside 17-1/2 inch open hole and cemented to the surface. An 8-½ inch open hole will be drilled to a TD of 1960m after which two 7 inch OD 29lb/ft (43.15 kg/m) N-80 casing (with 25 Cr treatment for the bottom 360m) with the above-mentioned instrumentation will be run into the well and (CO_2 resistant) cemented in place.

DEPTHS (M)	COMPLETION
	Casing
0 (-58)	Conductor: 20'' OD - 94 lb/ft H-40 BT&C set in a 26'' wellbore cemented to the surface
0 (-350)	Surface: 13-3/8'' OD - 61 lb/ft J55 BT&C set in a 17-1/2'' wellbore cemented to surface
0 (-1445)	Intermediate: 9.625'' OD - 43.5 lb/ft N-80 BT&C set in a 12-1/4" wellbore cemented to surface
0 (-1600)	Production casing: 7'' OD - 29 lb/ft N-80 set in a 8-1/2'' wellbore cemented to liner top
1600 (-1960)	Production casing: 7" OD - 29 lb/ft, 80 Ksi, 25 Cr with premium flush joint connections

Table 4.11 Casing program for the generic monitoring well

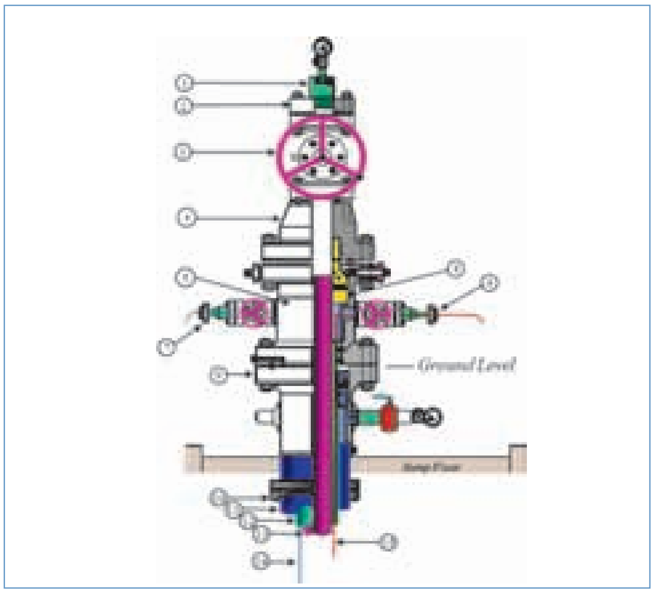


Figure 4.12 Wellhead and the X-mas tree

4.2.3.4 Storage FEED Engineering

The injection system comprises surface facilities at the injection site, where there are a distribution manifold at the end of the transport pipeline, distribution pipelines to wells, additional compression facilities if needed, measurement and control systems, wellhead(s) and the injection wells.

Next picture presents a block flow diagram, indicating the overall flow and distribution of CO_2 from the OXY-CFB-300 plant to the deep saline aquifers. Developing a aquifer for CO_2 storage involves:

- Drilling and equipping injection wells
- Installation of high-pressure injection equipment and related piping

The storage site will be able to handle 70 kg/s of CO_2 daily.

Determining the required CO_2 pressure at the top of the well requires consideration of the pressure required at the bottom of the well to force CO_2 into the injection zone, the pressure increase in the pipe due to the height of the CO_2 column, and the pressure loss due to flow in the pipe. Moving the CO_2 into the reservoir requires raising the CO_2 sufficiently above the in situ pressure to provide a driving force, but not so high as to risk hydrofracturing the injection interval (Energy Information Administration, 2000). It is found that the pipeline delivery pressure, 100 bars, will be adequate for injection.

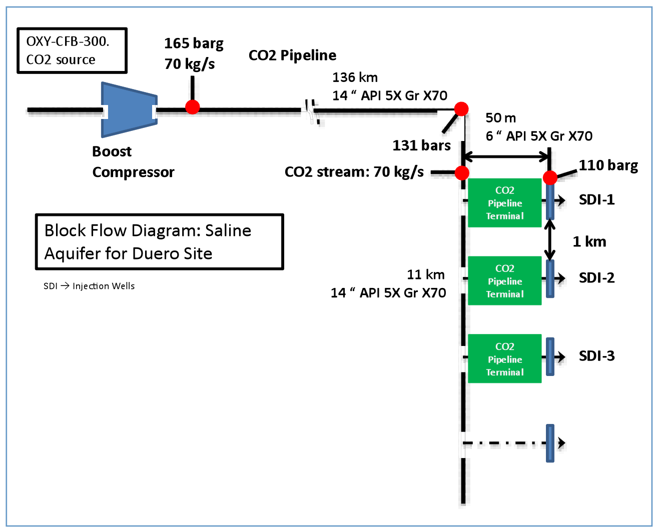


Figure 4.13 CO_2 injection Block Flow Diagram (preliminary data)

4.2.4 Overall Project Data

4.2.4.1 Performance

OXY MODE	19/07/2012	
Coal consumption (kg/s)	30.9	
Limestone consumption (Ton/h)	28.76	
Gross power (MW)	345.2	
Gross power plant efficiency (%) (LHV)	48.4	
Auxiliary total (MW)	107.6	
Net power (MW)	237.7	
Boiler efficiency (%) (LHV) excluding HRS	93.83	
Net power plant efficiency (%) (LHV)	33.3	
CO_2 produced (kg/s)	70.08	
CO_2 captured (kg/s)	63.77	
CO_2 emitted (kg/s)	6.31	
Capture ratio (%)	91	
Annual equivalent operation hours for the first 5/10 years of operation	4400	5004
CO_2 captured for the first 5/10 years of operation (Million Tons)	5.05	11.49

AIR MODE		19/07/2012	
Coal consumption (kg/s)		28.49	
Limestone consumption (Ton/h)		26.78	
Gross power (MW)		299.8	
Gross power plant efficiency (%) (LHV)		45.6	
Auxiliary total (MW)		29.8	
Net power (MW)		270	
Boiler efficiency (%) (LHV) excluding HRS		90.2	
Net power plant efficiency (%) (LHV)		41.1	
CO_2 produced (kg/s)		64.25	
CO_2 captured (kg/s)		0.00	
CO_2 emitted (kg/s)		64.25	
Capture ratio (%)		0	
28/12/2012	Coal LHV (KJ/Kg)		23060

Table 4.12 CO_2 Balance.

CO_2 PARAMETERS (INCLUDING TRANSPORT COMPRESSOR)	
CO_2 Captured (% weight CO_2)	91%
CO_2 Captured (ton/yr)*	1,287,007
CO_2 Emitted (ton/yr)*(OXY+AIR)	218,417
*5606 equivalent operating hours OXY mode 394 equivalent operating hours AIR mode	
CO_2 Captured (g/kWh)	965.8
CO_2 Emitted (g/kWh)	95.5
CO_2 Avoided (g/kWh)	761.1

Table 4.13 CO_2 parameters

All CO_2-related data have to be taken with extreme care because the amount of CO_2 actually captured/emitted depends on the number of oxycombustion operating hours and on plant load. It is very risky to express CO_2 data on a yearly basis because important misunderstandings may be created if the number of full load equivalent operating hours is not specified. Continuous rates (kg/s) are more accurate, provided that boiler load is specified. Data given in kg/s in the tables above correspond to 100% load operation.

4.2.4.2. CO_2 Transport and Storage Main Data

	Baseline (planned values)	Actual	Comments
Transport pipeline			
Pipeline design Pressure (bar)	220	220	
Pipeline inlet Pressure (bar)	180	150	Change in the injection location
Pipeline diameter (inches)	12	14	Increased to reduce losses and increase future capacity if needed
Pipeline lenght (Km)	135	135,5	Change in the injection location
Storage			
Storage Injection wells (number)	5	2+1	Three injection wells
Monitoring wells (number)	8	2+3	
Injectivity (kg/s)	64,00	70,00	
Estimated Capacity (Mill TonCO2)	37	42	
Injection pressure at well head barg	112 - 90	60 - 80	
Injection rate (kg/s)	8	23 - 35	
Injection temp ºC	0 - 32	-5 - 20	A surface temperature of 10 degC is assumed and the base case WHT is assumed to be equal to this surface temperature. Variation from -5 t 20ºC

Table 4.14 Transport and Storage Planned and Actual values comparison at the end of Phase I

4.3 LAYOUT AND CONSTRUCTION

4.3.1 Site Location

4.3.1.1 Capture

Location

The OXY-CFB-300 plant will be situated on lands belonging to the current Compostilla Power Station, in the municipality of Cubillos de Sil, which is located in the North East of the province of Leon, at a distance of 110 km from the capital city, León, and 4.3 km from the mining town of Ponferrada.

The four thermal power generation units of the current power station (different ages and power) are located near the site. Part of the coal supply infrastructure of these units will be used for the new plant and the 400 kV substation.

The approximate geographical coordinates of the site where the power station will be located are.

- Longitude: 42º 36' 49.85" N
- Latitude: 06º 33' 49.24" W
- Altitude: +577 m above sea level

Figure 4.14 Location of the OXYCFB300 plant

The site can be reached directly from the regional road, CL-631 "Ponferrada-Villabilno", through Pantano Avenue. Other modes of transport that service this area are:

- Railway: The coal railway line is located near the power station.
- Airport: The nearest airport is Leon Airport, at a distance of 110 km.

Justification for the Site

The Compostilla Power Station is located in a consolidated industrial area dedicated to generating electricity using coal. It features a range of infrastructures that facilitate the installation of the OXY-CFB-300 plant, as they can also be used by the new power station.

This location offers space, power evacuation capacity, water, coal storage yard, etc. All this makes it a particularly attractive option. In addition, it is in the midst of an industrial area that will favour the installation of new power generating capacity.

Moreover, the existence of coal in the region is a distinct advantage regarding the availability of fuel for the plant, together with the use of the coal management and storage infrastructure, which can handle both local and imported coal.

Finally, in the vicinity of the site chosen, we have CIUDEN's 30MW technology development plant (PDT), which is of interest regarding the use of any experience obtained at a smaller scale.

4.3.1.2 Transport

General Description of the Route

The selected route starts inside the Compostilla Power Station, more specifically in the planned CO_2 capture installations in the MA of Cubillos del Sil, and goes round these installations by the west to then, at Dehesas del Obispo, turns east and runs parallel to the existing infrastructures.

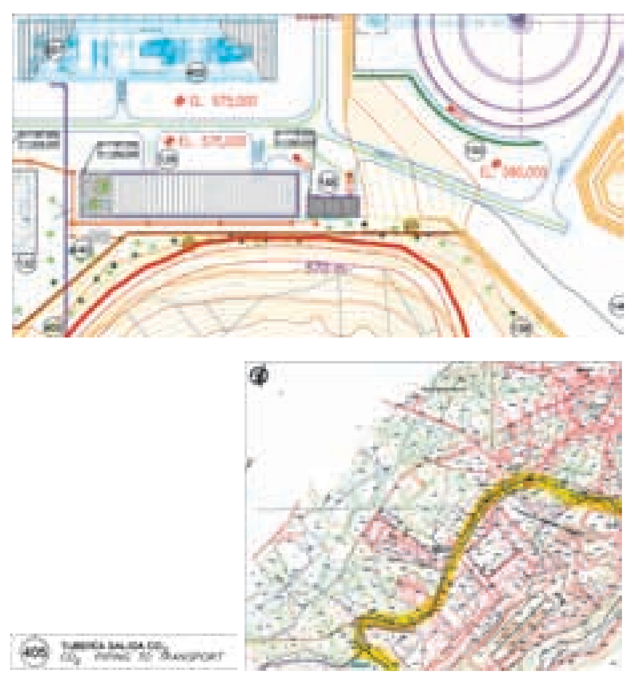


Figure 4.15 General description of the route

Still heading eastwards it comes to the site of La Corela with rugged orography and classified as natural habitat. As it travels through this site, the CO_2 pipeline runs in parallel to the railway tracks, and then crosses the River Sil where it flows into the Bárcena Reservoir.

Then, and still heading eastwards, the CO_2 pipeline runs to the north of the town of Congosto and the south of Santuario de la Virgen de la Peña, now in the Municipal Area of Congosto, where it follows the same layout on the land as the A-6, during several kilometres.

MUNICIPAL LIMITS	Φ	L (m)
Cubillos del Sil	14"	4,910
Congosto	14"	5,363
Bembibre	14"	8,266
Folgoso de la Ribera	14"	9,226
Torre del Bierzo	14"	4,676
Villagatón	14"	9,610
Magaz de Cepeda	14"	4,148
Villameji	14"	9,260
Quintana del Castillo	14"	1,458
Benavides de Órbigo	14"	4,060
Turcia	14"	7,046
Santa Marina del Rey	14"	2,132
Villadangos del Páramo	14"	8,490
Chozas de Abajo	14"	13,830
Ardón	14"	2,016
Vega de Infanzones	14"	3,193
Villaturiel	14"	1,250
Villanueva de las Manzanas	14"	6,737
Mansilla de las Mulas	14"	200
Santas Martas	14"	13,518
Valdepolo	14"	6,507
Santa Marina del Monte de Cea	14"	7,812
Villamol	14"	1,791
	TOTAL LENGTH:	135,499 m

Table 4.15 Municipal limits of the transport pipeline trace

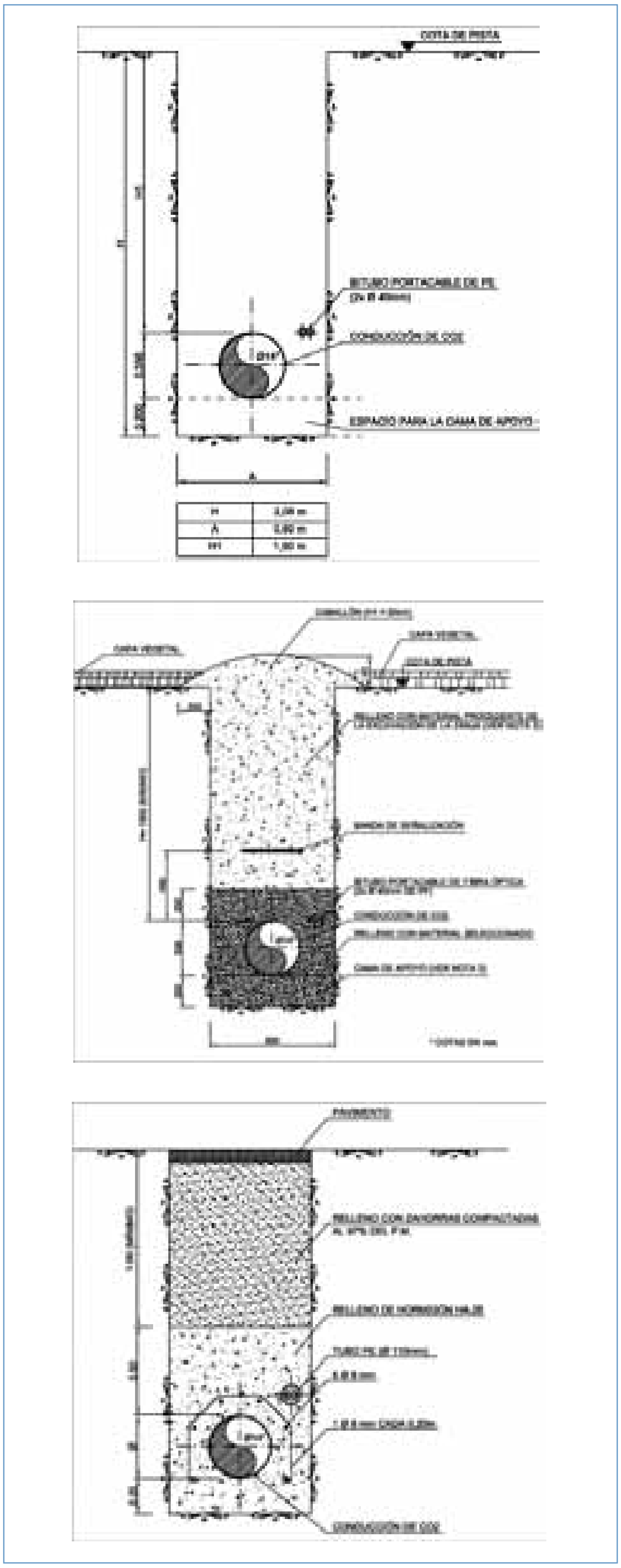


Figure 4.16 Pipeline layout

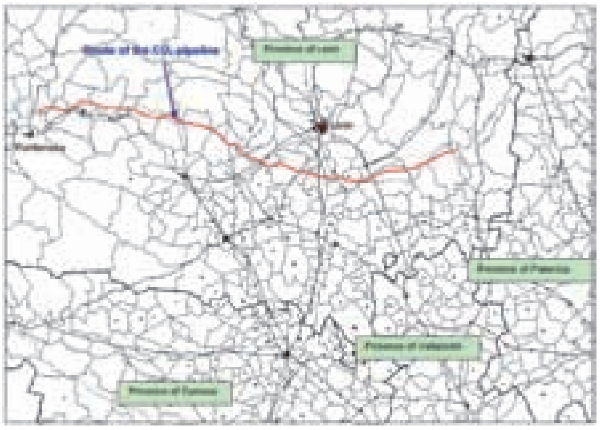


Figure 4.17 Route of the CO_2 pipeline.

4.3.1.3 CO_2 Storage

Location

The intended location of the surface CO_2 injection facilities is also in the province of Leon, about 140 km from the power station, near the provincial border of León and Palencia.

The selected location is in the Duero River basin and the following was taken into account when selecting it: the results of the Appraisal Program and certain socio-economic criteria, such as the low population density of the area (less than 10 inhabitants per km2

Storage will be in a deep saline aquifer from the Cretaceous period by means of a number of injection wells that have not yet been defined, but that will range between a maximum of nine and a minimum of two.

Figure 4.18 Location of the CO_2 pipe and storage

4.3.2 Layout General Description

4.3.2.1 Capture Plant

Initial Design

Several alternatives were studied regarding the installation of the OXY-CFB-300 plant in different areas owned by ENDESA in order to find the most appropriate location.

The approach to these alternatives took into account the fact that the space freed by Groups 1 (currently out of service) and 2 could be used and that the space occupied by Group 3 could not be used under any circumstances. The building of future groups 6, 7 and 8 at the combined cycle plant was also taken into account together with the new coal yard to the north of the current one.

The conclusion, after studying the different alternatives, was that the most advantageous option was to use a plot next to groups 4 and 5. This would avoid the need to remodel or demolish existing structures and enable us to build a "greenfield" project. Furthermore, this proposal provides a larger plot, which makes it possible to optimize the relative position between assemblies in order to minimize large diameter pipe runs.

The advantages of this option are:

- An open plot of the correct size.
- It minimizes the cost of power evacuation.
- It does not interfere with any expansion or future project.

Therefore, in the draft project, the new group lies south of current Groups 4 and 5 and next to the power station's 400 kV substation, on land owned by ENDESA that are part of the municipality of Cubillos del Sil.

In this arrangement, the turbine building, boiler and precipitator are aligned northeast-southwest from the cooling tower of group IV, with the current 400 KV Substation to the west. The ASU and the CPU are placed to the west of the other new units, respecting the easement for the future Montearenas high voltage line. The cooling tower has been planned to the southeast of these facilities, next to the landfill where waste from the Power Plant's Waste-Water Treatment Plant. The altitude of the area varies between +575.0 and +580.0.

The general layout was developed during the stages that followed the Draft project, during the Pre-FEED and FEED phases, when aspects that could be improved were detected. The following describes the considerations taken into account during the seven developments that emerged.

Figure 4.19 General Layout (preliminary)

Figure 4.20 Areas of the overall implementation

Development in FEED Phase

In this phase, changes to and the relocation of the Wastewater Treatment Plant was studied, along with the complete design of OXY-CFB-300, including the coal handling system and its interconnection with the existing system southwest of the plant, the new NHIW landfill located north of the plant and the equipment to operate it and the final disposition of the areas assigned to the ASU and CPU.

The overall implementation was completed in the final phase with a detailed study of the drainage network, and the comprehensive treatment of effluents up to the authorized discharge point. This last phase takes into account the new dimensions of the six main modules, adapted to the latest designs for the Boiler, ASU and CPU, together with the optimization of common services.

COVERED AREAS	
Description	**(m^2)**
Steam turbine/electrical buildings	5,175
Boiler and auxiliary building	15,275
ASU	11,530
CPU	14,997
CW and Cooling tower area	14,147
Wastewater Treatment Plant	20 (-340)
Sub-total (6 areas)	81,464
Rest of areas	116,766
Total covered area	198,230

Table 4.16 Layout covered areas

Below is the final implementation and a 3D view of the plant.

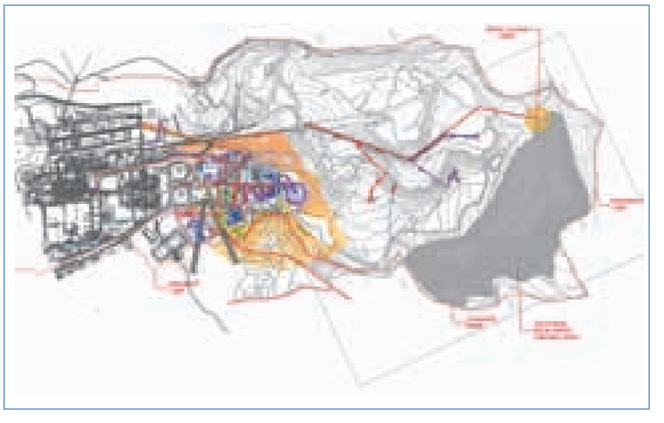


Figure 4.21 Final implementation

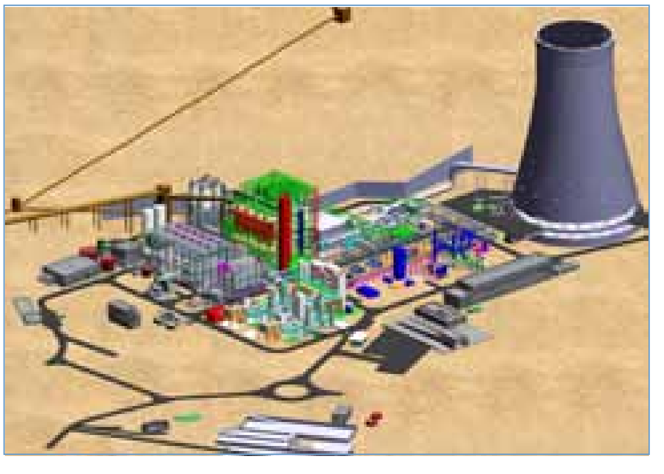


Figure 4.22 3D view of the plant

4.3.2.2 CO_2 Storage Site

The injector wells will place approximately 1.5 km to the south of the appraisal well SD-4, in the southern side of the syncline. Three injector wells will be placed in a line perpendicular to the dip to optimize the sweep efficiency (contact area between the CO_2 plume and the formation water) that would improve the dissolution and residual trapping as the plume moves towards the direction of the dip. Well spacing of 1000m was applied.

Injection facilities are responsible for distributing the flow of CO_2 to the injection wells. Conceptually, their scope begins at the last position of the valves of the CO_2 transport line, whose position is very close to the first injection well (well 19).

The 3 injection wells are aligned and, regarding the distribution of CO_2, it was decided to maintain the 14" pipe design with identical characteristics to the rest of CO_2 pipe. The derivations to each of the 3 wells branch out from this distribution line.

LOCATION OF INJECTION WELLS			
Well No.	UTM X	UTM Y	UTM Z
11b	329,249.23	4,712,410.24	901.67
12b	330,356.14	4,712,136.69	877.14
19	327,808.67	4,712,920.78	943.90

Table 4.17 Location of injection wells

The wells have cut-off, retention, regulation, and bleed valves as well as flow meters to perform injection tasks in safety and in a controlled manner.

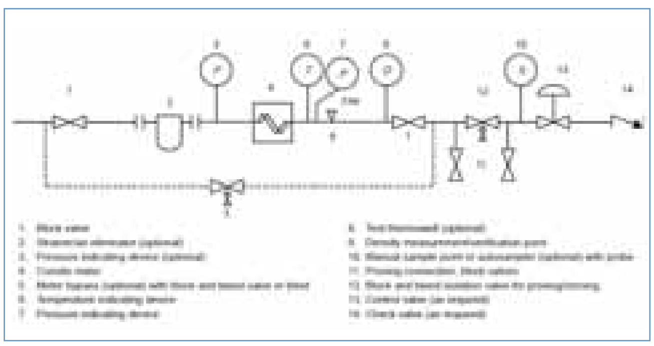


Figure 4.23 Diagram of valves in the injection wells

The electric power for well 19 is supplied at low voltage from position 7 in the valve line while a medium voltage line (50 kVA) has been planned for wells 11b and 12b.

Figure 4.24 Lay-out of injection wells

4.3.3 Existing Installations

The location of Plant OXY-CFB-300 at the COMPOSTILLA Power Plant is adjacent to existing number 4 and number 5 coal fired, 350 MW, units. The implementation chosen as the most advantageous is to place the plant to the south of these groups, next to the power station's 400 kV Substation, which would make it possible to share the following services with the existing plant.

4.3.3. 1 Coal Yard

The existing coal park that supplies the Compostilla power plant will be used. More specifically:

- The current yard will supply the required ready-prepared mix to the new coaling system, as it has the capacity to prepare this mix which was established at 70% coke/30% coal in the design.
- The interface of the new coaling system with existing facilities will be in the existing transfer tower.
- The system will feature reception and storage silos for the ready-made mix, screening and grinding system to achieve the required particle size and conveyor belts to the silos serving the new boiler. The new facility will be situated on the land available opposite the current coal yard transfer tower.

The figure below illustrates the planned layout.

Figure 4.25 Planned layout of the coal yard

4.4 OPERATION

4.4.1 Design Life Criteria

4.4.1.1 Generation and Capture Plant

The OXYCFB300 power plant has been designed considering a 25 years operational life and a maximum of 8000 h per year of effective operation. When facing design life criteria the following has been considered:

- Issues coming from process fluids and process parameters (pressure-temperature) inherently related to ultrasupercritical power plants, considering also that the OXYCFB300 plant is coupled to CCS architecture.
- Issues coming from expected plant operation.

4.4.1.2 Piping and Onshore Facilities

The facilities are designed for a life of 40 years. Where it is impractical for elements of the facilities to be specified with such a life (i.e. joints, bellows, valves trim …) a maintenance routine will be planned.

4.4.1.3 CO_2 Geological Storage

ENDESA has assumed the design life of the site and associated injection facilities for Duero Site to be 30 years but also able to extend the life 10 year more in order to align it with OXY-CFB-300 power plant and potential reservoir operating scenarios.

4.4.2 Operation Philosophy

4.4.2.1 Generation and Capture Plant

The OXY-CFB-300 plant features a Control System consisting of hardware, software and communications networks that constitute the human-machine interface and that controls the operation of the plant. The control system is based on digital technology, built from microprocessors.

The plant's control system makes it possible to control all the systems that make up the plant, including the fluid bed boiler, ASU and CPU plants, turbine island and all its ancillary plants and systems, as well as monitoring and controlling CO_2 transport and storage.

The control system comprises:

- The Control Room equipment, which consists of operating stations to control and supervise the installation, as well as the necessary furniture for the comfort of the operators.
- The Distributed Control System (DCS) itself consists of a set of servers, processors and signal and data acquisition cards installed in control cabinets, distributed throughout the plant. The DCS is the central control system that processes all the signals received from the plant and provides the operating consoles via the communications network.
- The field instrumentation required to achieve the highest possible degree of automation.
- The infrastructure required to operate the devices mentioned above (wires, pipes, trays…).

As for the design criteria governing the plant's protection systems, 3 levels were indicated, according to the minimum redundancy requirements listed below. Reserve equipment, emergency stop buttons, safe positions, protection or alarm and permissive circuits have been planned:

- **Critical systems (Triple Redundant Measures).**
  To be used in critical loops. Critical control loops are understood to be those that, if taken out of service, will severely compromises the availability, security, operational capacity of the plant or may result in catastrophic damage to the plant's main equipment or injuries to people or damage to the environment. This includes, for example, boiler and turbine shut-downs.
- **Integrity of the Plant and equipment shut-down (Double Redundant Measures).**
  Applicable to system and equipment controls that, if operated beyond the limits, could directly affect the operation of the plant, its production, or damage the equipment. In these cases, double redundancy will be used.
- **Non-critical systems (Simple Measures).**
  Applicable to systems for which any control failure can be readily rectified before the operation of the plant or its production is affected. An example of a system of this type is chemical dosage. For these systems, single control and monitoring equipment arrangements are acceptable. The failure of a single component can cause a failure or disruption of normal control and monitoring functions.
- **Start-up reserve equipment.**
  The components of equipment held in reserve, such as condensate pumps or boiler feed pumps, will remain on hold based on the provisions of a protection plan. The backup pump will start-up, if in standby mode, when the pump that is in operation triggers an alarm or when one of the process parameters indicates that the pump in operation has failed. Once the backup pump has started-up, it will not stop automatically unless an operator causes it to stop / trip.
- **Emergency shut-down buttons.**
  Emergency shut-down buttons for major equipment or equipment that may cause damage will be installed in the main control room. This is applicable, for example, to the emergency shut-down of the steam turbine. The buttons will be wired directly to the end control device, which shall be independent of the SCD. The trigger buttons will be red and protected to prevent accidental activation.
- **Fail-safe design.**
  In general the plant will be failsafe. If the control signal or power supply is lost, the system and the control equipment will fail to a position that will not cause the failure / damage of any other equipment.

The alarm and protection circuits are de-energized when they trip. However, if shut-down protection is applied, the necessary redundancy will be implemented as well as the corresponding logical scrutiny (2oo3 ó 1oO2 voting logic) and the power supply will be ensured.

- **Protection or alarm circuits.**

  In general, an alarm is generated when the circuits open (contacts are normally closed or signals are normally energized) and the protection circuits will trigger when signals are not active.

  Some of the plant's control systems will be designed and certified for use in functional safety applications according to IEC 61508, with a SIL based on the study of their security requirements.

This applies, for example, to the boiler's burner management system (BMS) and to the boiler protection system (BPS). In the case of components without SIL, if any, the Supplier will provide the reliability data needed to support the SIS analysis.

Safety systems will ensure the following:

- On-line replacement of components.
- Protection against unauthorized changes to the control program.
- Extensive diagnostic testing on systems with the capability to prepare reports.
- Response time in milliseconds.
- System error checking on all communication and control functions to eliminate false control commands and incorrect data.
  - Conditions.

    Conditions will be used for safety issues and for the sequential start-stop of system equipment. The conditions, timers and signals will be used in the most effective way to ensure optimum operation, the highest level of safety and reliability in any mode of operation and also to minimize the actions of operators and equipment failure.

CPU Control Strategy

The theoretical CPU load profile is continuous 100% and 40% operation with two 100%-40% load shifts per day, as illustrated in the following Figure:

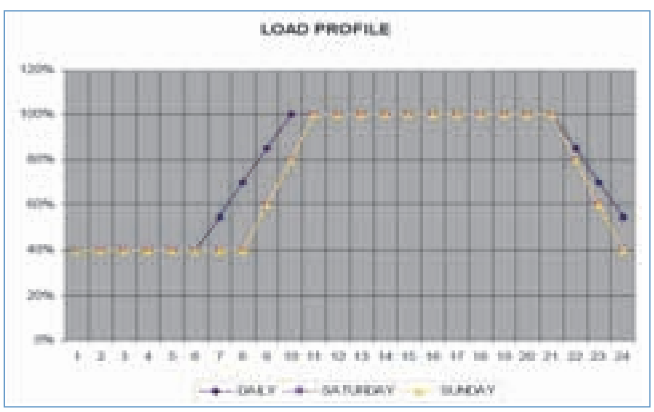


Figure 4.26 Theoretical CPU load profile

The OXY-CFB-300 facility is expected to participate in the Spanish electrical system Secondary regulation. Consequently, the CPU shall be configured to allow efficient operation under the resulting load profile.

OXY-CFB-300 operation under Secondary regulation is expected to result in load oscillations between 40% and 50% at night and between 75% and 100% during daytime; refer to "Power Plant Expected Schedule",

Flue gas feed flow and resulting CO_2 product flow are expected to continuously oscillate with load variations; as a minimum CO_2 quality to be in accordance with requirements listed in Table 4. CPU to be configured to avoid wide variations in CO_2 Product quality.

CPU to be configured to provide a continuous delivery of stable high pressure supercritical CO_2 flow.

"CPU follows" philosophy: CPU operation depends on the gas flow exhausted from the boiler, which in turn depends of plant operating load. In no case shall CPU operation affect boiler operation. CPU rapid-response vent capacity shall be installed to prevent boiler fans from tripping (this is particularly important during boiler ramp-up transitory).

Predicted architecture of fans and blowers upstream the CPU is illustrated in the following Figure.

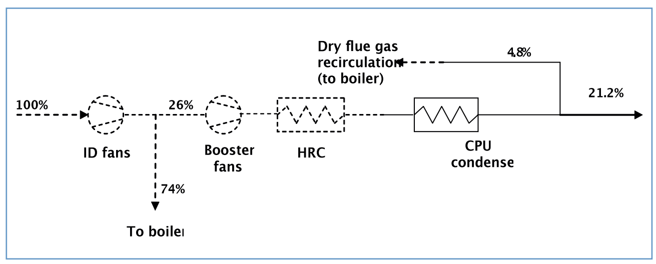


Figure 4.27 Equipment architecture at boiler exhaust-CPU inlet (by-pass lines and control dampers not shown)

Note: *(Dashed: boiler scope; Plain: CPU scope; Numbers: gas percentages when operating at design load)*

Distributed Control System (DCS)

The control system shall include the facilities and systems necessary to operate the plant.

The normal operational mode for the installation is automatic, with the possibility of manual controls from the operator stations.

The control system is based on the remote start-stop of the auxiliary mechanical elements from the operating stations. The boiler, steam turbine, CPU plant and ASU plant can be started and stopped remotely from the DCS operation stations in the control room. The plant can be started/stopped automatically from the highest hierarchical level by means of the plant's start and stop sequences.

Operating Modes

Due to the intrinsic nature of the plant as a "technology demonstration project", plant operation will require a certain level of flexibility.

Normal Operation

The OXY-CFB-300 plant has been designed to operate as a base power station (i.e. permanently in operation), following the demand curve of the Spanish electricity system for a minimum of 25 years of effective operation. It has not been designed, however, for frequent start-ups and shut-downs.

Operation in Oxy-fuel combustion mode ("OXY" Mode): 100% Load

The plant has been designed and optimized for operation in "oxy" mode. It is in this mode for which the 100% load has been defined (matching "load" to "feedwater flow") and that ensures a gross output of approximately 345 MWe at full load.

During operation in "oxy" mode, all the facility's equipment must be operating, including the flue gas recirculation system ("FGR System") and the flue gas heat recovery system ("HR System") .

Additionally, an essential condition to operate in this OXY mode is having an adequate CO_2 transport and injection capacity. If this capacity is not available, it would still be theoretically possible to operate, since the CPU has been designed with full venting capacity.

The average raw power at the alternator terminal expected at full power exceeds 340 MWe, according to the corresponding thermal balance. At full power, the steam turbine will operate at pure sliding pressure (VWO mode) and reach full power with steam pressures of 270.4 bar(a) upstream of the control valve in the HP section of the steam turbine and about 55.6 bar(a) upstream of the intercepting valves of the MP section of said steam turbine and maintaining a constant pressure of 0.042 bar (a) in the condenser.

Operation in Conventional Combustion Mode ("Air" Mode): 90% Load

The plant has also been designed to operate continuously in "air" mode, to the point that it is in this mode when net power production is maximised (as the ASU and CPU do not consume electricity). Although the operational differences between "air" mode and "oxy" mode are significant, operating in conventional mode (with air as oxidizer in the boiler) will be strictly necessary in the event of any prolonged unavailability of the ASU and, to a lesser extent, of the CPU and of the CO_2 transport/injection facilities. More specifically, boiler blowdown and the startup of the boiler up to 40% load (technical minimum) will be performed in "air" mode.

In detail, the differences in both modes of operation are:

- In "air" mode, the steam flow at full load is substantially lower (approximately 10% lower) than that produced in "oxy" mode and, consequently, the gross power output will also lower than the design figure. Full load operation in air mode is limited by technical criteria; particularly flue gas speed.
- When operating in "air" more, the ASU, CPU, the equipment linked to CO_2 transport and the boiler flue gas recirculation system are not in operation and, therefore, the net yield and power increase.
- The composition of the flue gases is very different. When operating in "air" mode, the density of the gas falls by approximately 24% (due to the dilution of CO_2). In practice, this implies a reduction in the mass flow (maintaining constant velocity) and has an impact on the amount of gases to be recirculated in "oxy" mode (gas velocity must be constant). Additionally, the heat capacity of the said gases also decreases.
- Fuel consumption at full load is lower in "air" mode. Consequently, the consumption of limestone and ash flow is also lower.
- When operating in "air" mode, the HRS will not heat the O2 produced in the ASU, but the combustion air.
- When operating in "air" mode, the gas flow actually discharged to the atmosphere is considerably increased (tripled). The temperature of the flow is similar in both modes, but the increase of the flow and the fact that it is discharged through the cooling tower affects the draugth of the tower.

Operational Flexibility

From the standpoint of operational flexibility, the plant has been designed to operate without restrictions either in "oxy" or in "air" mode and it is not necessary to interrupt the electrical power output in order to switch between modes. This feature provides a degree of flexibility from the viewpoint of electric power produced, as exportable net power is considerably higher when operating in "air" mode (12% higher, approximately, when operating at full load).

However, if due to reasons of demand (or other unavailability of any of the plant's facilities) it is not necessary to operate at full load, the boiler, which is the most limiting element from the point of view of load variation, allows the range of flexibility listed in the Table below.

The continuous operating range is between 40 and 100% of boiler load, considering that the boiler load is equivalent to the flow of feedwater. Below 40% boiler load, permanent operation with solid fuel is not possible. This load level must only be achieved in "air" mode as the absence of a stable flow of flue gas makes flue gas recirculation impossible.

OPERATIONAL FLEXIBILITY OF THE BOILER	
Load	**Fuel**
60% - 100%	Load Range using coal/petcoke as fuel. Supercritical operation
40% - 60%	Load Range using coal/petcoke as fuel. Subcritical operation
0% - 40%	Not designed for continuous operation or oxycombustion. Use of start-up burners required.

Table 4.18 Operational flexibility of the Boiler

For the boiler, the transition between 40% and 100% load is achieved according to a certain ramp defined by the supplier of the equipment and according to the secondary regulation of Spanish electricity market. This ramp does not exceed 3% per minute, while the initial transient in firing rate can reach 30% per minute (in the case of very sudden demands of load variation). The steam turbine operates at sliding pressure during continuous operation. Therefore, its adaptation to transient operations involving moderate load variations can be considered immediate.

The ASU and CPU have been designed taking into account the operational flexibility of the boiler.

On the other hand, the CPU also has sufficient venting capacity to derive all the gas flow to the cooling tower. Such venting capability make it possible to separate its operational from the state of the site. Consequently, the boiler is the limiting element and the one that will react more slowly to any sudden load variations.

External Regulation

The plant has been designed to follow the demand of the Spanish electricity system. The figure below shows the daily load cycle of the design.

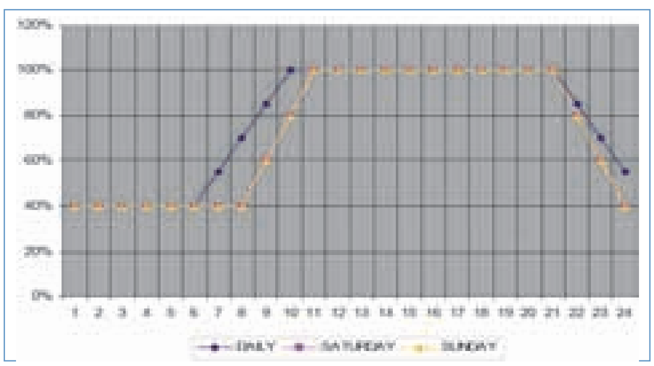


Figure 4.28 Designed load profile for the power station

From the point of view of external adjustment, the plant has been designed to participate in the primary and secondary regulation of the electricity system to which it is connected according to the operating procedures of *Red Eléctrica de España* (PO7.1 for the primary regulation and PO7.2 for secondary regulation).

Primary regulation, which will be conducted by the turbine control valves, implies load variations of 1.5% of the maximum load will be possible in order to recover the grid frequency in 15 sec once it has varied by 100 mHz.

Secondary regulation is designed according to the following figure, so that the maximum rate of change in load required is 3% · of the maximum load per minute.

4.4.2.2 CO_2 Transport Pipeline and Storage

The well signals for control and monitoring of the injection wells will be routed to the fibre optic cable available for the control and communications of the injection facilities and the transport pipeline, and routed to the Power plant control room. Some of the signals from the wells will be used for the control of the injection equipment.

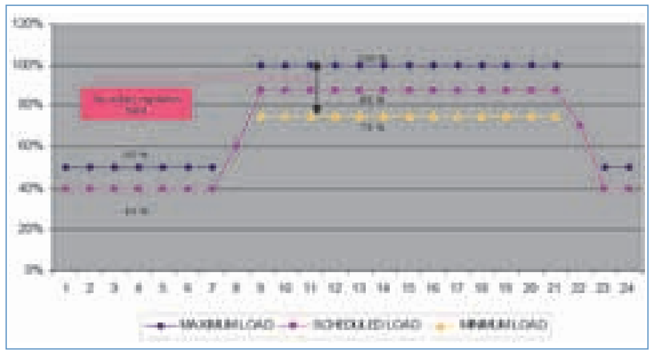


Figure 4.29 Secondary regulation profile

The main power supply to feed the injection wells will be from the power supply available in the injection facilities. For the monitoring wells, and depending on their location, a separate study of the power supply and data transmission means shall be done, but does not form part of this design scope.

Initial Startups

All line pipe / piping must be thoroughly cleaned of debris and scale and this must be done prior to hydrostatic testing, thoroughly drained and dried.

Initial filling of the pipeline will include dewatering after hydro-testing, purging and initial pressurization of the pipeline. This operation will be manned and monitored at all times. In addition, coordination with the CPU facilities will be required to ensure proper temperature and pressures are maintained during the pressurization.

Subsequent Startups

During restart the mainline valves should be opened in sequence starting from the valve closest to the CPU. Each bypass valve should be opened first to ensure that there is minimal differential pressure across the mainline valves.

Emergency Shutdowns

Pipeline rupture/fracture event

An emergency contingency plan is in place with an emergency contact list for local governmental authorities and key area contacts. The rupture can readily be identified and located with the leak detection system in place. Once identified, the affected section of pipeline between the block valves must be immediately isolated with the use of the remotely operated block valves. No other action should be implemented until an inspection of the site of the rupture/fracture is conducted and assessment of damage documented. A situation specific restart re-pressurization plan will need to be implemented after complete repair of the pipeline.

Emergency Shutdown (ESD)

Levels of Emergency Shutdown:

- ESD -1 – this level of release of CO_2. Level one ESD will shutdown the entire pipeline, send a command to either shutdown the compressor or put it in recycle mode, close all mainline block valves in order segment the pipeline, and shut.
- ESD-2 – Level two ESD is local to each wellhead and will shutdown only the affected well in the event of a wellhead rupture or a significant CO_2 leak is discovered.

4.4.2.3 Full System Metering And Monitoring Concept

The most significant components to monitor are H_2O, H_2S, CO and O_2. Each of these components significantly impacts the potential for corrosion in the pipeline. The CPU analyzers data are available for the pipeline control system.

Process monitoring CO_2 Pressure above 80 bar to avoid pressure drops (being out of the two phase region). Process monitoring CO_2 Temperature above 10ºC to avoid water condensation within the pipeline. Flow control is maintained at each well site. Normal depressurization should be performed with a complete notification, possible evacuation and monitoring of the surrounding areas near the blow down riser.

Monitoring, Verification and Accounting

The monitoring, verification, and accounting (MVA) plan for a storage project will have a broad scope, covering CO_2 storage conformance and containment, monitoring techniques for internal quality control, and verification and accounting for regulators and monetizing benefits of geological storage. In OXY-CFB-300, the MVA is an important part of making storage of CO_2 safe, effective, and permanent in all types of geologic formations.

OXY-CFB-300 MVA plan will be developed in accordance with Spanish Act 40/2010 for Geological CO_2 Storage, but also it will include components for meeting regulatory requirements, monitoring the CO_2 plume, monitoring water/brine behaviour, detecting potential release pathways, and quantifying releases. In this way, our MVA defines monitoring objectives, risk-based performance metrics, and resources allocated for monitoring activities. In addition, a comprehensive plan includes the reviewed of monitoring tools' effectiveness, stakeholder communications, procedures for documenting monitoring activities, and processes used to evaluate monitoring performance.

Updating and validating of reservoir simulation models with data from the monitoring program is a primary activity in the Carbon Dioxide Injection MVA. Demonstrating the integrity of a CO_2 injection project through monitoring the behaviour of injected CO_2 will be integral to gaining community support for the subsurface injection of CO_2. Key objectives for the monitoring and verification activities therefore include:

- Generating clear, comprehensive, timely and accurate information that will be used to effectively and responsibly manage environmental, health, safety and economic risks and to ensure that set performance standards are being met.
- Determining, to an appropriate level of accuracy, the quality, composition and location of gas captured, injected and stored and the net abatement of emissions. This should include identification and accounting of fugitive emissions.
- Demonstrating that the residual risk of leakage is acceptably low at the time of site closure.

The following table shows the current estimated well operating range.

DUERO SITE: OPERATING PARAMETERS RANGE	VALUE
Pressure at surface (barg)	0 - 110
Pressure at BH (barg)	0 - 300
Temperature at surface (°C)	-20 - 50
Temperature at BH (°C)	0 - 60

Table 4.19 Current estimated injection wells operating range

4.4.2.4 Full System Leak Detection and Venting Philosophy

Piping and Onshore Facilities

Full system leak detection

Leak Detection System (LDS) does comply with the following requirements:

- Detect leakages defined for each line, including its location.
- Limit false alarms.
- Minimize the lack of sensitivity in detection leakages while changes in the normal operation like changes in the injection conditions.

Leak Detection System (LDS) can cope with the following operation situations:

- Distinguish pressure changes because of temperature changes and not because of leakages.
- Use the available time windows of the SCADA to do its calibrations and tests.
- Understand the changes of all control parameters in blocked or out of order lines exposed to solar radiation or adverse environmental conditions.
- Be aware of the temporal variations of the control parameters due to operational changes in the injection, as a well shut-down, or the different ways to operate them.
- Take into account non uniform flows in the system.
- Take into account transient conditions (start-up, shut-down, compressors replacement…)

Venting

Scheduled venting operations may occur during the lifetime of the pipeline. These venting activities can be required due to:

- Commissioning
- Pre-Commissioning
- Hydro test
- Repair of a pipeline section
- Repair a main line block valve
- Batch of CO_2 is contaminated (High Water Concentration)

When venting occurs, the block valves on both ends of a section are closed and one vent line is opened. The high pressure CO_2 is released from a 3-inch vertical vent line located on the top of the valve station.

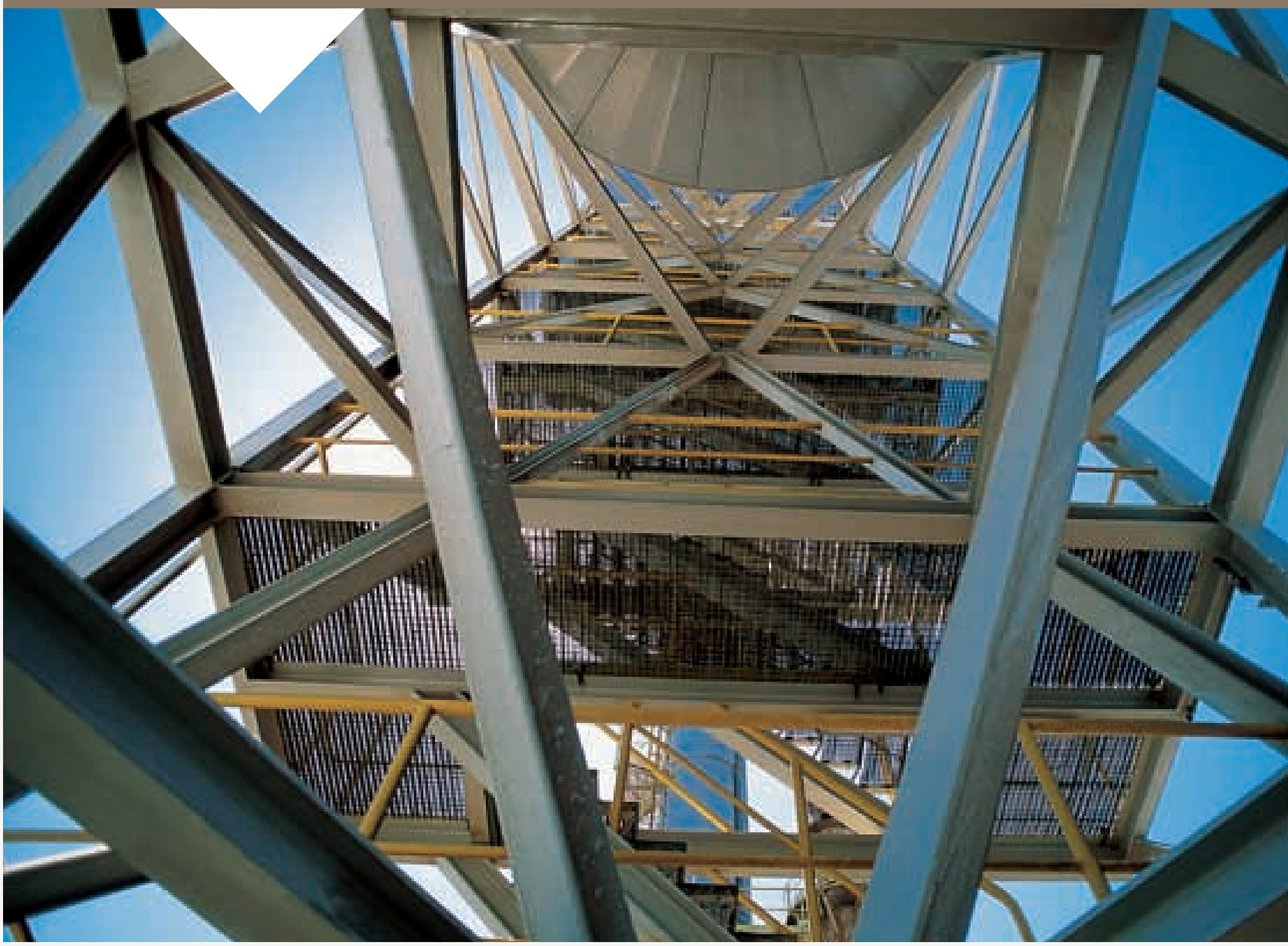
All valve stations have the same design and are spaced to block in similar pipeline lengths. While the pressure along the pipeline varies, the blocked in pressure does not vary enough to change the state of the material or properties of the initial release. Therefore, venting from any valve station along the pipeline will produce similar results.

The venting operation begins with closing the block valves at valve stations at both ends of the desire pipe length to be vented. Then, the valve station is fully opened and CO_2 is vented vertically. The venting operation is designed to avoid formation of free water.

A pipeline segment of 25,000 meters long will require approximately 4 days depressurizing. Release rates of 51.7 kg/s, 32.9 kg/s and 1.3 kg/s describe the release rate at 10 minutes, 60 minutes and 4 days (Terminal Venting Rate) after the venting starts, respectively

Storage

In storage site, in order to avoid potential leakage risks and control through wells, several devices will be installed.



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5

Technological Development Plants

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5.1 CAPTURE

5.1.1 Description of the Test Facility

As CFB technology has been commercially demonstrated for conventional air firing but additional efforts to ensure the technological applicability to oxyfiring were required, the Technological Development Plant (TDP) owned by CIUDEN includes a 30 MWth Oxy-CFB boiler as its core unit, using the same technology that will be incorporated to the commercial Demo Plant. A complete test program has been carried out in this TDP, with the aim of validating the full chain of processes from fuel preparation to CO_2 purification, producing a stream product ready for transport and storage in order to obtain enough data for scaling-up the technology.

The configuration of the TDP is flexible, modular and versatile in order to test a wide range of operating conditions including different coals and combustion conditions from air mode to oxymode, using independent but interconnected units for simultaneous or separate operation.

The TDP incorporates advanced equipment for the development of oxycombustion technologies, namely (see following figure):

- Fuel preparation system.
- Circulating fluidized bed boiler (CFB up to 30 MWth).
- Pulverized coal boiler (PC – up to 20 MWth).
- Flue gas cleaning equipment:
- Cyclones
- Selective Catalytic Reduction (SCR) unit for NOx abatement
- Bag filter
- System for collection, transport and storage of solids and ashes
- Flue gas recirculation (FRG) and oxidant preparation systems.
- CO_2 compression and purification unit (CPU)
- CO_2 transport test rig.
- Auxiliary service systems (oxygen, compressed air, LNG as auxiliary fuel, raw water, demineralised water, cooling water, CO_2 as inert fluid, etc).

Figure 5.1 CIUDEN´s Technological Development Plant, close to the ENDESA Compostilla Power Station

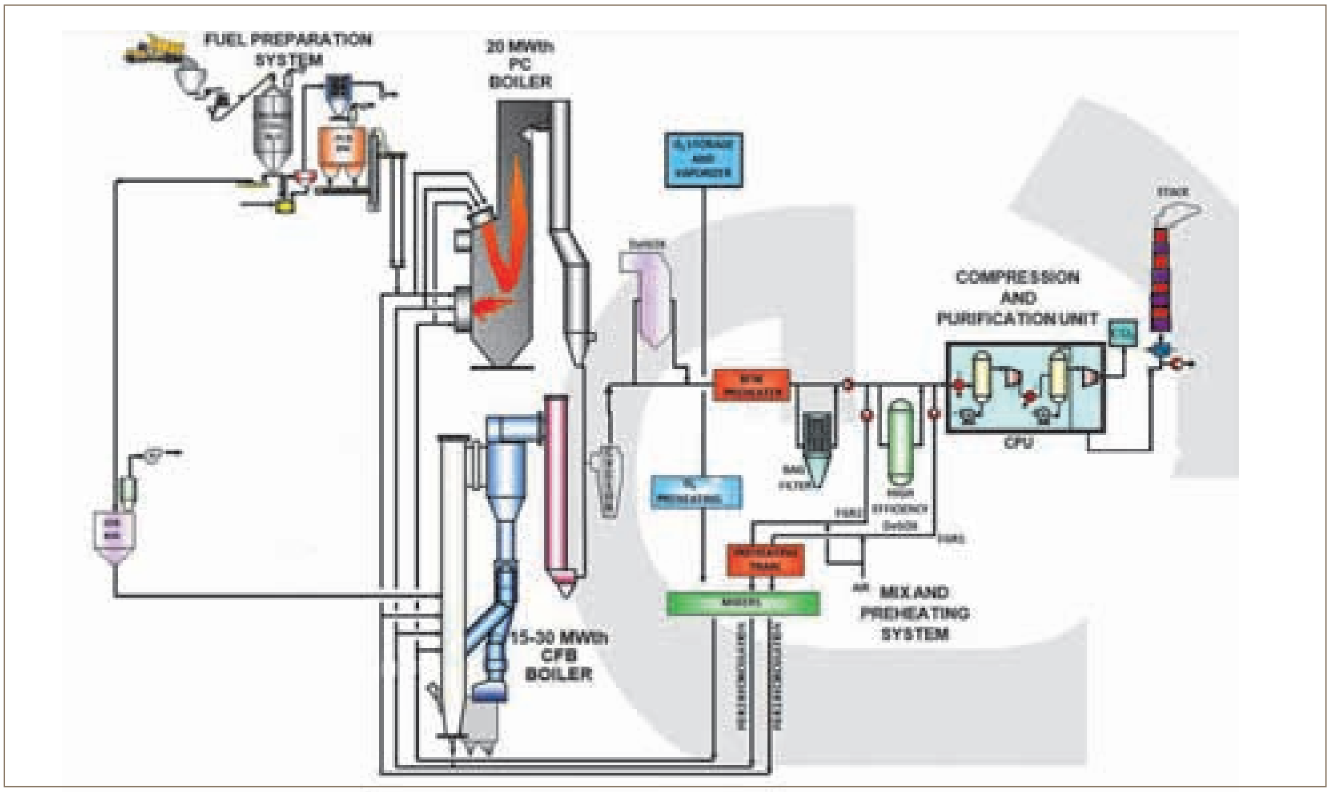

Figure 5.2 Schematic process flow diagram of CIUDEN's TDP

The variety of fuels to be used includes different ranges of coal and biomass. In particular, anthracites, bituminous and sub-bituminous European indigenous coals and pet coke were tested. This approach provides a valuable support to the requirements of ENDESA regarding fuels utilization at the Demo Plant, and will contribute to demonstrate the capabilities of the OxyCFB technology to process different fuels of interest for other Utilities in Europe in an efficient way.

As the Reader can see, CIUDEN's TDP includes the necessary units to obtain the CO_2 stream ready to be transported considering an semi-industrial size, roughly 1:30[12] scale compared to the Demo Plant.

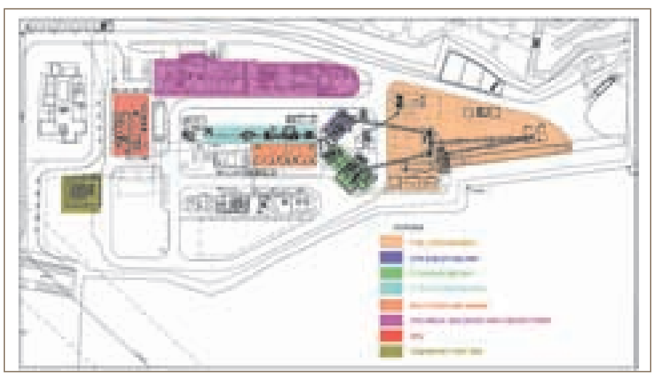

Figure 5.3 TDP layout

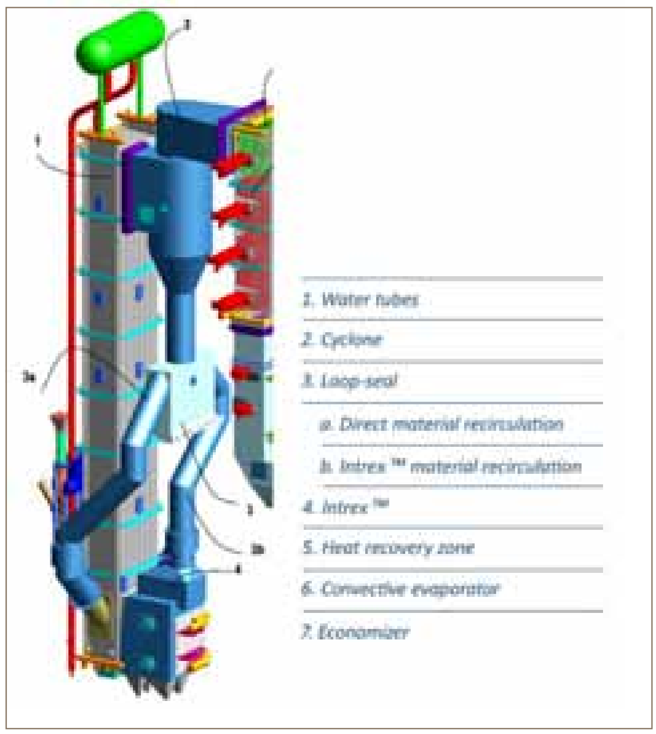

Figure 5.4 CIUDEN pilot CFB boiler

12 Average ratio based on boilers design thermal loads.

Feed water is heated using an appropriately designed economizer and the steam is produced in a natural circulation combustor circuit comprising downcomers, evaporative surface, riser tubes and steam drum.

The boiler heat recovery zone contains an evaporative tube bundle and economizer, and the steam-cooled walls act as the first superheating stage. It is also provided with several sootblowers distributed in the heat recovery zone, the convective evaporator and the economizer.

5.1.2 CPU subunits

CIUDEN´s Compression and Purification unit (CPU) has the capacity to capture CO_2 from oxy-combustion flue gases. The CPU has been designed in a modular way that allows different process-system configurations by having the possibility to by-pass some of its sub-units. As the rest of the TDP, the CPU size has been chosen to facilitate the testing of technologies that will be 'upscalable' to the size required for a commercial demonstration unit while maintaining a reasonable cost and power consumption.

In a general view, the unit comprehends two main parts:

- Warm section or pre-treatment part: This has been sized to treat the whole flue gas flow produced in either the Pulverised Coal (PC) or the Circulating Fluidised Bed (CFB) boilers. This has been done in order to have the possibility to test innovative flue gas scrubbing systems, filtration and drying at a sufficiently large enough size to allow the extrapolation of the design at a commercial scale as a next step. In terms of equivalent "CO_2 capacity", this important part of the unit could be rated as a 165 tpd.
- Cold section: at a commercial scale, centrifugal technology would be used for CO_2 compression. However, the CO_2 flow at CIUDEN is not sufficient to make the implementation of this type of machines economically feasible so alternative technology, such as reciprocating compressors, must be used. Since centrifugal compressors are not used, the compression and cryogenic separation parts of the process have been scaled to produce 10 tons per day of CO_2 in order to reduce the overall investment cost of the unit. In addition cryogenic technology is well probed at all sizes. With such capacity, the unit still demonstrates a capacity larger than the majority of the CO_2 capture pilot plants installed worldwide or in progress for coal power plants.

5.1.3 Measurement and Data Acquisition

The instrumentation of the CFB boiler consists of around 800 measurements in addition to the instruments for motors, frequency converters and valve actuators. This instrumentation mainly comprises temperature and pressure measurements, heat flux profiles in boiler, flow meters and gas analyzers.

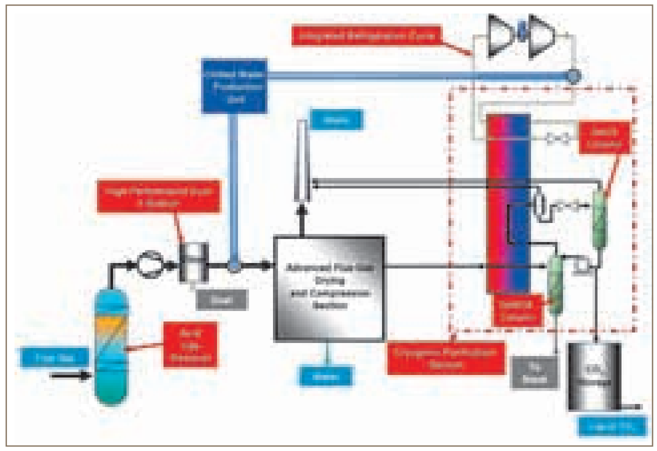

Figure 5.5 Simplified process block diagram

The following figure shows the minimum instrumentation necessary to close the mass and energy balance of the boiler i.e. flows, temperatures, pressures and compositions of the inputs and output streams etc. In addition to those shown, there are a number of measurements allowing mapping out detailed conditions inside the combustion process.

In the flue gas recirculation system and fuel preparation system there are almost 400 additional signals corresponding to its own instrumentation consisting of flow meters, gas analyzers, weighting cells, flow velocity meters and temperature and pressure measurements.

All the above-mentioned signals are collected in the DCS (Distributed Control System) where they are recorded and saved in the history database to assist in data analysis.

The DCS is a single centralized platform capable of supporting any commercial communication bus system (modbus, profibus, Fieldbus ...) that allows the diagnosis and the programming of the different devices from a "single control desk".

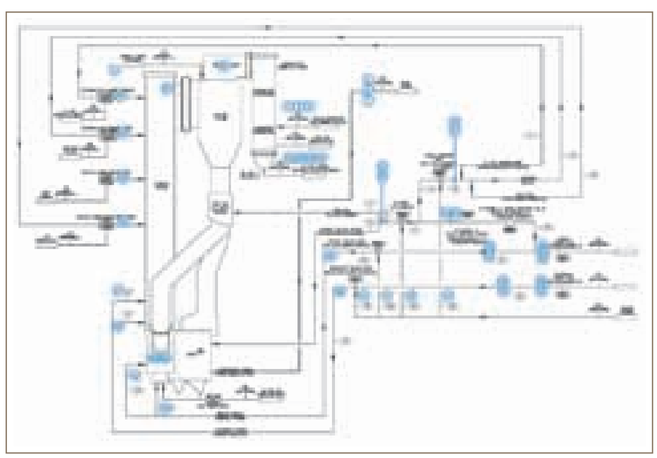

Figure 5.6 CIUDEN pilot CFB boiler PFD including instrumentation locations

5.1.4. CO_2 Capture Test Results and Conclusions

Both CIUDEN´s TDP and the Demo Plant incorporate, in the core unit (CFB boiler), a set of additional process units allowing the production of purified and compressed CO_2 for transport and storage.

Under this task, long duration runs for the optimization of operating modes, dynamic performance and control strategies were performed jointly by the Consortium, searching for the most efficient procedures to achieve a safe and reliable operation, to know the load follow-up capabilities, to develop shut-down/starting-up routines and to carry out the performance of the integrated TDP.

These tests were carried during the last quarter of 2012. Originally the test program was divided in six main blocks with different goals for each one:

- Base Case: Stable Operation Integrated plant: a base line was established for different loads in the CFB boiler and in the CPU (mainly working with the CPU warm part due to the CPU cold part was designed for a constant flue rate). The fuel used was local anthracite with coke (ratio 70/30 in weight basis).
- Boiler Testing: this block is focused on the CFB boiler so the CPU was in operation always when possible.
- Air Separation Unit (ASU) Transients: considering that a future commercial plant will include an ASU and that CIUDEN´s TDP has the oxygen supply from pressure vessels, common failures or malfunctions in a commercial ASU were simulated in CIUDEN´s plant to know the influence in the CFB boiler.
- Integrated Plant Transients: focused on the integration of the plant, this block and the next one could be the most representative blocks; in this case, increase and/or decrease of loads and malfunctions were done in the plant in order to study how the CPU works in accordance with the CFB boiler considering a near-zero emission plant.
- Emissions and CPU Integration: during this block, increasing of air ingress upstream the CPU, effects of SOx peaks produced in the CFB boiler and analysis of SOx and NOx removal in CPU were studied.
- Second Fuel: in terms of tests, this block was planned in a similar way compared with the first block with the exception of the fuel; the fuel tested was bituminous coal.

After the result analysis, exceptional inputs were provided to the engineering design of the commercial power plant and a very valuable operational experience to ENDESA´s staff, including:

- Infiltration reduction.
- Integration of the CFB & CPU units.
- Variation in the composition of flue gases fed in the CPU.
- Integration of the CFB & ASU.

5.2 TRANSPORT

To complete the CO_2 Pipeline Specific Studies, different experimental tests have been made on the CIUDEN transport test rig. Real CPU composition gases from CIUDEN's TDP were processed in the closed-loop test rig. Major safety issues associated with CO_2 transport by pipeline were intended to be identified, in order to develop the necessary health and safety knowledge associated with pipeline management and operation. Special attention was to be paid to the presence of impurities, material failure, corrosion and outside force.

To support this task, a CO_2 closed-loop transport test rig has been designed, constructed and operated by CIUDEN at the TDP. Its design covers a wide range of operating conditions compatible with the recommended general guidelines for CO_2 transport. The experimental program has dealt with the effects on pipeline performance of the following parameters: CO_2 composition from the oxy-CFB process and materials behaviour and process performance (corrosion, pressure and temperature changes, pressure drops in pipelines and accessories).

Figure 5.7 Aerial picture of CIUDEN's TDP

5.2.1 Description of Test Facility

The facility consists of a 3,000 m long closed pipe loop, and some experimentation areas, apart from the main equipment and instrumentation for the operation of the rig. The closed loop is divided into 10 different pipe grids of 300 m each, with a 2" diameter. Any of the grids can be bypassed, so that the length of any run can be set from 300 to 3,000 m.

The CO_2 transport rig is located in a closed, thermally isolated building with temperature control, except for the two pumping units used to transfer the liquid CO_2 from the TDP. The aim of the building is to maintain the temperature as constant as possible for the experimentation process, preventing the effects of ambient temperature and thus approaching the isothermal transport conditions that are typical of the buried sections of a pipeline.

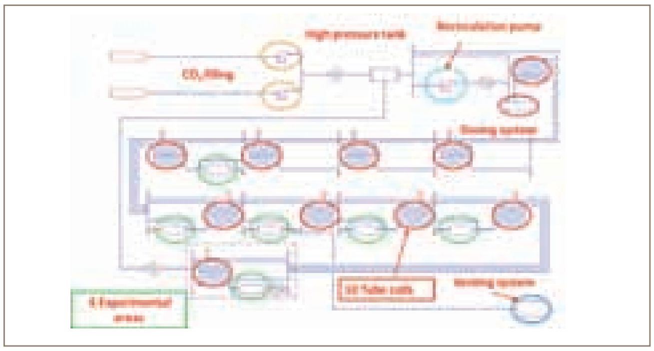

Figure 5.8 Transport rig PFD

The main units of the installation, as seen in the upper figure are:

- Pumping system to fill the closed loop rig.
- High pressure vessel to avoid fluctuations in the flow.
- Recirculation pump and heat exchanger system in order to set operation pressures and temperatures.
- Dosing equipment to add impurities and contaminants and simulate different CO_2 stream compositions. Any tailor-made stream with substances such as H_2O, NOx, SOx, N2, O2, Ar, CO, H2, H2S and CH4 could be achieved.
- Tube coils with variable length and different materials:
  - Stainless steel 316-L
  - Stainless steel DUPLEX 2254
  - Carbon steel A106B
  - Experimentation areas such as:
    - Pressure drops
    - Instrumentation testing
    - De pressurization
    - Corrosion and material testing
    - Leaks

In the following table, a summary of the main design parameters of the rig are shown:

Operating P (barg)	80 - 110
Operating T (°C)	10 / 31
Pipeline size (inch)	2
Total pipeline length (m)	3,000
Recirculation Pump (m^3/h)	15 (Gear pump)
High Pressure Vessel (m^3)	4.5
Pressure Drop (bar)	30
Building (m3)	23x18x8.5
Pipe material	CS (+ 2 SS tube coils)

Table 5.1 Design parameters of the transport rig

The transport rig has the necessary safety measures to assure the safe operation of the tests.

By means of experiments in the transport rig, the idea is to characterize the behaviour of the CO_2 transported and its influence on several parameters, materials, etc. The main characteristics of the installation is that is large size, and the ability to make dynamic tests on a given CO_2 flow in conditions similar to those in a real pipe, will make it possible to scale up of the results.

Figure 5.9 Partial view of the transport rig at CIUDEN's TDP

5.2.2 CO_2 Transport Test Results and Conclusions

The test program consisted in two main blocks: characterization tests and parametric tests. The first ones aim to obtain in-depth knowledge of the plant itself, and understand how the installation behaves and what the limits for experimentation are. The parametric tests were done in a continuous manner, since the experience obtained during the commissioning of the unit showed that start-up and shutdown times should be minimized since they take quite a few hours to stabilize the rig, while transition between different conditions (P & T) can be reached in less than an hour.

Each session consisted of several tests. The average stable time for each test was between half an hour and an hour, after stable conditions were reached. The main variables considered to define stable conditions are: pumping outlet pressure, flow-rate and pumping outlet temperature. All the sessions have basically similar structure but different operating parameters. The operation ranges were set between 60 and 100 bar, and from 12 to 27 °C. The fluid was in dense phase.

5.2.2.1 Parametric Tests

Session 1. CO_2 from CPU

Test runs carried out during Session 1, comprised a total number of 27 tests of stable conditions under different scenarios. The study of fluid properties varying pumping outlet pressure and pumping outlet temperature were the main goal. The CO_2 circulated through two different ways:

Via tube coils: For each pair of pumping outlet pressure and pumping outlet temperature, the outlet temperature of the intermediate heat exchanger was varied.

Via pressure drop valves: The last test consisted on running the installation for several hours at fixed pumping outlet pressure and pumping outlet temperature with CO_2 from the CPU to evaluate the system behaviour under steady state conditions.

Session 2. Contaminants Doping

The test runs carried out during Session 2 comprised a total number of 12 tests of stable conditions under different scenarios. The study of fluid properties and behaviour varying pumping outlet pressure and pumping outlet temperature was the main goal when increasing the concentration of certain contaminants expected in real captured CO_2. Priority was given to the increase of water content, N_2O and O_2. A doping sequence was followed to identify possible responses from the unit. In addition, at night during this session, the unit was kept closed to evaluate stagnant conditions and system evolution. Each component composition has been recorded in the analysers' software as well as in the DCS. Below Table 4 showing contaminants measured.

5.2.2.2 Results

Due to the high level of monitorization that the transport rig has, a lot of signals and valuable data have been gathered through the DCS. The study of the data gathered, is important and useful information to understand the behaviour of the fluid and its effect on the transport infrastructure, such as pipelines and accessories, for the engineering and even future management of the transport infrastructure in Phase II.

5.3 CO_2 STORAGE

5.3.1 Site Selection and Geological Characterization

The site selection phase consisted in the study of a set of pre-existing data from different areas, where the Hontomín geological characteristics, as well as the amount of available and valuable information of the underground structure, allowed the selection of this site, for the consequent detailed characterization.

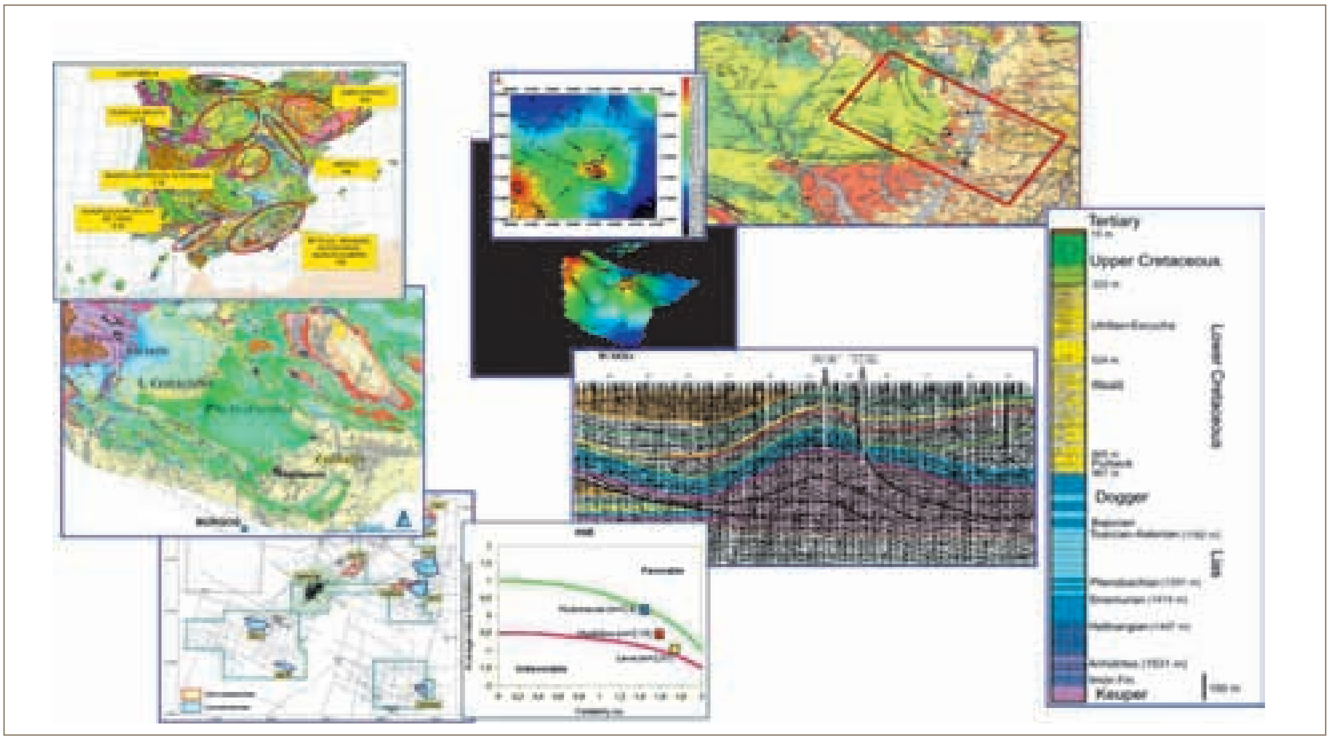

Figure 5.10 Site selection studies

5.3.2 Plant Components

The Technological Development Plant for CO_2 geological storage (hereafter TDP) shall consist of the following elements:

- Injection well (H-I).
- Monitoring well (H-A).
- CO_2 injection plant.
- Water treatment plant and ponds.
- Auxiliary buildings.

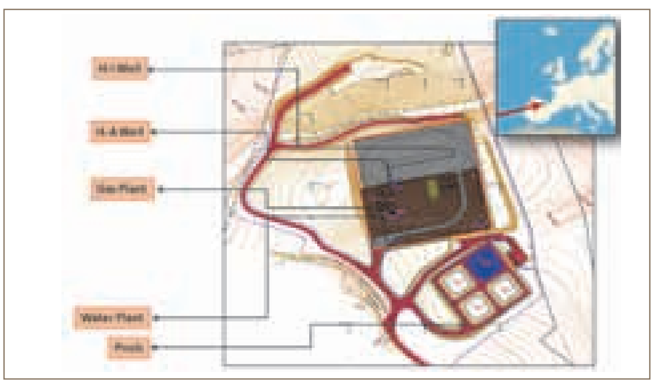

Figure 5.11 Technological development plant for CO_2 storage

5.3.3 Monitoring Techniques

With the overall objective of establishing associated baselines and, thus, of contrasting this initial information with that obtained after the injection of CO_2, we have considered the following monitoring techniques for use at Hontomín TDP:

Seismic monitoring (Microseismic and SeisMovie), to detect changes in the physical and mechanical properties, track the evolution of the injected gas/fluid, establish CO_2 migration lines, determine the seismic activity induced by injection and characterize the presence microfractures.

- Microgravimetry monitoring to determine the geometry and density distribution of the reservoir, evaluate the distribution of the injected CO_2 plume and monitor its migration along the reservoir.
- Magnetotelluric monitoring using different electromagnetic techniques that, at different scales, can measure physical parameters related to rock porosity and permeability.
- Monitoring gas emissions, resulting in a map of natural emissions.
- Hydrogeological monitoring to evaluate-the permeability of different formations, the existence of aquifers shallower than the

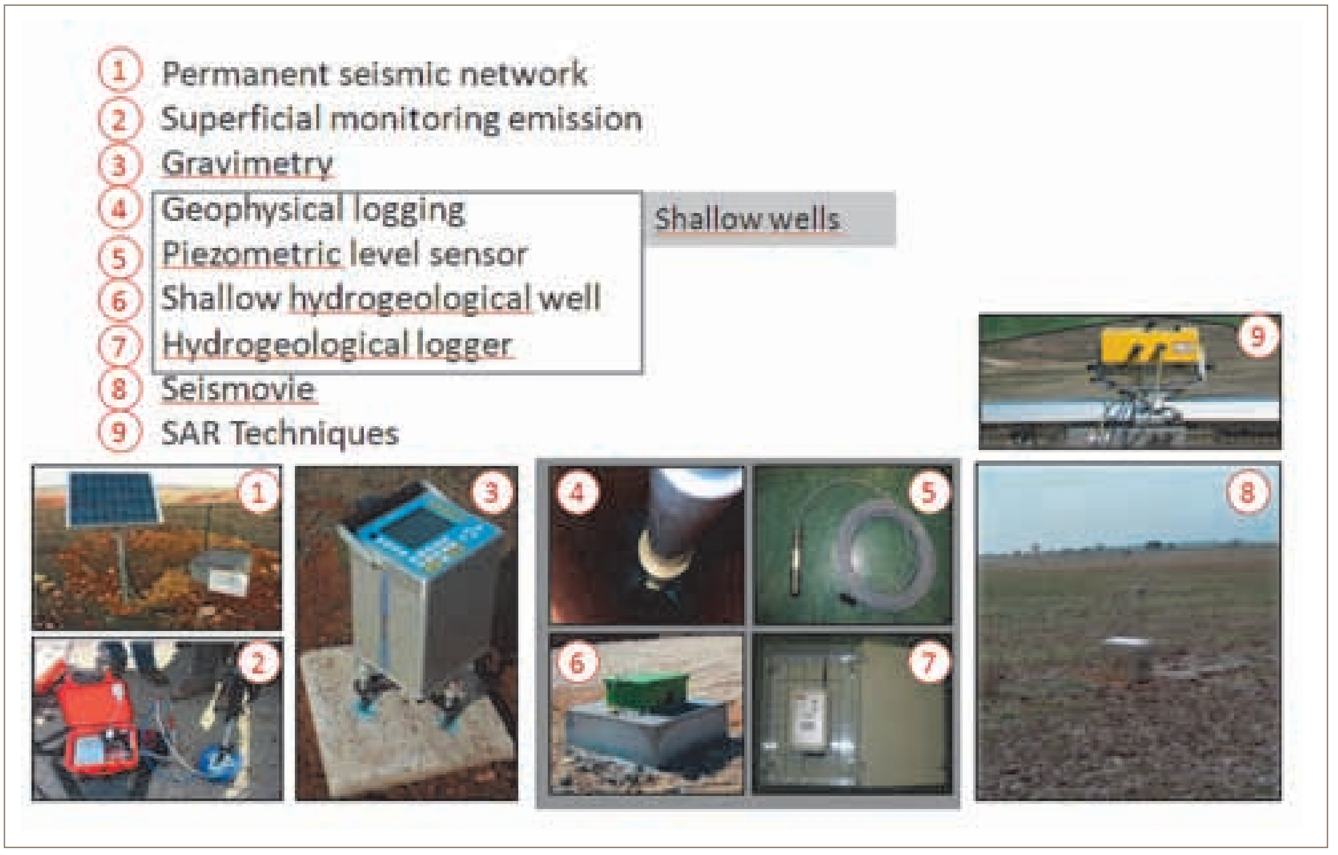

Figure 5.12 Set of monitoring techniques currently deployed in the Hontomin Area

Figure 5.13 Drilling and completion of hydrogeological wells in Hontomín

Figure 5.14 Applying DInSAR and SAR (GB-SAR) techniques at Hontomín

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6

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6.1 ENVIRONMENTAL ASPECTS

This chapter summarizes the main environmental aspects of the project OXY-CFB-300, in terms of generating air emissions, discharges, waste production and consumption of natural resources. The information collected is based on environmental impact studies, finiished for generation and capture facilities, and transportation, and in development phase for geological storage complex.

6.1.1. Generation and capture facilities

6.1.1.1 Summary of key environmental impacts

All the impacts generated during the construction phase of specific and temporary conditions, and the project being located in areas of the current Compostilla Power Station, it is considered that the impacts of the construction of the project for generation and capture OXY-CFB-300 will be not significant for the environment, compared to those generated in the operational phase.

Atmosphere

The choice for the project of a supercritical group of circulating fluidized bed (CFB) coal with oxy-fuel and CO_2 capture is, itself, a corrective measure of the environmental impact. The use of oxy-fuel technology implies a reduced flue gas flow, with total emissions of major pollutants NOx, SO_2 and particles, of low levels compared with other technologies of thermal electricity generation.

The boiler shall be equipped with a system of gas desulfurization by adding limestone to the bed of the boiler, which will ensure SO_2 emissions below 200 mg/Nm^3, technique considered as BAT in the BREF on Large Combustion Plants. Furthermore, for removing particulate there will be bag filters of very high efficiency, which will retain the fly ash in the lue gases and ensure maximum emissions of 10 mg/Nm^3. This system is considered as BAT for the removal of particles in the BREF on Large Combustion Plants. Also, the boiler will have a SNCR system for reduction of NOX emissions (Non Selective Catalytic Reduction), able to keep emissions below 150 mg/Nm^3.

The use of capture technology entails higher requirements regarding the purity of the flue gases. Thus, besides the control measures associated of pollutant emissions to the generation plant, the CPU plant will have a acid gas removal system and a mercury removal system.

Currently, there is no legislation on industrial emissions from oxy-combustion facilities with CO_2 capture. Existing law neither provides emission limit valuesfor CO_2 compression and purification-plants. In this situation, the generation and capture facility has been designed to comply with the emission limit values set out in Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions apply to combustion plants> 300 thermal MW.

Next tables show the values of oxy-mode emission (vent plant of CO_2 compression and purification) and limit values for air mode application to normal operating conditions, considering the design fuel (70% domestic anthracite and 30% petroleum coke) and a mixture of coals of high sulfur content:

PARAMETERS	FUEL	
	DESIGN MIXTURE	MIXTURE OF HIGH SULFUR CONTENT
NOX (g/s)	3,33	5,37
SOX (g/s)	0,14	0,18
Partícles (g/s)	0,006	0,006
PM2,5(g/s)	0,0001	0,0001
COVs (g/s)	0,85	0,85
CO (g/s)	49,56	49,59
CO_2 (g/s)	5,1	5,1

Table 6.1 Emission values in oxyfuel mode (vent plant CO_2 compression and purification), in normal operating conditions

PARAMETERS	EMISSION LIMIT VALUES(MG/NM^3)	
	DIRECTIVE 2010/75/UE	
NOX (mg/Nm^3)	150	5,37
SOX (mg/Nm^3)	200	0,18
Particles (mg/Nm^3)	10	5,1

Table 6.2 Emission Limit Values Directive 2010/75/EU

The release chimney of the flue gases is integrated in the cooling tower, in such a way as to take advantage of the plume raising caused by water vapor avoiding the potential impact on the landscape by building a chimney.

As part of the environmental impact study has been carried out the modeling of the immission levels using the model Calpuff, backed by the U.S. Environmental Protection Agency. In addition to compliance with immission values set out in the implementing legislation, it should be noted the small contribution of the Project to the existing emission levels due to the technology selected for the project development OXY-CFB-300.

The following tables summarize the limits to meet from January 2010 established in Royal Decree 102/2011, of 28th January, on the improvement of air quality which sets out the air quality objectives with respect to the concentrations of sulfur dioxide, nitrogen dioxide and nitrogen oxides, particles, etc.. And following are the values obtained in the modeling of the immission levels against the limit values of the rules highlighting the minimum contribution of the project running in “oxy mode” along with operational groups (Groups 3, 4 and 5) Compostilla PS.

Limit Values From Nitrogen Dioxide And Nitrogen Oxides [1], Established in Royal Decree 102/2011

	AVERAGE PERIOD	LIMIT VALUE	TOLERANCE RANGE	DATE OF MEETING OF LIMIT VALUE
Hourly limit value	One hour	NO_2 200 µg/m^3 cannot be exceeded more than 18 times a calendar year	50% at July 19, 1999, value to be reduced in January the 1st, 2001, and thereafter every 12 months, in equal annual percentages to reach 0% by 1 January 2010. 50% in the zones and agglomerations in which an extension has been granted in accordance with Article 23.	To be achieved the 1st of January 2010
Annual limit value	One calendar year	40 µg/m^3 of NO_2	50% at July 19, 1999, value to be decreasedin January the 1st, 2001, and thereafter every 12 months thereafter by equal annual percentages to reach 0% by 1 January 2010. 50% in the zones and agglomerations in which an extension has been granted in accordance with Article 23.	To be achieved the 1st of January 2010
Critical level [2]	One calendar year	30 µg/m^3 of NOx	None	In force since 11thJune 2008
The alert threshold for nitrogen dioxide is 400 ug/m^3. It will be overcome considered when during three consecutive hours, the said value may be exceeded every hour at representative locations of air quality in an area of, at least 100 km^2 or an area or whole agglomeration, taking the smallest surface.				

Table 6.3 Limit Values From Nitrogen Dioxide And Nitrogen Oxides
[1] The limit values are expressed in µg/m^3, the volume must be standardized at a temperature of 293 K and at a pressure of 101.3 kPa.
[2] For the application of this limit will be considered data from measurement stations specified in paragraph II.b Annex III of the Royal Decree 102/2011.

The maximum contribution in the area of study at the annual average levels of NO_2 and NOx is 1.86 µg/m3 and 2.29 µg/m3 respectively, happening at 6.7 km to NE of the Project site OXY-CFB-300 in both cases, compared to the limit values for annual average established by Royal Decree 102/2011: 40 g/m3 NO_2 for protection of human health and 30 µg/m3 NOx for the protection of vegetation. The following figures represent the contributions to annual average immission levels of nitrogen dioxide and oxides of nitrogen.

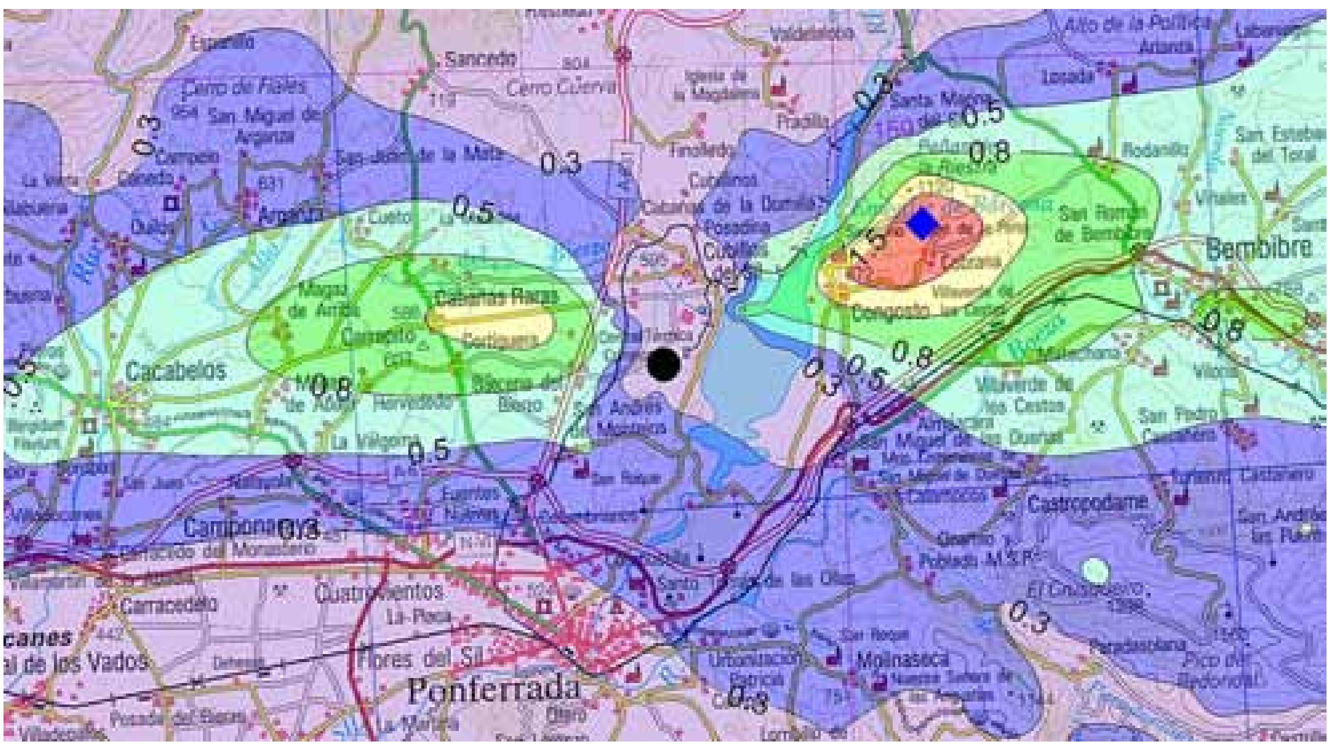

Figure 6.1 Contribution of Project OXY-CFB-300 (AIR mode)with Compostilla P.Sat an annual average immision level of NO_2

The following table lists the limit values set out in Royal Decree 102/2011 for sulfur dioxide.

Limit values and alert threshold for sulfur dioxide [1] set out in Royal Decree 102/2011

	AVERAGING PERIOD	LIMIT VALUE	COMPLIANCE DATE LIMIT VALUE V
HOURLY LIMIT VALUE	1 hour	350 µg/m³, value not to be exceeded more than 24 times per calendar year.	In force since June, 11th of 2005
DAILY LIMIT VALUE	24 hours	125 µg/m³, value not to be exceeded more than three times per calendar year.	In force since June, 11th of 2005
CRITICAL LEVEL[2]	Calendar year and winter (October 1st to March 31th).	20 µg/m³	In force since June, 11th of 2008
The alert threshold for SO_2 is 500 µg/m³. It will be considered overcome when for three consecutive hours it excees that amount every hour at locations representative of air quality in an area of at least 100 km² or an area or whole agglomeration, taking the surface is less.			

Table 6.4 Limit Values and Threshold Alert Sulfur Dioxide

(1) The limit values are expressed in µg/m³. The volume at the temperature of 293 K and pressure101.3 kPa.

(2) For the application of this limit it will be considered data from measuring stations representative of the ecosystems to be protected, without prejudice, where appropriate, the use of other assessment techniques.

The maximum contribution in the study area to average annual levels of SO_2 is 5.08 µg/m³, at 6.7 km NE of the Project OXY-CFB-300, which is insignificant compared to the limit value 20 µg/m³ for the protection of ecosystems marking the Royal Decree 102/2011.

The following figure represents the contributions to annual average levels of sulfur dioxide immission.

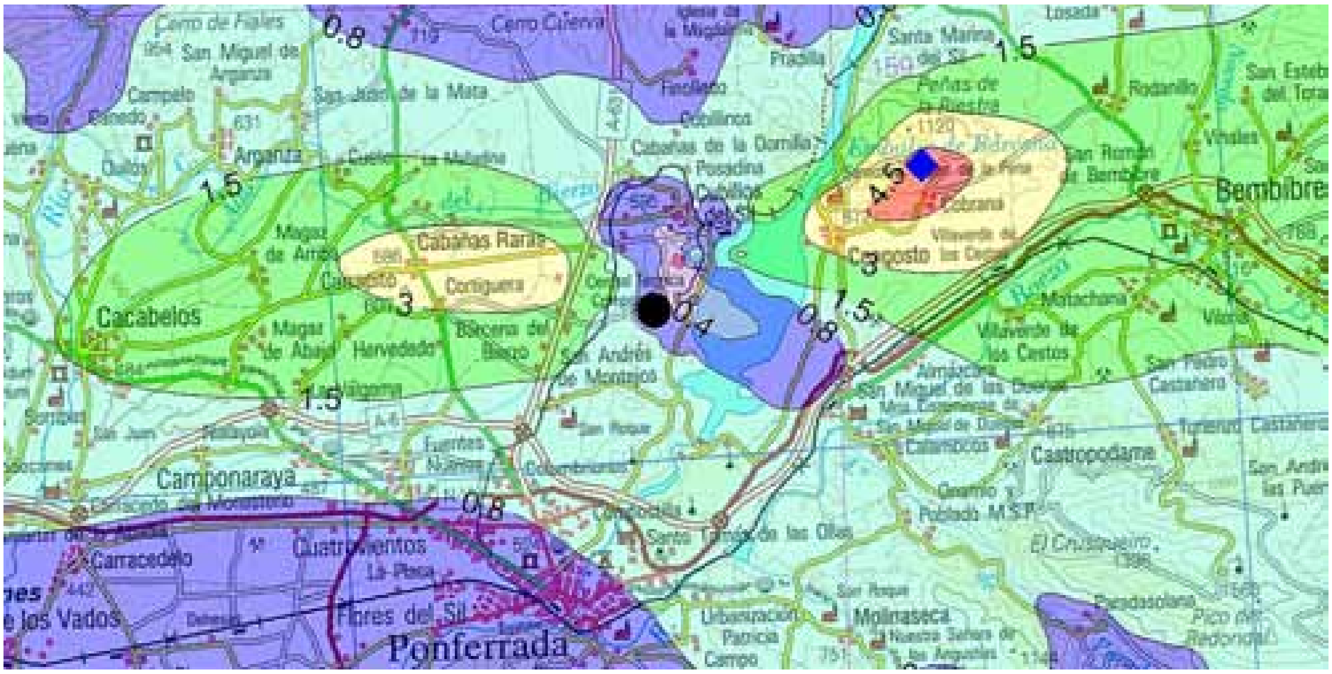

Figure 6. 2. Project OXY-CFB-300 Contribution (OXY mode) along the Compostilla PP at the average annual level of SO_2 immission.

In the area there are 2 immission station networks, these are the Immission Network of CT Compostilla, made up of eight stations and Immision Network of the Ministry of Environment of the Junta de Castilla y León, with three stations. After implementation of the Project, both networks are considered sufficient to control the air quality in the area.

Acoustic Impact

In the design of the plant it has been considered to prevent and minimize noise effects. The main measures taken to limit noise emissions are:

The turbine and boiler will have the appropriate enclosures to ensure a reduced acoustic emission level.

ASU and CPU plants will have enclosures for focal points of highest noise generation.

In general, suppliers be required to guarantee low noise emission levels in the buying process and selection of equipment that make up the plant.

The cooling tower shall provide sound attenuation equipment necessary in order to comply with the noise emission levels set out in the implementing legislation.

As part of the work produced EIA noise immission was modeled, ensuring compliance with applicable legislation.

Water consumption

The main water consumption is associated with the cooling requirements, the choice of a cooling system in a closed circuit is consistent with indicated in Refrigeration Systems BREF. The use of this system will involve much lower water requirements than a system of open circuit cooling.

The plant needs to operate water supply, provided from two different sources:

- From reservoir water collector of Barcena that currently supplies the Compostilla PP.
- From municipal drinking water system to input the potable water tank will supply to various Central services.

The following table shows the required water flow during the operation of the plant and its various sources of supply:

REQUIRED WATER FLOW			
SERVICE	UNIT	DESIGN CONDITIONS (12,6ºC, 66% HR)	MAXIMUM ENVIRONMENTAL CONDITIONS (45ºC)
SOURCE: BÁRCENA RESERVOIR			
Water supply to cooling tower	t/h	621.06	891.16
Water supply to treatment plant	t/h	26.67	26.67
SOURCE: MUNICIPAL DRINKING WATER SYSTEMS			
Water supply to drinking water tank	t/h	0.25	0.25

Table 6.4 Water Supply Flow

Effluents

The effluent streams that are generated as a result of the Project are:

- Cooling towers purges
- Boiler purges
- Cycle Drains
- Oily Plant Drains
- Nonoily Plant Drains
- Rejections of water treatment plant
- Rejections of condensate purification plant (polishing)
- Effluents produced in pure oxygen production plant (ASU) and the gas purification plant (CPU) for oxycombustion mode operation
- Auxiliary Boiler drain (in the case of plant startup)
- The drain neutralized in the heat recovery system HRC of the boiler
- Sanitary water
- Rainwater
- Leachate from pond of new landfill of the plant

All effluent generated, except the purges of the cooling tower shall be conditioned in a new effluent treatment plant (ETP), before being downloaded to the control valve box for controlled discharge to the receiving environment (Los Barredos stream) along the landfill of the Compostilla PP. The table below specifies the flow of leakage:

LEAKAGE OF COMPOSTILLA P.P. AND OXY-CFB-300		
PARAMETER	UNIT	RANK
Maximum waste flow with ambient max. Temperature (45ºC)	m^3/h	3862
Average Temperature	ºC	20
Salinity	psu	0.25

Table 6.5 Waste flows

Within the developed environmental work it has studied the potential impact of this spill on the receiving environment, both its temperature and its salt content, ranking the impact on the receiving environment as insignificant.

Finally, preventive and protective elements have been provided the in case of leaks or accidental spills through concrete bunds with sufficient capacity to prevent leaks or spills of fuels and other hazardous products.

Waste

The generated waste during operation of the facilities will be treated and managed properly, given preferential treatment to valorization options thereof.

The main non-hazardous waste to be generated during the operation of the plant are fly ash separated by baghouses (LER 100102) and slag collected at the bottom of the boiler furnace (LER 100101). This waste will be deposited in the new landfill to be built on land next to the location of the project, with a capacity of 9,281,703 m3 spill.

This new landfill, in compliance with current regulations, have a leachate collection system and a leachate pond where all water in contact with waste will be collect. The leachate pond perform regulatory functions and decanting against rainfall events, and from where the leachate will be pumped to the spill treatment plant.

Hazardous waste that will be generated mainly will be used oils and adsorbent material from the purification of combustion gases in the CPU plant, as chemical reagents used for the treatment of water and effluents. Hazardous wastes generated at the facility will be collected at their respective points of origin and stored in an area prepared for the purpose, until delivery to an authorized agent.

6.1.2 CO_2 Transport Infrastructure

Having found that the risk of rupture of the pipeline has a low probability, it is proceed to detail the rest of the environmental impacts that are essentially concentrated in the construction phase of CO_2 pipeline.

6.1.2.1 Summary of main environmental impacts

Considering the type of work (buried corridor), changes are linearly generated along the entire route on the various environmental elements. Such alterations are generated temporarily in the construction phase, practically disappearing during the operational phase, except for the positions and electrical connections. After the return, land recover its previous uses to works remaining such use during the operation of the infrastructure.

Atmosphere

The impact of the work, especially in track and trench opening and because of the movement of machinery and vehicles on air quality is due to the presence of fine solids in suspension. It is a medium intensity impact, timely, immediate, temporary and short-term recoverable, it ceases to be submitted to complete of the works, but to decrease its action measures such as watering tracks are implemented.

Alteration of sound levels

The increased noise is produced by heavy machinery for excavating and drilling, especially jackhammer in rock areas is the machine that causes more noise. In general, this noise increase is small in magnitude since it is a specific activity, temporal and discontinuously along the trace.

Geomorphology

The landform alteration is an impact caused by earthworks made in those sections in which it will be neededto perform clearing of land for the track opening, in order to adapt for machinery entrance. After completion of the works measures will be introduced for the recovery of the initial conditions of the terrain.

Pedology

There will be impact on the width of the track (14 m.) needed to perform the works, for soil loss and compaction by vehicles passage during the execution of works. As a minimizer, highlights the removal, storage and maintenance of topsoil. Its proper use is to enable short-term recovery of the land and natural vegetation areas affected.

Hydrology

The direct water route affectationsto traversed water courses are: alterations of the riverbed and brims, by the clearing of vegetation, and removal of sludge and loose materials in the riverbed and the resulting drag back, by the movement of machinery in the banks. This represents a decrease in the quality of water by turbidity, resuspension of sedimented contaminants in the background, redistribution of nutrients, etc.

This impact on hydrology supports preventive and corrective measures, especially in brims restoration, rehabilitation of the hydro-morphology of the route and therefore the correct choice of technique (open pit), and the point and period of crossing, and the application of Environmental Restoration Project.

Vegetation

The alteration of vegetation is the most significant impact that will occur during construction as necessary felling and clearing of vegetation present in the work track for the passage of machinery and vehicles. The recovery of the area requires the implementation of corrective measures, involving the reforestation of the area cleared.

During the operation phase, due to the obligation to leave 4 m in total easement of the pipeline, where planting is prohibited taproots species, and restoring the surface of 4 m. track with tree species will not be allowed, but with bushes and shrubby species will be allowed.

Wildlife

The removal of vegetation cover can make the affectation of the habitat of species associated with it. This is a recoverable impact with reforestation of the area after completion of the construction phase.

In the case of new electrical connections under this project, the affectation for alterations to wildlife is very low. As for the birds, the affectation has a potential and permanent character, being necessary preventive and minimizers measures of the potential impact, such as inventory carrying nest prior to commencing construction activities, adjust the work to the breeding season of birds, especially plan the implementation of the most annoying (opening trench and track) out of breeding periods.

Natural Areas

The opening of track is a temporary impact on environmental values of affected protected areas: LIC "Órbigo riverbanks and tributaries" and several Public Utility Woodland. It will be established the following suggested actions:

- Monitor the times of breeding and rearing of fish fauna and aquatic mammals, such as environmental values representative
- Perfect identification and knowledge of natural areas affected by the track for the entire staff of the work;
- Do not run the beaches of collection and storage in these spaces,
- Restoration of all changed items to its original state.

Due to corrective measures implemented the affectation of natural areas will almost disappear completely once the construction phase have been completed.

Population

The affectation of the population by the projected CO_2 pipeline construction should be considered generally positive for the jobs that will be generated in the construction phase. During the operation phase, the presence of CO_2 pipeline will create jobs for the maintenance of the infrastructure.

Productive Sectors

The affectation of farmland has been greatly reduced because it will be to cross the limits thereon, to be located mainly in the parallel drawn infrastructure to affect a single row planting.

Infrastructures

The crossing of the infrastructure (canals, roads, railways, etc..) will be done through horizontal drilling, which involves no interruption of its functionality.

Archaeological and cultural heritage

It will follow the preventive measures identified by the Ministry of Culture and Tourism of Castilla y León to preserve the archaeological and cultural sites (Camino de Santiago).

Among other on-site presence of an archaeologist will be mainly in all phases of work involving earthworks, reducing the affectation to sites not inventoried, nor detected in surface studies.

Livestock Trails

At the junction with livestock trails will take measures to avoid the interruption of transit of cattle.

6.1.3 Geological Storage Complex

For this Endesa Generación, SA, in the framework of the Environmental Impact Assessment and the studies required by Law 40/2010 on the geological storage of carbon dioxide, has made determining of baseline of CO_2 in the environment in the pre-injection phase, so that as a reference for Monitoring, Verification and Accounting Plan (MVA) during operation and after closure of the facility.

This study establishes an environmental baseline condition, in order to identify environmental resources and services present in the scope of study from the storage complex and to define its conservation status. Detailed knowledge of the characteristics of the site along with the processes taking place in it allows accurate assessment of the safety of CO_2 storage system against a possible leak.

According to Law 40/2010 (Annex I, Stage I), characterization and evaluation of the potential storage complex and surrounding area should include the collection of data relating to:

- Geology and geophysics
- Hydrogeology (in particular existence of aquifers for consumption)
- Deposits engineering or geological structure of the storage (e.g. volumetric calculations of pore space for CO_2 injection and ultimate storage capacity)
- Geochemistry (dissolution rates, mineralization rates)
- Seismicity
- Presence and passageways state natural or artificial, including wells and boreholes

In addition, the following characteristics should be documented from the proximity of the complex:

- Areas surrounding the storage complex that may be affected by the storage of CO_2 in the storage place.
- Distribution of the population in the region in which is situated the place of storage.
- Proximity of valuable natural resources (in particular areas included in the Natura 2000 Network in accordance with Council Directive 79/409/EEC of April 2nd of 1979 on the conservation of wild birds and the Council Directive 92/43/CEE of May 21th of 1992 on the conservation of natural habitats and of wild fauna and flora).
- Activities around the storage complex and possible interactions with these activities (e.g., exploration, production and storage of hydrocarbons, geothermal use of aquifers and groundwater reserves).
- Proximity of the source or sources of CO_2 (including estimates of the potential mass of CO_2 economically available for storage) and adequate transport networks.

6.1.3.1 Summary of environmental impacts

Below is a summary of the main environmental impacts expected for both construction phase and operational phase:

CO_2 effects on health

CO_2 effects on human health are mainly due to displacement of oxygen when a leak occurs in large quantities of CO_2, resulting in an asphyxiating atmosphere. These effects may include dizziness, headache, high blood pressure, rapid heart rate, unconsciousness, and finally death. Although CO_2 toxicity is mainly due to asphyxiation by displacement of inhalation of high concentrations of CO_2, pH of the blood can also get lower and cause respiratory, cardiovascular and central nervous system effects.

CO_2 Levels/benchmarks are established for toxic effects in humans taking into account the requirements of major accident legislation (Royal Decree 1254/1999) for the assessment of toxic effects on human health.

The Monitoring, Verification and Accounting Plan, will incorporate a range of management responses in the unlikely event that unpredicted migration of CO_2 is detected.

The probability of CO_2 migrating to the surface has been determined to be remote with potential environmental consequences limited to localized impacts on flora and possible detrimental impacts on subterranean fauna. The environmental risks associated with the injection of CO_2 have been assessed and the environmental impact reduced to minimum. The monitoring and reservoir management program will be critical in ensuring that the migrating CO_2 does not reach these environments.

Atmosphere

The impact of the work, especially access opening and the machinery and vehicles passage on air quality is due to the presence of fine solids in suspension. It is a medium intensity impact, timely, immediate, temporary and short-term recoverable, it ceases to be submitted to complete the works, but to decrease its action is implemented measures such as watering tracks.

During the operation phase there will be no emissions that affect air quality. Below are the results of the baseline of atmospheric measurements which are summarized in the following table:

CO_2 CONCENTRATION (PPM)	SUMMER	AUTUMN
ATMOSPHERE	344-412	376-421
SOIL	397-8975	125-5262

Table 6.6 Seasonal range of CO_2 concentrations in atmosphere and soil in the study are

Acoustic Impact

The increased noise is produced by heavy machinery for drilling work. In general, this noise increase is small in magnitude since it is a specific and temporal activity.

The storage operation of the complex does not involve the use of mechanical equipment that alter the sound levels in the area.

Hydrology

The storage complex study area is in the Duero Hydrographic Demarcation. Within the study area are located many waterways belonging to the sub-basins Elsa-Valderaduey, Carrion and Pisuerga.

Surface facilities pose no direct involvement on the waterways. During the different phases of the project the status of surface water mass will be monitored in order to rule out any condition on surface water for storage malfunction.

Hydrogeology and Aquifers

The storage complex in Duero area sits on a large tertiary aquifer that coincides with what is known as the Meseta del Duero. About this, surficial aquifer are supported: limestone fells, screes and aluvial. At the edges of the tertiary aquifer aquifers are located mesozoic acquifers made of sedimentary rocks mainly limestone.

It has carried out the characterization of “zero state” of groundwater mass including piezometric data, hydrochemical data and CO_2 content in the water. Note that the concentration range of the carbon dioxide baseline present in groundwater is between 0.28% V and 10.8% V, with an average value of 5.1% CO_2.

During the operational phases of the project, the evolution of aquifers will be controlledfrom baseline in order to rule out any influence on the environment, due to a malfunction of the storage.

Vegetation

The vegetation will be impacted by the cuts and clearing of vegetation present at the entrances and the area occupied by the equipment and infrastructure needed for injection. It should be mentioned that the occupied area have a minimum area, minimizing the need for reforestation.

Natural Areas

In the environment of storage complex there are eighteen spaces belonging to the Natura 2000 Network (ten LICs and eight ZEPAs). Not being localized surface facilities in any of these areas, the proper characterization and monitoring of the storage complex will rule out any condition on the protected areas.

Archaeological and Cultural Heritage

It will follow the preventive measures identified by the Ministry of Culture and Tourism of Castilla y León to preserve the archaeological and cultural sites.

6.2 HEALTH AND SAFETY

The continuous improvement of working conditions and health protection are core values of Endesa corporate culture. Therefore, the company assumes the following commitments:

- Commitment to the nature and extent of risks.
- Commitment to full compliance with the law.
- Commitment to the improvement of the working conditions, safety and health.
- Commitment to personal and professional conduct.
- Commitment to contractors.
- Commitment to information.
- Commitment to training.
- Commitment to consultation and participation.
- Commitment to our customers.
- Commitment to citizens.

These commitments, based on OHSAS 18001:2007 are duly documented and available to the stakeholders of the company. They are periodically reviewed for adequacy and modification, if necessary, and they provide the framework for establishing and measuring business objectives for safety and health.

Given the special conditions of the Project (where it will be of application both the Basic Safety Regulation for Construction works as well as, in certain actions, the Basic Mining Safety Regulations) and as it covers 3 major areas of action (capture, transport and storage) most of them geographically distant (obviously with shared work areas) is essential to ensure a proper Coordination of Business Activities, according to the established in Royal Decree 171/2004. To this purpose Endesa will designate (by hiring specialized companies):

- A Health and Safety Coordinator in Project implementation phase, which will coordinate during the project phase of the work, the application of the principles mentioned in Article 8 of Royal Decree 1627/97.
- Functional Director and Safety and Health Coordinator in construction work phase for every of the main parts in which the General Project is divided (capture, transportation and storage)
- Functional Director and Coordinator of Business Activities for those phases of the Project where Safety Mining Basic Regulation is to applied (Royal Decree 863/85).
- The procedures implemented to ensure the coordination of business activities by these persons shall comply with the provisions of the applicable legislation and standards defined in OHSAS 18001:2007.

6.2.1 Legal Documents in The Prevention Area

For each partial Project in which the General Project is divided, Endesa, implementing the regulation in prevention matter for the Construction Works, will develop the site Health and Safety Plan (article 5 Royal Decree 1627/97).

Similarly and in jobs where applicable the Basic Standard Mining Ruling, Endesa will develop a Safety and Health Document (ITC/101//2006 of RD 863/85).

In both documents:

- Will be described the procedures, technical equipment and auxiliary resources to be used or whose use may be expected.
- Will be identified the occupational risks that can be avoided, indicating with that purpose the necessary technical measures;
- Will be mentioned the occupational risks that cannot be eliminated as well as the prevention measures and the technical safeguards designed to control and reduce these risks.

In the preparation of these documents will be in very special consideration those actions resulting from the findings obtained in the different studies and risk analysis already completed or underway such as:

- HAZOP Studies.
- Identification of External Hazard Occupational Studies, external and in HAZID premises.
- Quantitative Risk Analysis (QRA)
- Potential leaks detection studies .
- Studies derive from the possible enforcement of SEVESO normative

Each contractor will prepare a Health and Safety Plan / specific prevention plan which will analyze, explore, develop and supplement the provisions contained in the documents produced by ENDESA and described in the previous points (Health and Safety Study and/or Health and Safety Document).

Finally, it will be required proper preparation and implementation of an Specific site Emergency Plan to ensure the adequate protection of life and health of both workers and potential off-site affected by planning the actions to follow, in front of certain emergency situations. These emergency situations will be especially relevant during the setting up of the equipment built (and obviously during its subsequent running). See points beyond.

6.2.2 Special Risk Activities during the Construction Process

It will be considered in this Project activities of special risk:

- Works with particularly severe risk of falling from a height, assembly of large structures, chimney, deep excavations, etc.
- Works with burial or subsidence risk; CO_2 pipeline, underground tanks, benches and angle plates, pipes, whose risk, among others, may involve cutting underground gas pipes.
- Works in confined spaces. For this project we will consider that a confined space is any environment that:
- Have limited means of entry and exit. Meaning those which do not allow an input or and output in a safe and fast manner for all its occupants, for instance, sewers, spaces which entry or exit is via ladder, saddle or elevation system with harness.
- Do not have natural ventilation that allows:
  - — Ensure a suitable atmosphere for human life (before and in the process of the works).
  - — Make it inert so as to eliminate any possibility of fire and /or explosion (before and in the process of the works).
  - — It is not designed to be occupied by humans continuously.
- Works with the presence of CO_2.These activities will be significant during the setting up process considering that CO_2 is a simple asphyxiant, but in high concentrations is toxic.
- Works in explosive atmospheres or where explosives are used.
- Once constructed certain equipments and facilities, during the setting up and subsequent operation, are likely to generate explosive atmospheres (battery rooms, generators, turbines, certain gases storage tanks).
- During some phases of the construction process, especially in the phase of drilling will be necessary to use explosives for certain activities. At this stage it is probable also the formation of explosive atmospheres for the affectation to underground gas pockets.
- Works in pressure equipments. Special consideration will have those facilities using/carrying pressurized CO_2 that may lead to potential CO_2 pressure leakage that can cause serious damage to the personnel exposed.
- Works in voltage / in proximity.Energization of equipment, proximity to high-voltage lines, in particular regarding the construction operations for the transportation area which are capable of finding on its way high-voltage power lines.
- Works with exposure to ionizing radiation. Given the particular characteristics of the materials used is foreseen a large number of tests by radiography.
- Works involving the handling or presence of gases, chemicals, etc.
- Works with noise exposure. Due to the machinery and activities involve during the construction phase of the Project is expected that noise emissions in all of these activities may be elevated, for that purpose control and mitigation measures will be taken to minimize its impact both inthe occupational and environmental level.

For all these specific activities mentioned and taking into account the studies outlined in subsequent points specific work procedures and actions that describe technical and administrative measures to implement efforts to prevent / minimize the risks identifiedwill be developed. These procedures shall include the approval of both Endesa and the Functional Direction and Coordinators appointed for the project.

6.2.3 Most Important General Considerations in Matters of Safety and Health an Environment

The most important aspects to consider in safety, health and environment have been separated below in different sections:

6.2.3.1 CO_2 Capture

Hazards derivated from exposure to main hazardous products handled in the facilities:

- Gas oil: due to its combustible properties its storage must be properly confined by a dam and adequately protected by a firefighting system. At the same time the entire area of oil storage and handling must comply with the ATEX ruling, which imposes the classification of hazardous areas and to specify equipment and systems suitable for its installation in classified areas.
- Oxygen: Oxygen associated risks occur primarily within the operation of the CFB boiler, where by both default and excesses of O2 concentration in the combustion may give place to potential scenarios of fire or explosion. The risks arising from both situations have been analyzed in the boiler HAZOP study and the protective measures / additional security have been identified for future implementation in later phases of the project design. Additionally in its storage and distribution the risks associated with its high oxidizing power have to be taken in account. Storage areas must be properly marked and their access restricted to only authorize personnel and should be away from combustible materials, whatever requires the standards applicable.
- Sulfuric acid: being a highly corrosive substance its storage and handling must consider the following protective measures:
- Storage must be carried out in areas with systems that confines potential spills and the surface of the mentioned dams must be coated with layers of insulating material acid-resistant to prevent it from entering the ground and cause a potential scenario of site contamination. At the same time signage measures in floor have to be provided, as well as personnel protective equipment and work procedures for proper handling to avoid the risks of an exposure.
- Additives and Chemicals: it must be provided protective measures for exposure to harsh chemicals and irritants so that the management areas on the same floor should be properly marked, potential spills controlls, safety showers and eyewashes , as well as fire-protection measures if are required by the characteristics of the chemical, must be provided in the area at a distance of between 3 and 15 meters and with an easy access to them, and the operators in charge of handle them should be trained and provided with the proper procedures for handling them and the appropriate individual protection equipment (IPE).
- CO_2: the risks and control measures of exposure to CO_2 have been

described in detail in section 2, CO_2 transport and Infrastructure, where CO_2 is the main source of danger.

- Noise emissions: although environmental emissions have been described in section 5.1 in this section it is important to highlight the potential impact of the introduction of the CO_2 capture plant as it will increase the noise in the existing plant primarily due to the CO_2 compression prior to its shipment for transportation, to the presence of the cooling tower and boiler equipment rest, etc. Thus in later detailed design phases noisy equipment must be provided with the necessary noise mitigation measures to avoid high noise contribution to the current level of the plant.

6.2.3.2 CO_2 Transportation Infrastructure

The most important potential risks that influence the design of the CO_2 transport section are:

- Exposure to stifling levels by the presence of CO_2.
- Exposure to low temperatures by the rapid cooling effects of CO_2.
- Exposure to high pressures for CO_2 leakage.
- Exposure to low concentrations (trace) of toxic substances in the fluid (H_2S, CO, SO_2, NOx) contained in the gas (CO_2).

Of the mentioned risks, the one regarding the exposure to stifling levels by the presence of CO_2 is clearly the most important and therefore is the one which has been considered more control-safety measures in design.

To eliminate or minimize to the maximum the risks listed above the following monitoring and security systems should be implemented at least in the critical areas, whose specifications have been already developed in this phase of the project:

- Appropriate selection of materials that avoid or minimize the corrosion in the pipes produced by CO_2.
- A Pipeline Leak Detection System.
- A Control and Communication system.

The operators who in the future perform the control and monitoring of the CO_2 Transport section must be fully trained in the interpretation and diagnosis of the protocols that command such leak detection systems, control and communications oriented to the decision making.

Additionally, in the following phase of the Project should be evaluated the need to install or not CO_2 detectors in buildings and facilities that may require human presence and may be affected by its proximity to a potential CO_2 leakage point.

6.2.3.3 CO_2 Storage and Injection

The main conditioning factors in safety, health and environment in the geological storage of CO_2 are closely related to the selection of wells, their location and the test to be performed in order to evaluate its possible leakage of CO_2 that can be produced in it and that may impact on both the population and the near environment. Most of the risk scenarios analyzed in the studies of the storage wells indicate that the hazards due to deviations in their design must be tackled by implementing actions in the capture and transport systems that avoid such disturbances regarding purity, pressure or temperature in the CO_2 injected into the wells.

Design considerations and measures or design conditions above exposed should be complemented with the recommendations for improvement resulting from risk studies performed to the Project to this stage.

6.2.4 Most Important General Considerations in Matters of Safety, Health and Environment to Highlight in the Operation Phase

6.2.4.1 Coordination/Planning of Activities in Preventive Matters

After the construction of the plant its commercial exploitation will begin. Most operational risks presented at this stage of the plant will have been identified in studies of risk and in environmental impact studies already made in the project and therefore the risks will have been eliminated or reduced to reasonably acceptable levels (ALARP) for Endesa by the proper compliance with the design standards of Endesa, or for those cases where necessary for the level of risk associated with them, they will have been implemented the additional safeguards required in each case. Some risks will have already been submitted as commons to the implementation phase.

To summarize important safety and healthy aspects in the operation phase are written down again:

- Ensure through the monitoring systems implemented as a result of the Project that the limits of the contaminating emissions to air, water and solid waste generation respect the limits imposed by regulations and current standards.
- Ensure at all times that storage, management and injection of CO_2 into the boiler systems respect the security measures and security procedures implemented. .
- Ensure the proper use, monitoring and interpretation of the data provided by the leak detection system of CO_2 in the CO_2 Transport.
- Perform the entirenecessary test to the wells and know how to interpret the source of potential problems presented in them whose origin is mostly operational errors or incidents occur in them.
- In order to give a satisfactory and safe response to the potential problems described above it is considered essential theformation and complete training of operators in these matters and specifically their familiarity with potential accidents that can be raised if the appropriate action is not take on such risk scenarios.

From the organizational and administrative point of view, proper coordination will be required as well as the planning of preventive activities, in ensuring compliance with RD 171/2004. Planning of the preventive activity must consider:

- Necessary human resources and materials, and the allocation of the accurate economic funds.
- Assessments and risk analysis of workers and equipment, systems and activities.
- Emergency measures. Self-protection manual.
- Health surveillance expected.
- Information and training of the workers in prevention.
- Plans of compliance assurance of legal requirements demanded/demandable to the installation.
- Preventive activity should be planned for a given period, setting the phases and priorities of its development depending on the magnitude of the risks and the number of workers exposed to them, as well should set up its periodic monitoring and control. In the event that the period in which to develop preventive activity exceeds one year, an annual program of activities must be established.
- Personnel will be appointed to ensure the proper coordination in prevention activity and to track the activity planning.
- The procedures to ensure coordination of business activities in the operating facility shall comply with the provisions of the applicable legislation and standards defined in OHSAS 18001:2007.

6.3 QUALITY MANAGEMENT

During the project development the functions of Assurance and Quality Control are made in accordance with the operating procedures and technical instructions given by Endesa and with the manufacturing technical requirements included in each of the technical specifications of the main packages that comprise the project.

6.3.1 Quality System during FEED Phase

In the section concerning Quality Assurance, through the application of these procedures and technical instructions, have been regulated those activities critical to the proper functioning and organization of the project which can be summarized as:

- Documentation Flow Control between organizations, identifying the actions required by each one.
- Activities Description and responsibility of each person or organization involved in the project.
- Systematic approach to the implementation on every activity reflected on the scope of the contract.
- Coding of documents.
- Document control, its status, review and approval.
- Planning and monitoring tasks.

All these points have been developed in the corresponding quality plans applicable to the project:

- OXY-00-YG-DPQ-EA-001 Rev.02-Capture Plant Project Quality Plan.
- OXTR-HEY-GPR-END-1208-Rev.A – Quality Plan - Transport.
- OXYST-SID-M-00002-A – Quality Plan – Storage. This plan is supplemented with the following plans:
- FO-ES-HAL-HPM-Q001-Rev.01 – Quality Plan - Supervision and Technical Direction of Deep Drilling.
- FO-ES-HAL-HPM-QC-FDP Quality Plan – Well's Construction Procedures & Standards.
- FO-ES-HAL-HPM-1100 05 Quality Plan – Well's Record List
- FO-ES-HAL-HPM-Q-010 Quality Plan – Well's Operation monitoring meetings program.
- FO-ES-HAL-HPM-1505 01 Quality Plan – Well's Design.
- FO-ES-HAL-HPM-1502 01 Quality Plan – Drilling pipes & dragged gears.
- FO-ES-HAL-HPM-QC-BR Quality Plan – Drills.
- FO-ES-HAL-HPM-QC-FDP Quality Plan – Drilling fluids.
- FO-ES-HAL-HPM-QC-ML Quality Plan – Mudlogging
- FO-ES-HAL-HPM-QC-WLP01 Quality Plan – electrical enclosures.
- FO-ES-HAL-HPM-1505 Quality Plan – Coating.
- OXYST-WFT-WFT-N-00001-015 Quality Plan–Cementation procedure.
- FO-ES-HAL-HPM-6000 5 Quality Plan – Efficiency measures.
- FO-ES-HAL-HPM-QC-CORE Quality Plan – Training sampling.
- FO-ES-HAL-HPM-QC-MWD-LWD Quality Plan – MWD-LWD

6.3.2 Quality System for Phase II: Construction of the Plant

The Quality System to be established for the project, once its construction is decided, will ensure that their activities will be developed in accordance with the project quality requirements and the quality standards rules.

The management system is documented in the Project Quality Plan, which is aimed at the activities of importance to the quality, such as:

- Indentifying the needs of Endesa;
- Definition of the methods to be used to meet those needs;
- Allocation of responsibility and definition of the controls to be performed;
- Control of the design;
- Generation and maintenance of the necessary quality records;
- Quality Audits;
- Continuous improvement, Lessons Learned.

Project Procedures, along with Contractor's corporate Procedures applicable, will as well integrate the Project Quality System Documentation, and will be implemented during its evolution. These documents will be prepared on the basis of the Endesa requirements for the Project.The documentation will cover the quality aspects related to the design, procurement, and construction supervision.

A Quality Plan on the site will be issued prior to the commencement of work activities, and its aim will be to ensure that the construction activities are developed in accordance with the design drawings and specifications of the project.

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Project Permitting

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Before starting with the processing of the project, was carried out an analysis of its compatibility with current environmental legislation, of industrial and urban safety, as well as its chances of getting the award for the taking of water needed for cooling and the possibility of connection to the electricity transmission network to evacuate power generated.

All these initial analysis showed that the project was viable from these points of view, although is not the developer the one to decide about it ultimately but the competent authorities in each one of the subjects. Thus, the consortium understood that, a priori, the project will receive all such authorizations being them favorable to its construction.

Prior to and during procedures for obtaining the different authorizations, Endesa Generación SA met or attended several meeting with the Competent Authorities which award the different permits required for development of the Project.

7.1 GENERATION AND CAPTURE PLANT

At the time of this writing, the status of processing of authorizations for the generation and capture plant of the project described in the previous section is the following.

- Initial Document. Report beginning with the environmental processing. This document is processed by the decision-making body, this one sends it to the Ministry of Environment which makes the queries to local administrations and organizations that may be involved.
- Procedure for Environmental Impact Assessment (aimed to obtain the Environmental Impact Statement): Submitted the Initial document and received comments concerning the level of detail and the scope that environmental impact study should have. Written and submitted the Environmental Impact Study.
- Integrated Environmental Authorization. Written the Basic Project for the request of Integrated Environmental Authorization and submitted to the Department of Development and Environment of La Junta de Castilla y León.
- Administrative authorization. Written the preliminary project and submitted to the Administration.
- Declaration of Public Utility. Written the required document for its application and submitted to the Administration.
- Authorization to connect to the transport electrical network. Submitted the application to the network manager (Red Eléctrica de Spain) and confirmed by him the technical feasibility of such connection.
- Concession of the use of Barcena reservoir's water for the plant-cooling. Requested to the Cuenca Competent Organization (Hydrographic Confederation Miño-Sil River) with the submission of the project. Informed about the beginning of the concession file by that organization.
- Rest of the authorization not yet applied because it is not appropriate to do so due to the progress of the previous authorizations.

7.2 PIPING AND ONSHORE FACILITIES

Prior to and during procedures for obtaining the different approvals, Endesa Generación SA has held meetings with the Competent Authorities which award the different authorizations required for development of the Project.

At the time of this writing, the status of the processing project authorizations is as follows.

- Environmental Impact Assessment (aimed at obtaining the Environmental Impact Statement): Submission of the Initial document and received comments on the level of detail and scope that Environmental Impact Study should have. Written and submitted the Environmental Impact Study.
- Administrative and Project Authorization. Written the project and submitted to the Administration.
- Declaration of Public Utility. Written the required document for its application and submitted to the Administration.
- It has been initiated the process for awarding of the point of connection to the network of the local electric distribution companies for feeding positions isolating valves. These companies have responded with connection points proposals, although we have not officially received them.
- Rest authorizations no yet applied because it is not appropriate to do so given the progress of the previous authorizations.

7.3 STORAGE AND SUBSURFACE ENGINEERING

At the beginning of feasibility study for selected site, the Act 40/2010 of December 29th concerning the geological storage of carbon dioxide, had not yet entered into force, therefore it was needed to obtain permits and authorizations to carry out the exploration according to the Mining Act (22/1973, of July 21st).

Once the 40/2010 Act entered into force and following what it states, it has presented the corresponding documentation to the Competent Administration to adapt the research permits obtained under the Mining Law to the new Law.

Once the work site is technically validated permanently, it will be necessary to apply for the concession to use it as place for CO_2 storage.

As stipulated in Law 40/2010, the Environmental Impact Assessment will be included in the processing for obtaining the Storage Concession. Thus, the Initial Document will be submitted with the Application of the Storage Concession, interrupting the processing of the concession until the obtaining of the Environmental Impact Assessment once the corresponding Environmental Impact Study is submitted.

Surface installations, including injection wells were defined and located into storage complex site. For monitoring plan, several wells for monitoring the plume were located based on dynamic simulations as well.

Once the permit application for CO_2 storage has been approved and authorized, the necessary design and documentation will be issued for each electrical connection (tie-in) to the power network which will be best suited to the necessities of the injection well surface facilities and monitoring wells. In either case, the power supply to the injection well surface facilities will be done with an aerial power line and a transformer control center which will be installed in the vicinity of the surface facilities.

The power line, which is subject of this document, will pass through the municipalities of Villamol, Villaselán and Villazanzo de Valderaduey, in the province de León.

7.4 POTENTIAL IMPACTS AND UNCERTAINTIES

Requests for authorizations which have been described in previous sections are currently in various stages of processing, being all pending to be obtained.

The most important uncertainties and risks to get some unfavorable authorizations are due to the novelty of the technologies that are intended to be implemented, because it has never been performed environmental assessments of this kind of projects in Spain.

This situation occurs especially in the parts of the project concerning to transport and underground storage of CO_2 It can also show technical problems (not environmental) the concession of the authorization for novel equipment assembly never before installed in this country.

Another possible source of problems at the time of obtaining the project authorizations is the opposition of environmental groups or other condition contrary to the project that could exert pressure against the authorizations.

Therefore, the time periods that are finally necessary to obtain all authorizations constitute a clear uncertainty and medium - high risk in the project.

The regulatory and permitting WT objective was to examine the current permit situation of the Compostilla OXY-CFB300 project and also to analyze the regulatory risks that impact directly on it.

The Spanish regulatory market instability is a high risk to face a Final Investment Decision, especially in a project where is required a strong institutional support. Regulatory risks are much higher in demonstration phase technologies which are not economical feasible based on the tender market prices. This feature makes decision making and forward planning complicated. Robust regulatory frameworks that support the business case for all investors in the CCS value chain are essential to develop large-scale demonstration projects.

It is therefore essential that CCS should be fully integrated into an EU 2030 Energy and Climate Policy framework. This should be coordinated with structural reform of the ETS in order to strengthen the EUA price and provide a long-term incentive for investment.

From the point of view of regulation as remuneration system, the base load operation should be taken into account. The inertia of the OXYCFB300 Project, associated to the auxiliary equipments, reduces the operation flexibility in secondary regulation (short term supply and demand adjustments generation) and availability premium. It should be also considered that Spanish market mix is in favor of renewable energies.

Lack of CCS legislation as a global process increases the potential problems in obtaining environmental integrated authorization.

To sum up, development of a regulatory framework is necessary but not sufficient to catalyze CCS deployment, and also economic and political barriers would need to be addressed.

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8.1 PROJECT ORGANIZATION

During the technology development stage several meetings were organized to define strategy to address the FID: several working groups were organized and it was established a program of activities to meet FID milestone.

It was agreed to create specific work teams, considering the current Project Organization and the risks defined.

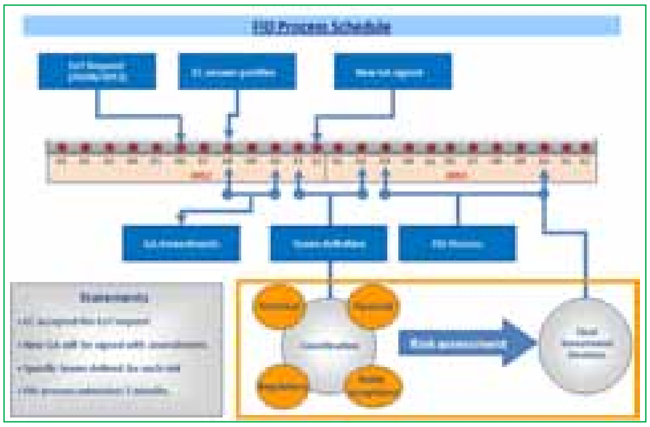

Figure 8.1 FID Process Schedule

The Coordination team, led by ENDESA, will be responsible for collecting the team contributions and elaborating final FID report to be approved by Steering Committee. Final report will be submitted to the European Commission as milestone to be achieved for EEPR program.

The Shareholder Agreements and By-Laws of the company are currently being discussed by the Parties in order to define the responsibilities of each Party in the development of the Project and to foresee the role of potential new Participants.

At present and based on EEPR program, both Parties and FWEOy (Oxy CFB technology provider) have signed a Collaboration Agreement with the aim of establishing a solid framework to develop the full capture technology for this project, from the previous technological development steps to the construction and operation of the plant phase.

Once the Special Purpose Vehicle will be incorporated, it will be opened to the possibility of an addition of other Partners during the lifetime of the Project, providing that this new Partners will contribute with added value to the main objectives of the Project. These further Partners will be admitted to the SPV only once the Award Decision and the FID will be taken.

8.2 WORK PACKAGES DESCRIPTION

8.2.1 Post FEED Additional Studies

For the preparation of the investment estimation, different contracting options were analyzed for the construction of the second phase of the Commercial Demonstration Plant.

CCS generation, pipeline transport and final storage of CO_2 projects consist of several discipline facilities where different types of companies are involved: power generation, gas, oil exploration and oil companies with different criteria and procedures, so that OXYCFB300 Project implementation is only feasible dividing the whole project by at least three plants. It was considered an additional interconnection work and the integration of the entire chain, both in resources such as economic planning and estimating by Promoter or by Promoter´s engineering.

The implementation of three EPC for each project, considering within each range the design of the facility, construction, installation and commissioning of the project, outsourcing works into small packages contracts, has been discarded due to a lack of experience in projects of these dimensions and the risk involved in depending on a single contractor for the execution of each floor, losing the promoter much of the control of the project. Additionally, given such innovative technologies used and the difficulties of specification and even of integration of the whole, it is extremely difficult that the “EPC” contractor take responsibility for performance and consumption, which represents the los s of the transfer of risk to the contractor, one of the main advantages of the “turnkey” projects.

The estimation of the investment for FEED studies of the three areas of capture, transport and storage have been performed considering a “package” contracting system and the requests for quotation made during the FEED final stage have been done considering this structure and distribution of scopes. This decision has been taken looking for a compromise that will allow a better management of the project, having a limited number of packages small enough to allow the promoter savings by reducing intermediaries and the control of technologies and sensitive equipment.

8.2.2 Detailed Engineering

On the occasion of promoting a greater participation of specialized companies, the project has been divided into several tenders, sharing the execution of works in different packages in a practical and coherent way.

This new strategy of outsourcing looks for package specialization and presents a challenge in control of interfaces and the management of a high number of different companies, in particular in its construction phase, being a limited physical area. Main items to pay particular attention are:

- Problems in establishing clear scopes. A greater number of companies involved increases the likelihood of more change orders requests and additional works from contractors to the Property which may cause impact on the deadline.
- Establishment of interfaces milestones and a general agreement on a single project schedule as a whole.
- Special Contract Management to minimize potential individual claims for extension of deadline of each tender. In a situation of disputes caused by the occupation of work areas in construction due to a greater number of subcontractors are more likely than normal that claims for an extension of time occurs. Granting a contractor a grace period may cause modifications in the major subcontractors programs. That would be detrimental to the chance of achieving the original deadline set for the project.
- The possibility of different endings between subcontractors - for example, because one of them has been granted a grace extension of time- may cause serious extra costs to the Property in recovery plans, as to keep contractors and vendors on site as well as maintaining conservation systems and equipment.

The particular feature of such a project, where so many companies are involved from the beginning, is further accentuated when analyzing the drawbacks and difficulties that we can find at different stages such a project in industrial sector may contain: Engineering (basic and detail), construction and commissioning.

Clearly, the need for a greater control by the Promoters will be increased and will force the Project Management to develop a complex system of communication management, activities, planning, responsibilities, contracts, etc. The experience gained during the FEED in OXYCFB300 Plant shows that for the proper execution of the engineering, construction and commissioning should be given a series of sequences and very specific activity programs if you want to successfully complete the project within the estimated deadline. That is why here is a description of major patterns obtained after FEED regarding detailed engineering:

If we focus on the first steps to be taken, once the Project Promoters get a positive response from the FID, main packages contracted from plant should be noted as critical: Turbine and Boiler. This award should be carried out once the execution of the plant is confirmed due to the long supplying periods established. However, these packages require previous basic engineering that also directly impact on the rest of the plant equipment. For an integration of the work of the different tenders and monitoring construction tasks and implementation thereof, the Promoters of the project will require a contractor to provide engineering services integration and oversight. This company will be responsible for the previous works to the award of the main equipment of the plant and should, like the aforementioned teams, start works after taking decision or FID.

An integration and validation task of the completed work will be needed during the FEED adapted to a real award of the main equipment: Boiler and Turbine. Both will require small re-engineering efforts based on actual data from the equipment awarded. Once the studies are completed and modifications affecting the rest of competitions have finished too, promoters will be available to award the rest of packages providing a closed basic engineering.

Each package or tender shall be responsible for the detailed engineering of the corresponding scope. However electrical and civil detailed engineering of the Capture Project shall be fully responsibility of the Engineering Services Integration and oversight of Contractors. Feeding with documentation on time and shape the suppliers of electrical and civil works respectively.

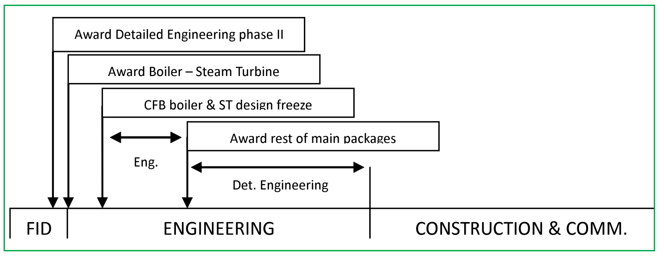

Figure 8.2 Sequencing scheme-Phase II engineering works

8.2.3 Project Management Strategy

Due to the special characteristics of OXYCFB300 Compostilla Project, with a high degree of technological innovation, new developments and high budget, an EPC or turnkey contract has been ruled out as procurement option. Instead of that, ENDESA has considered the definition of different bidding processes or work packages as contracting strategy for the project. This new strategy of subcontracting, looking for packages specialization, is a challenge in interferences control and management due to the high number of different companies, particularly on site, being a limited physical area.

During the FEED phase of the project, the entire supply of the plant has been divided into different packages or bidding processes, whose scope and terminal points have been carefully defined in order to avoid scope duplications between different packages, as well as to avoid the non-inclusion of any of the items of the project.

To get out the request for proposal, a request for quotation (RFQ) document has been prepared for each of the work packages or bidding processes, which defines the scope thereof (including any exceptions or optional supplies), and integrates all the required technical documentation for the bid submitted to meet the required scope and design criteria set out in the project.

During the FEED final phase, requests for supply have been made of all equipment and facilities of the plant, selecting between 2 and 5 potential suppliers for each package (as long as market offer would allow it) and prioritizing the selection of Spanish or European companies. The subsequent bid comparison consisted of a technical and economic analysis of received bids, according to the evaluation criteria defined for each work package. A technical comparison of the bid has been issued for each work package in order to validate the scope offered, identifying possible exceptions and deviations from the specification.

During the work packages proposal preparation phase, engineering has answered all the technical questions and doubts raised by suppliers on their bid preparation.

8.2.4 Work Packages Description

8.2.4.1 Generation and Capture Plant

In an early stage of the FEED phase, the Generation and Capture Project was divided into 30 different packages or bidding processes, although during their definition and developing phase it was found that this division was not optimal for the efficient execution of the project, identifying difficulties in the interface definition as well as disciplines mixture between several work packages. The number of work packages was reduced to 18, thus facilitating the bidding processes supply and simplified interphases, obtaining more appropriated and standardized scopes.

8.2.4.2 Piping and Onshore Facilities

The CO_2 Transport and Injection Project were divided into three (3) different work packages.

8.2.4.3 Storage and Subsurface Engineering

This subcontracting strategy for Storage Demo Plant aims for direct relationship with the various lines of services, and implies a challenge in management of interfaces, contracts and suppliers, especially to site works. Nevertheless, this scheme is the usual practice in the oil industry, and therefore has been assumed by Endesa, based on the previous experience during the phase I, as the most adequate, although the EPC contracting mode still remains open (with the risk of complex contract management if Technical Specifications are not precise).

The CO_2 Storage Project has been divided into thirty six (36) work packages.

8.3 OXYCFB300 IMPLEMENTATION PROGRAMME

8.3.1 Tasks Identification and General Description of the Implementation Phase

The programme presented covers all the construction activities to be performed since positive FID after Final Investment Decision process completion. The endpoint of the programme considered is the OXYCFB300 Compostilla Demo Plant completion after the construction period ready to perform the expected 5 first years of CCS technology demonstration period.

The implementation programme is divided into three main work areas: capture (construction of the Capture Power Plant), transportation (construction of the transport pipeline and associated injection facilities) and storage (construction of the injection and monitoring wells). Other activities to be run all along the construction (permitting, knowledge sharing, public acceptance, funding and investors management, stakeholders management, project management and others) are reflected either as project milestones, continuous activities or not reflected at all, with the understanding that even though are necessary for successfully completing the construction project but not on the critical path.

Commissioning for all the facilities, including integrated commissioning for the CCS chain, is reflected in the presented implementation programme. Further tuning activities of the CCS chain operation and Demo Plant improvements during the 5 first years of CCS technology demonstration period are not reflected. An exponential learning curve for those 5 years is expected.

Accordingly to what depicted above, the implementation schedule (if a positive final investment decision is taken) is expected to be run in between the following dates:

- FID completion: foreseen October 2013.
- Demo Plant construction completion: foreseen June 2018.
- Estimated construction period: 56 months.

8.3.2 Critical Path

Critical paths are diverse and certainly not just a single one in such a complex programme, as delay risk of each activity can make that one of several paths that was not considered as critical at the beginning would become critical. All the EEPR technological development activities performed during 2010, 2011, 2012 and early 2013 converge on a single clear and rigid-fixed milestone, the Final Investment Decision (FID), which is scheduled to be concluded for 31st October 2013, and this milestone is considered as the starting point for calculating the implementation schedule. The end point considered is the CCS chain operation start. Between both, the main critical paths identified during management of the project and FEED programme were the following:

- Regarding Oxyfuel (OXYCFB300) Capture Demo Plant, critical path goes through main equipment manufacturing (especially

Turbine Island, Boiler Island, and ASU and CPU units), construction and erection, and commissioning. Of all the equipment, the pre-engineering, manufacturing, delivery, erection and commissioning of the turbine island settles the critical path, as 56 months are needed for completing all the supply contract for this item. The main reason for this higher-than-expected period is that the supercritical steam turbine is not commercial equipment and needs specific development for this project. Other equipment and plants completion periods are pushed backwards by this period, as final commissioning of the plant can only be completed when all the systems are ready.

- Regarding transport pipeline, critical path goes through CO_2 transport pipeline land permits, purchasing, manufacturing and construction. Despite of the fact that transport activities are also critical for CCS full chain operation start, transport pipeline schedule show significant floats comparing to capture plant schedule. Because of the calculated floats, there are no expectations of critical path due to agreements with land owners, even if delays occur.
- Regarding storage reservoir, critical path goes through the injection engineering, long lead items procurement, and injection and monitoring wells drilling.

8.3.3 Key Dates

Next chart shows main milestones expected and envisaged month of achievement scheduled in the implementation programme of the demonstration plant:

MILESTONE NO.	DEMO PLANT AREA	DEMO PLANT CONSTRUCTION MILESTONE NAME	SCHEDULED MONTH
C1	Capture	NTP for engineering works	- 6
C2	Capture	NTP main equipment award (turbine island & CFB boiler)	0
C3	Capture	Heat / Water balance completed	0
C4	Capture	Permits available	0
C5	Capture	Access to site ready	0
C6	Capture	Site services available for construction	2
C7	Capture	ASU/CPU NTP award	4
C8	Capture	BOP NTP award	6
C9	Capture	Turbine Building Steel Structure Final Drawings	8
C10	Capture	Electrical & I&C Supply & Erection NTP award	11
C11	Capture	Boiler foundation finished	13
C12	Capture	Turbine pedestal finished	16
C13	Capture	Boiler main structure finished	19
C14	Capture	ASU & CPU main steel structure finished	23
C15	Capture	Solids handling erection start	26
C16	Capture	Overhead Crane Operative	30
C17	Capture	DCS FAT	30
C18	Capture	Condenser Lower Water Boxes delivered to site	31
C19	Capture	MV power supply available for precommissioning	33
C20	Capture	Raw water available for precommissioning	33
C21	Capture	DCS Cabins delivered to site	33
C22	Capture	Demin water available	36
C23	Capture	HV connection to grid available	37
C24	Capture	Start Boiler Hydro Test	37
C25	Capture	Main Transformer Energized	37
C26	Capture	Cooling System Available	39
C27	Capture	Fuel oil available for first fire (with aux. Fuel)	41
C28	Capture	Fire on oil	41
C29	Capture	Coal available for first fire (with coal)	44
C30	Capture	Steam to Turbine	45
C31	Capture	Generator Synchronization	45
C32	Capture	Fire on coal	46
C33	Capture	Construction acceptance	50
C34	Capture	CCS Chain operation start	50
T1	Transport	Project Kick-Off	0
T2	Transport	Environmental & Construction permits available	0
T3	Transport	Pipe and valves procurement start	6
T4	Transport	Construction award	18
T5	Transport	Release of land and all local permits obtained	22
T6	Transport	Construction Kick-Off	23
T7	Transport	Pipeline on site	23
T8	Transport	Main valves on site	23
T9	Transport	Transport start-up in isolated mode	34
T10	Transport	Transport start-up in CCS mode	46
T11	Transport	CCS Chain operation start	50
S1	Storage	Project kick-off	0
S2	Storage	Wellheads, casing and tubing procurement for Injection & Monitoring wells completed	6
S3	Storage	Basic Design Drilling Program ready (5 wells)	7
S4	Storage	2D seismic & micro seismic campaigns completed	11
S5	Storage	Baselines and InSAR activities completed	16
S6	Storage	Long Lead items for Injection & Monitoring wells supplied	19
S7	Storage	First injection well drilling completed	22
S8	Storage	Second injection well drilling completed	26
S9	Storage	Third injection well drilling completed	30
S10	Storage	Hydrogeological monitoring wells completed	33
S11	Storage	Monitoring wells drilling completed	39
S12	Storage	Storage start-up in CCS mode	46
S13	Storage	CCS Chain operation start	50

Table 8.1 Main milestones expected and envisaged month of achievement schedule.

8.4 DECOMMISSIONING AND PROJECT ABANDONMENT

ENDESA establishes three fundamental objectives that should be accomplished during the period which starts at the cessation of injection and specifies the systematic process to be followed to demonstrate and document compliance with these objectives. The three objectives are as follows:

- Sufficient understanding of the storage site's characteristics;
- Low residual risk; and
- Well integrity that is adequate and uninterrupted for a period of time as set by the designated authority.

8.5 OXYCFB300 RESOURCES

8.5.1 Execution Phase

A resources allocation study has been done based on the implementation programme. Next charts and graphs show the expected manpower resources for the construction of the demonstration plant, including:

- Planned man-month, total (including engineering, design and management teams) or at Compostilla construction site only; during project construction timeline.
- Manpower curve during project construction timeline, and manpower hours classified by execution stage.
- Hours in manpower resources classified by type of work.
- Expected workforce cost cash flow based on resources needs estimation (for illustrative purposes only).

8.5.2 Operation and Maintenance

A team of 50 to 75 people is estimated for permanently operating and maintaining the Capture Power Plant. Extra human resources will be needed for major overhauls and for the 5 first years of experimental operation.

Regarding transportation and storage operation, the control concept designed allows operating in remote control from the capture plant, without on-site operators. Nevertheless it is envisaged that an extra staff of 10 to 20 people will be necessary for permanent maintenance and monitoring of transport, injection and storage facilities. Also extra human resources will be needed for major overhauls and for the 5 first years of experimental operation.

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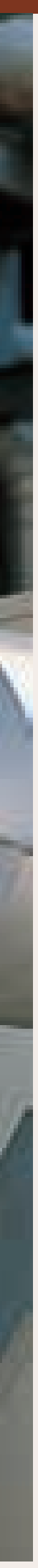

OXYCFB300 Risk Analysis

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9.1 OBJETIVES, SCOPE AND STATUS

Any business project requires the management of the risks inherent to the project.

In large projects such as this one with a significant level of investment, a high recovery period, a lengthily period required for research, design, construction and a complex operation, it is necessary to carry out an explicit definition of a risk management methodology which should begin in the first phases of the project and continue throughout its development to completion. This kind of project includes different types of risks that need to be managed and which may be grouped into the following main sections:

- Operational risks
- Market risks
- Business/ regulation risks

Operational risks are defined as any loss of value resulting from the occurrence of events caused by the inadequacy or failure of critical equipment, processes, breach of legislation or arising from external factors. Operational losses include economic, non-economic and reputational effects.

Market risk relates to potential losses due to changes in the price levels of commodities, exchange rates, interest rates and other products or indices listed on the market.

Business risks cover those risks which involve possible losses due to external factors such as the regulatory framework, economic cycles, competition levels, demand patterns, industry structure, together with other factors. This group also includes the risk of losses resulting from unsuitable decisions regarding the Consortium's business plans and future strategies. A particularly relevant risk within this typology is the regulatory risk, which is that linked to the regulatory framework in which business activities take place.

Business risks also encompass risks associated with project funding. In this sense it is necessary to consider the risks associated with the financing structure, debt instruments considered, the level of leverage, variability of interest rates, the term of the debt, the guarantees required and the particularities of the contractual clauses in general.

Sometimes the definition of the above sections is unclear and the classification of some risks may be debatable.

Risk management is a process divided into the following stages:

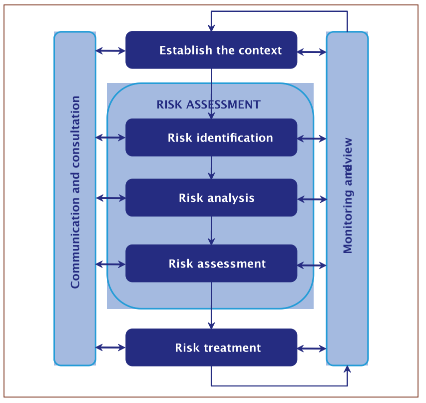

Figure 9.1 Risk management process.
[Methodology according to ISO 31000 and ISO 31010]

All the work framed within the Comprehensive Risk Assessment is aimed at achieving the objectives set out below:

- Conduct a comprehensive assessment of risks for OXY-CFB-300 Compostilla project.
- Identify significant risks for the purposes of the project feasibility.
- Identify differential risks of this technology not shared by conventional technologies.
- Quantify the risks analysed, as appropriate depending on their nature.
- Prioritise risks and analyse in detail those which are most critical.
- Support for the final investment decision (FID).

Comprehensive Risk Assessment has been developed according to a conceptual framework based on the following principles and relevant aspects:

- Situation analysis
- Detailed risk assessment planning. Identification of those responsible and experts involved in the project, and the prior development of a schedule showing the working groups that will participate in the risk identification and quantification of each of the areas.
- Gathering information. Gathering basic project documentation, technical risk documentation, project planning, operating parameters and costs.
- Preparation of a document including the critical aspects of the project. Identification of the specific and differential elements (technological, regulatory, contractual, market, etc.) of OXY-CFB-300 Compostilla project.
- Project context description. Contextualising OXY-CFB-300 Compostilla project: An overview of the global energy scenario, considerations regarding capture technology, the geological storage and the main alternatives.
- Risk identification, characterisation and quantification based on the best suited (available?) methodologies and processes for each type of risk.
- Risk Quantification Model (MCR, Spanish acronym). The MCR is used to measure risks associated with delays in the planning and obtaining of permissions, and to perform specific analyses (sensitivities, simulations) of critical variables.
- Preparing final documentation. Preparation of the final documents described in the DOW (D1.6, D2.2 and D3.4, codes associated with the deliverables of risk assessment for the capture, transport and storage areas respectively).

The work carried out under the Comprehensive Risk Assessment is subject to the limitations listed below:

- Limitations associated with the level of engineering development.
- Not including risks identified during the engineering development stage which have been closed prior to the FID.
- Limitations on the integration of the quantitative results derived from the different nature of the risks covered.

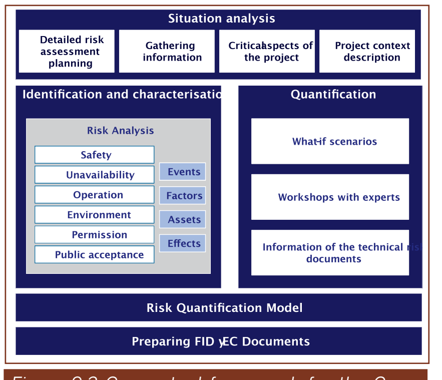

Figure 9.2 Conceptual framework for the Comprehensive Risk Assessment

9.2 OXYCFB300 RISK REGISTER

Once all the global quantitative risk assessment for the project, the project team proposed a set of mitigation measures to reduce the risk as much as reasonable possible. The team focused on risks categorized as extreme, as those are highly influential for the Final Investment Decision process.

The following table shows how a second assessment of the same risks -assuming that the additional mitigation measures proposed were implemented- would change the extreme risk category as shown in the following table:

Nº	RISK	INITIAL CATEGORY	POST-MITIGATION CATEGORY
1	Uncertainty in the plant scaling based on the experience of the pilot plant resulting in a performance of plant components during operation which is lower than anticipated in design	Extreme	Extreme
2	Strong dependency on suppliers in charge of constructing the injection and monitoring wells	Extreme	Moderate
3	High dependence on the boiler supplier in Stage II as a result of the technology development in Stage I, which can lead to delays in construction or investment cost deviations	Extreme	High
4	Failure in the first stage of CPU compression in the event that the removal of particles and / or the desulphurisation is not correctly carried out in the first stage of purification of exhausts gases.	Extreme	Moderate
5	Much longer execution terms than those planned due to the technical complexity of the project (the incorporation of new technologies, new suppliers or other differences) compared to a	Extreme	High
6	Errors in the preparation of contracts due to lack of previous references for contracts for this type of technology	Extreme	High
7	Increased time commitment of technologists during testing period derived from technology uncertainties and due to difficulties associated with equipment integration	Extreme	High
8	Air infiltration in the boiler	Extreme	High
9	Opposition of communities and environmental organisations in the area to CO2 storage operation, resulting in a loss of social support and public acceptance of the project	Extreme	High
10	Errors and / or delays in the communication and interaction between the various parties involved in the project	Extreme	Moderate
11	Errors due to inadequate definition of technical specifications by the company, the misinterpretation of the technical specifications by suppliers or the complexity of integrating the different plant units	Extreme	High
12	Delays in the processing of permits that are in progress or pending at the time of the FID with regard to statutory timeframes due to the novel nature of the project.	Extreme	Extreme
13	Failure to obtain permits that are in progress or pending at the time of the FID and which are required for the construction and operation due to the novelty of the project, to the possible Highly restrictive technical requirements set by the Public Authorities for obtaining permits due to the novelty of the project, its potential lack of public acceptance or other factors.	Extreme	Extreme

Table 9.1 Assessment of Risks initially qualified as Extreme after mitigation measures application

The fact that there is little previous experience and that subjective aspects can affect the occurrence of certain risks -such as project public acceptance or support from the public authorities- means that the quantification of the identified risk events has not been possible in some certain cases. Specifically, the quantification of the two risks shown in the next table has not been possible; however they must be taken into account in the project risk monitoring and management process.

The findings are divided into three sections: risk assessment based on questionnaires completed by a team of experts, further assessment based on stochastic simulations and finally additional considerations regarding other risk types.

Conclusions based on the expert assessment

- Of the 74 elements that make up the list of major risks, 13 have been rated as extreme. Assuming that the proposed mitigation measures were applied, 10 of the 13 risks would become high or moderate.
- There are three risks whose rating remains as extreme despite potential mitigation measures and which should ideally be analysed in depth and be monitored separately. These risks are the following:
  - Uncertainty in the scaling-up of the plant based on pilot plant data resulting in a lower performance of the plant in operation than those stipulated in the design.
  - Delays in the processing of permits that are in progress or pending at the time of the FID with regard to statutory timeframes due to the novel nature of the project.
  - Failure to obtain permits that are in progress or pending at the time of the

Nº	RISK	LEVEL OF RISK	CATEGORY
1	Permitting delays due to the lack of specific regulations defining the process for obtaining the required administrative authorization for the construction and operation of CO_2 ducts.	-	-
2	Highly restrictive technical requirements set by the Public Authorities for obtaining permits due to the novelty of the project or its potential lack of public acceptance.	-	-

Table 9.2 Conclusions based on the Global Risk Assessment

FID and which are required for the construction and operation due to the novelty of the project, to the possible Highly restrictive technical requirements set by the Public Authorities for obtaining permits due to the novelty of the project, its potential lack of public acceptance or other factors.

- The study area in which most risks have been identified is the capture area, amounting to 31 of which 5 are extreme. This is due to the technological complexity of this area and the important research and development component.
- Regarding storage, of the 18 risks assessed, 2 have been assessed as extreme, although additional mitigation measures have been identified for both. The risk profile for this area has improved thanks to reservoir characterisation tasks that have significantly reduced the uncertainty regarding the technical feasibility of the reservoir.
- Additional mitigation measures have not been identified for two of the extreme risks associated with the project permitting area, so their final rating remains as extreme.

The very nature of these risks makes their management difficult for the Consortium, because the role of the public authorities is decisive in both cases. Furthermore, the lack of a specific law that applies to the transport of CO_2 by pipeline, makes it extremely difficult to proceed with the associated permits.

It is compulsory for risks rated as extreme to be mitigated and this will require the appointment of persons responsible and regular monitoring mechanisms. For risks rated as high, an in-depth review is advisable to verify if they comply with the ALARP criterion; additional risk reduction measures should be analysed where appropriate.

A more detailed definition of risk managers (both internally and externally) is considered advisable at future stages in order to improve the monitoring and mitigation of risks.

Lastly, regarding the suppliers or other stakeholders, the Consortium should promote their active involvement in the risk monitoring and mitigation process.

Considerations regarding other risk types

The Compostilla OXY-CFB-300 project is exposed to the uncertainty inherent in different market, business and regulatory variables.

- The prices of CO_2 emission allowances determine the main competitive advantage of the project. The greater investment with regard to a conventional thermal plant associated with the capture, transport and storage installations means that much higher market prices than those existing are required to make it economically viable.
- There is uncertainty regarding the regulation of CO_2 emissions in the medium / long term. In this regard, the most recent decisions ratified by the European Parliament rejecting the Commission's proposal to delay the auctioning and marketing of new emissions allowances for the 2013-2015 period won't contribute to increase the low prices currently observed in the market.
- The lower performance of this plant compared to a conventional power plant implies a greater exposure to fuel prices per MW installed.
- The project is exposed to further possible regulatory changes that could affect its economic viability. The sector restructuring process is still in progress, and a new package of measures has been announced. Therefore, uncertainty surrounds the possible impact of such new measures on the various activities of the sector and how investor perceptions of the regulatory stability thereof may be affected.

These legislation amendments for the sector could hinder the development of a regulatory framework for the project itself, or for CCS technologies in general, intended to encourage commercial development thereof.

- The pent-up electricity demand scenario and the increased weight of renewable energy types under the special regime in the electricity mix are leaving ever less room for other electricity generation technologies.
- There is uncertainty regarding the evolution of oxy-fuel technology and of saline formation storage technology in relation to other capture technologies.
- CCS technologies require a higher investment than conventional power plants; this implies a much lower profitability than other conventional technologies and this is not helped by the lack of a specific regulatory framework to promote the development of these technologies.
- Social acceptance on this technology is still unknown entailing the risk of being rejected as an alternative to other technologies.

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10

Final Conclusions

The present report summarizes all the engineering studies and considerations developed during the three-year FEED phase of the OXYCFB300 Compostilla Project. From the original conceptual idea, FEED engineering works have yielded a functional and technically feasible power plant, which successfully integrates oxycombustion technology with a state-of-the-art ultrasupercritical regenerative power cycle and with a CO_2 purification and compression with an innovative process, integrated with a transport line that conducts the CO_2 at dense phase to the final CO_2 geologic sequestration site. Nevertheless, some technical risks are still relevant.

FEED study results confirm compliance with initial design criteria:

- Minimum power production levels are reached without significant issues in both, air-operation and oxy-operation.
- A minimum recovery rate of 91% of incoming mass flow of CO_2 shall be achieved in accordance with European Union guide lines.
- The CFB boiler is capable of continuous oxycombustion operation between its technical minimum load (40%MCR) and the maximum load (100% or MCR). It is also fully flexible in the type of fuel to burn and in the operation mode. All different fuels and fuel blends specified can be continuously burnt without slagging or overloading any equipment and there is no need to stop the boiler to shift from air-operation to oxy-operation.
- All package plants comply with the defined minimum load change rate of 3%MCR·min-1.
- All package plants and all different individual equipments comply with the specified operational life of 25 years. None of the equipment suppliers inquired has presented any deviation on the subject.
- Different package plants are perfectly capable of continuously working in an integrated way the ones with the others. No large storages are strictly necessary (even if a certain oxygen storage is considered for operation optimization).
- The power plant fits in the available space (there is no strict need to enlarge current layout).
- No large interference with Compostilla-site existing power plants exists. The installation of the new OXYCFB300 plant will not interfere with their day-to-day operation.
- The project complies with all Spanish applicable environmental legislation, irrespective of the mode of operation (air / oxy). Proof is that plant Environmental Impact Study has been prepared and submitted to Spanish Government for approval. Process is ongoing at the date of issuance of the present document. Exception to this affirmation is the fact that no Spanish (or European) directive establishing emission limits for oxycombustion operation power plants currently exists.
- The commissioning and testing of the CIUDEN TDP operating experience must be considered during OXYCFB300 Compostilla Project detail engineering, implementing all the required design modifications following operational troubles experienced in CIUDEN TDP.
- Regarding implementation of Phase II, a clear structure of workpackages for the construction of the three main facilities of the demo plant (capture, transport and storage) has been defined.

Based on both Request for Quotations and market analysis performed during FEED, prequalified suppliers are deemed fully capable of successfully delivering all the equipment and services required for the Phase II. However, the number of feasible suppliers for some specific packages is reduced, and therefore success is highly dependant to them.

- The forecasted period for the Phase II is 56 months. Based on the construction studies performed, the schedule for the demo plant construction is estimated in 50 months, from the award of manufacturing of the main packages to the end of commissioning of the plant, ready to start the demonstration period. Prior to the construction, additional 6 months are needed to perform contract management, engineering development and to straighten relationships with suppliers. The critical path goes through the construction of the capture plant.
- The CO_2-pipeline route, selected among the three possible routes presented in the Basic Project, is the most economically and environmentally feasible.
- After the material studies performed, steel grade X-70 for the pipeline and Nitrile (NBR) or EPDM elastomers as sealing materials are suitable for the pipeline construction under the specifications required, and fully capable of withstanding corrosion in the range of impurities designed for the dense-phase CO_2 to be transported.
- The CO_2-pipeline hydraulic calculations performed with the selected layout and pipeline material determine 14" as the optimal diameter. These dynamic calculations guarantee a dense phase CO_2 injection, considering the minimum pressure plant output.
- The installation of 8 sectional (isolation) valves stations along the CO_2-pipeline allows minimize potential risk that a pipeline break or fault could result in goods, services and people. The sectional valves location has been selected in order to avoid urban centre and high population density areas, as well as motorways, roads, railways or pathway with high traffic of vehicle of persons.
- CO_2-pipeline design has been focussed on maintaining the installation integrity as well as the continuity of CO_2 transport and injection into injection wells. To this purpose, CO_2-pipeline is provided with a security system that protects installations, detects anomalous operating situations and allows fast action in case of incidents.
- CO_2 in dense phase will be injected into the geologic sequestration site through a maximum of 9 injection wells, with a design flow rate of 8 kg/s of CO_2 at 115 barg, and through 6" diameter pipelines, manufactured with the same material as main CO_2-pipeline (API 5L Gr. X-70).
- The selection of a serial well injection network is optimal compared with a branched network (with manifolds), minimizing the amount of piping required and generating minimum ground affection.
- Injection wells will have all the instrumentation required to ensure safe operation. In this respect, each injection well is equipped, besides the required devices for proper operation (temperature, pressure and density devices, flow meters, control valves, etc), safety devices as motor operated valves actuators, CO_2 and H2S detectors and intrusion detection alarms.
- Scraper traps installed at CO_2-pipeline make possible cleaning and inspection test inside the duct.
- A Dynamic Model and Geomechanical approach was taken in which different scenarios were simulated to select to most suitable one for the OXY Storage Project.
- Five appraisal wells; SD-1, SD-2, SD-3, SD-4 and SDE-3 were drilled to acquire data in the Duero Basin. The dynamic data collected includes permeability, pressure, temperature gradient, water properties, rock compaction, capillary pressure, and relative permeability. CO_2 solubility data was also acquired to estimate the dissolution trapping.
- The Utrillas formation has good storage properties and appears to have a good injectivity. A high injection rate was maintained in SD-3 DST-1
- The Boñar formation appears to have a very low permeability and does not seem to have a sufficient injectivity to accommodate a commercial injection target. It could, help containment by trapping the CO_2 injected into the Utrillas, acting similarly to an additional seal.
- The Garumn does have the potential to act as the primary seal; it consists mainly of massive claystones with low permeability and high pore entry pressure.
- The Tertiary could act as a secondary seal. It consists of shaly sandstones with very low permeability.
- The pressure gradient acquired in the Utrillas and the Boñar are close to a hydrostatic gradient, which is in line with the formation water density. However, both formations are underpressured, by 9 and 5 bar at 1000 mSS, respectively.
- The different pressure regime between the two formations could indicate that there is some level of discontinuity (partially or entirely) between the Utrillas and the Boñar.
- High irreducible water saturation and low residual CO_2 saturation were identified during the core flood experiments.
- The dynamic model of the Duero syncline was constructed using the appraisal data. This model was used as a means of technical performance evaluation where injectivity, storage capacity, and containment were defined. A compositional simulator with Peng Robinson EOS was used to model the CO_2 injection stream properties.
- Evaluation of the capacity and injectivity has been performed for the Duero Site. The targeted storage formation is the Utrillas reservoir, which appraisal data indicates a good porosity and permeability.
- The well injectivity and well counts are not constrained by the reservoir; they are constrained by the tubing deliverability. Erosional velocity in the tubing has been the main limiting factor.
- WTHP tends to be relatively low as the reservoir was under pressured and has high injectivity. It is thus a challenge to maintain the WTHP above the bubble point and avoid multiphase flow. This implies that perforation length should be minimized, and temporarily operating with two wells (instead of three) might be required after a long shut-in or when the WTHP decreases for any other reason (decrease in WHT, etc).
- The cumulative CO_2 injection estimation is associated to uncertainties on the horizontal permeability, Should the horizontal per-

meability be lower than the base case, more perforations should be added, and if this is not sufficient to achieve the injection target, one additional injector might be required.

- The injection pressure estimation is associated to uncertainties on the horizontal permeability, relative permeability, skin, and WHT. Again, should the WTHP goes below the bubble point, one of the wells should be shut in and injection should be performed with two wells to increase the injection pressure and avoid a two phase flow.
- The plume extent stabilizes after 1000 years, leaving a very slow plume migration rate (15 cm/year in average). The dissolution appears to be the main trapping mechanism; 80% of the total injected CO_2 will dissolved 7500 years after the injection finishes. 15% of the injected CO_2 will be trapped as residual gas saturation.
- The plume extent might vary with the variation in absolute permeability, relative permeability, irreducible water saturations, and the fault sealing capacity. Within the range of uncertainty in this study, however, the plume extent appears to stay within the storage complex constraints, outside the zone where the salinity is less than 5000 ppm and where the top Boñar is less than 800 m below ground level.
- Base on the Duero Site Engineering results, the selected site has got a capacity, injectivity, and containment able for storing the CO_2 during the cycle life of OXYCFB300 project.

Even if OXYCFB300 Compostilla Project FEED phase has been satisfactorily concluded in all engineering disciplines further work is still ahead. A very detailed power plant concept has emerged from the FEED phase (including capture, transport and storage projects); however plant detailed engineering must include some optimization work, looking for better efficiency and engineering designs that further improve interactions between the different package plants.

It can be finally concluded then that, **regarding the technical aspects** of the Project, **the Compostilla OXY-CFB-300 plant can be considered feasible although some technical risks are still relevant**. Main concerns are related to the integration between ASU, Boiler and CPU.

The plant efficiency (33,32%) is conditioned by the limited operation flexibility. Additionally, considering that the OXY-CFB-300 is a "First of a Kind" concept, there is a considerable risk of performance reduction over time. From a competitive point of view, the next series of commercial power plants will cannibalize this demo plant through the knowledge sharing programmes. It shortens the useful lifetime of this plant (25 years vs 40 years).

The capture plant scheme seems to be robust and reliable, nevertheless plant flexibility is reduced. Base load operation is required to avoid further reductions of efficiency. This fact limits the successful entry of the plant to the electricity markets. On the other hand, fuel flexibility is an advantage for future market price volatility and the capability to burn a significant amount of biomass is an additional advantage.

Regarding the CO_2 transport, there are minor concerns related only to possible pipeline local corrosion for off-design operations. The proposed CO_2 Transport solution is based on a mature technology and seems to be feasible.

CO_2 storage in the Duero site seems to be technically feasible. The Duero site has the required capacity to store the total amount of the CO_2 produced in the lifetime of the OXY-CFB-300 under safe conditions. Risks related to the storage are considered low, although malfunction of the injection area selected could have a notable impact on the Project execution and subsequent operation.

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