PilotSTRATEGY

WP4 -Deliverable 4.2

Conceptual scenarios definition to enable decision support

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1. Document History

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Disclaimer

2. Executive summary

The objective of the WP4 is to provide complete information on the optimum development concept applicable to the proposed pilots. The development concept and its viability decision must be based on strategic information to identify and address existing risks and to commit available resources, maximising the potential for success. This strategic information was identified during a framing session phase conducted previously in the project and summarised in the D4.1 public deliverable "Methodology for alternatives definition, Prioritisation, and Selection," published in May 2023, for Paris Basin, Lusitanian Basin, and Ebro Basin. In this document in also described the results for West Macedonian and Silesia regions, carried out in October 2023 and September 2023, respectively.

This report shows the different strategies outlined by every region involved in the PilotSTRATEGY projects, before a comprehensive analysis of those strategies and their associated scenarios.

In the PilotSTRATEGY project frame, "conceptual scenario" refers to a technical description and planning of the CO_2 storage site life cycle valid for a specific strategy. These strategies are not only economy-driven but should also consider the different interests of potential stakeholders.

Here, the five regions have provided a description of the pool of strategies selected, and the decisions that fit with those strategies. All of these have been explained briefly since, at this stage of the project, there are still uncertainties that may be clarified or limited later in the project thanks to other work-packages studies. Nevertheless, these scenarios and strategies will be the basis for further project analysis that eventually will enable decision support, as it is stated in this deliverable title.

The description of each conceptual scenario must include:

- Strategy description (brief)
- Time frame: construction phase, first injection, end injection.
- Application goal: Research/commercial
- CO_2 source (impurities, volume per year)
- CO_2 transport: type, construction phase, volume per year
- Injector(s) well(s) type, injection rate, and number
- Monitoring, Measurement and Verification (MMV) programme

Scenarios are used to create awareness and prepare for an uncertain future to deal with the inherent uncertainty of exploring mid and long-term developments (e.g., CO_2 storage life cycle), and help to test the robustness of different strategies against multiple possible futures.

The objective of this document is to identify required information (what is available and what is not), to take specific decisions when it is possible, and to cover as wider (but manageable!) range of possibilities for the storage site development.

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PilotSTRATEGY

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3. Introduction

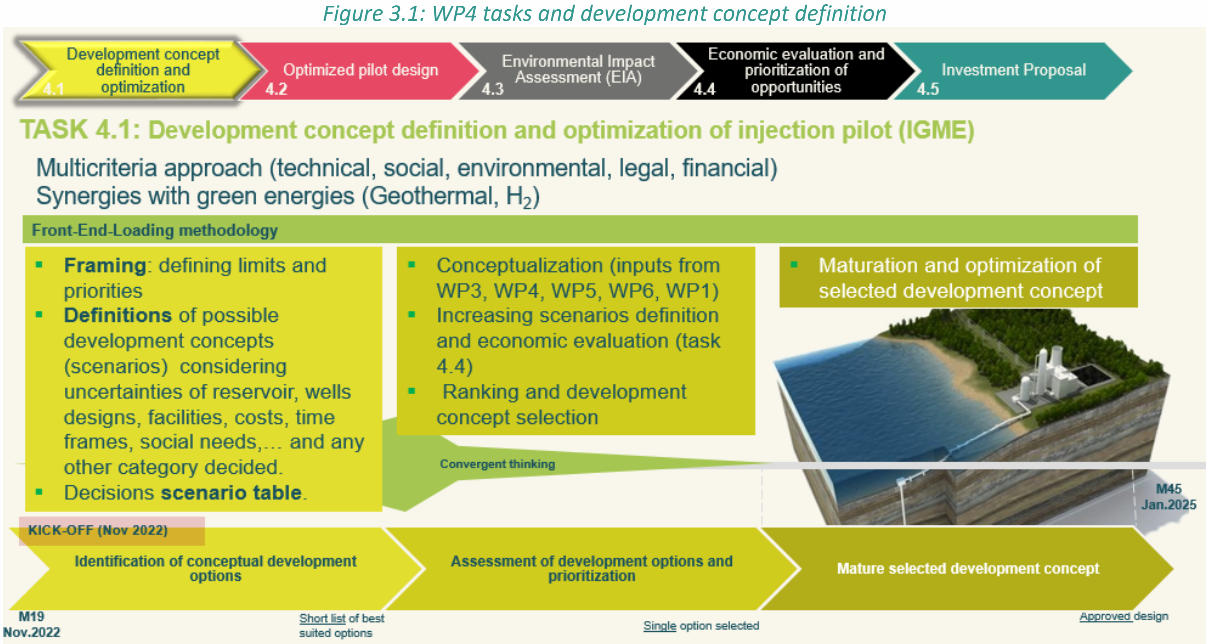
The objective of the WP4 is to provide complete information on the optimum development concept applicable to the proposed pilots of the Paris Basin (FR), Lusitanian Basin (PT), and Ebro Basin (ES) to go ahead with the decision of whether this pilot is viable technically, commercially, considering social and environmental demands, and in the existing European and local regulatory frame. We will also enhance our knowledge of CO_2 storage options in West Macedonia region (GR) and Upper Silesia region (PL).

To conclude whether a pilot is viable is a major decision for a project. This decision must be based on strategic information to identify and address existing risks and to commit available resources, maximising the potential for success. It must be established at the very first steps of the project, when the ability to influence changes in design is high while the cost of them is low.

This strategic information was identified during a framing session phase conducted previously in the project and summarised in the D4.1 public deliverable “Methodology for alternatives definition, Prioritisation, and Selection,” for Paris Basin, Lusitanian Basin and Ebro Basin published in May 2023. In addition, this document describes the results for West Macedonian and Silesia regions since both regions have done an extra effort of following proposed methodology and learning during the process.

These development concepts need to be described for the full life cycle (including reservoir behaviour with the support of WP3 and dynamic modelling; wells and facilities design from task 4.2; and WP5 for the risks evaluation) and evaluate economically (task 4.4) to final selection.

Figure 3.1: WP4 tasks and development concept definition



3.1 Framing session methodology

The methodology proposed for collecting information, sorting, and selecting several desirable alternatives—conducted earlier in WP4—is here briefly described as the starting point. It is adapted from the “Decision Quality” approach, proposed by the Society of Decision Professionals, to the needs of the PilotSTRATEGY project.

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The framing session ensured that all participants had a clear and common understanding of the objectives, limitations, givens, and decisions. The session facilitated collecting views from all technical, social, legal, commercial, and regulatory disciplines. This provides space to establish a set of four to six different strategies to reach the project goal. These strategies defined during the framing sessions have been translated into conceptual scenarios (this is the goal of this document). They will be techno-economically evaluated (task 4.4), prioritised, and eventually the optimum one will be selected.

Paris Basin team, Lusitania Basin team and Ebro Basin team performed this exercise in two sessions between January- February 2023, resulting a list of 5 to 6 strategies (alternatives) each of them. In the same way, Poland team decided to initiate a framing session in May 2023, and Greece performed the same exercise in September 2023, in both cases carried out in parallel with a broad representatives' stakeholders. As example, Greece Team involved HEREMA (HHRM), which is the permit authority in Greece for CO2 storage, and the main results were communicated both times in the parliament as the latter requested a comprehensive briefing.

4. Conceptual scenarios definition

Scenarios are used to create awareness and prepare for an uncertain future to deal with the inherent uncertainty of exploring mid and long-term developments (e.g., CO_2 storage life cycle), and help to test the robustness of different strategies against multiple possible futures[1].

In the context of this document and tacking as starting point the strategies table defined and described in deliverable D4.1[2] for each region, conceptual scenario refers to a technical description and planning of the CO_2 storage site life cycle valid for a specific strategy.

The description of each conceptual scenario must include, at least:

- Strategy description (brief)
- Time frame: construction phase, first injection, end injection.
- Application goal: Research/commercial
- CO_2 source (impurities, volume per year)
- CO_2 transport: type, construction phase, volume per year
- Injector(s) well(s) type, injection rate, and number
- Monitoring, Measurement and Verification (MMV) programme

In most, if not in all cases, the strategies could be described in different ways. This is due to the high level of uncertainty at this phase. For instance, dynamic models are still being built; wells designs or limitations are unclear, or in some cases, it is unknown the CO_2 source and then its quality. To describe each case with a coherent and consistent narrative suitable for the latter economic evaluation, cost allocation and economic scenario forecast are needed. This will be provided in task 4.4. This will allow to identify those decisions that cannot be taken now but can be analysed later by sensitivity analysis.

[1] Types of scenario planning and their effectiveness: A review of reviews Kathya Cordova-Pozo*, Etienne A.J.A. Rouwette Institute for Management Research, Radboud University, P.O. Box 9108, 6500 HK Nijmegen, the Netherlands

[2] Canteli, P.; García, D.; Jannel, H. & Casacão, J. 2023. Methodology for alternatives definition, prioritisation, and selection. Deliverable D4.1, PilotSTRATEGY EU project (101022664). https://pilotstrategy.eu/sites/default/files/2023-06/PilotSTRATEGY_WP4_D4_1.pdf

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4.1 Paris Basin (France) conceptual scenarios

Five strategies were agreed upon, and defined corresponding scenarios according to the following tables:

1) Pilot fast-track development at minimal cost to prove technical feasibility.
2) Prepare/develop a pilot for commercial development (e.g., attract project developers).
3) Minimise the project footprint on local communities.
4) Foster local economy and nearby communities' development.
5) Showcase CCS solutions and associated advantages, e.g., build a world-class CCS demonstrator.

4.1.1 Pilot fast-track development at minimal cost to prove technical feasibility

The minimum investment strategy is based on reducing (financial) risks due to geological uncertainty by minimising capital costs at front, based on a 3-year pilot injection to test formation behaviour, plume monitoring, and ensuring proper future storage profile management in case of positive results. The financial investment is limited, with the possibility of being financed by national or European funds.

Table 4.1.1: Pilot fast track development at minimal cost strategy of French region.

Strategies	**DECISIONS**										
	CO2 Source	***CO2 Transport***	***Supply***	***Total CO2 quantity***	***Surface facilities***	***Power supply***	***Well design***	***Monitoring***	***next phase Funding***	***Project duration***	***Project budget***
1. Pilot fast-track	LAT NITRO	Onsite (3)	Continuous	< 100 k tons (4)	No facilities (7)	power grid	Vertical (10)	4D seismic	UE	5 years	< 10 M€
	Total Grandpuits	Trucks	Intermittent	Min. (5)	Temporary (8)	solar / wind	Deviated, (11)	DAS	State initiative	Min. 3 years (13)	< 20 M€
	Large CO2 emitters (1)	Train		Commercial scale (6)	Permanent (9)	geothermal		New wells (12)	consortium public/private	Commercial (14)	Commercial (15)
	Distant CO2 emitters (2)	Pipeline						legacy O&G wells	Private equity		
	CO_2 market										

(1) Waste incinerators, large CO_2 emitters nearby Paris (as identified in STRATEGY CCUS).
(2) Distant CO_2 emitters (e.g. steel industry in Northern France).
(3) Onsite (injection well within CO_2 plant).
(4) Research permit (< 100 kt)
(5) Minimum to obtain meaningful results (~30 kt).
(6) Amount to achieve commercial scale ("autorisation environnementale unique").
(7) No facilities i.e. manifold hooked up to injection well.
(8) Temporary surface facilities with reduced footprint.
(9) Permanent injection facility.
(10) Vertical, basic completion.
(11) Deviated, enhanced completion design.
(12) New surveillance wells
(13) Minimum to obtain results (30 kt) i.e. 3 years
(14) Commercial design life e.g. 30 years
(15) Commercial scale (~100 M€)

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The CO_2 source is assumed to be from the closer point (industry) at a few kilometres from the storage site; a limited amount of up to 30 kt of CO_2 could be injected intermittently. Should an industrially relevant injection rate be considered, high peak rates, e.g., 2 kg/s, during a long enough period, surface storage tanks would be required. Such peak rates will be determined by ongoing characterization and modelling studies. The truck transport is considered a flexible solution that minimises the risk of costly infrastructure that could be evaluated later in the project. However, transport by trucks and buffering storage (storage tanks) requires liquefied CO2 increasing costs of conditioning.

The power supply to the injection well site will come from the power grid to minimise the cost of the pilot project. Further cost reductions might be obtained through the rental of the surface storage tanks. The well will be vertical or slightly deviated to minimise drilling costs and complexity, but the design of its completion and material is not finalized. As the injection location is not finalised, a legacy well located within the premises of the CO_2 emission plant might be used for monitoring to further reduce the cost of the pilot. The estimated cost of this pilot fast-track development is expected to be up to 10 M€.

The MMV plan has yet to be outlined since the risk analysis has not yet been performed at this report delivery date. So far, for all the scenarios in this area, the MMV plan will consist of the recommended procedures for these projects.

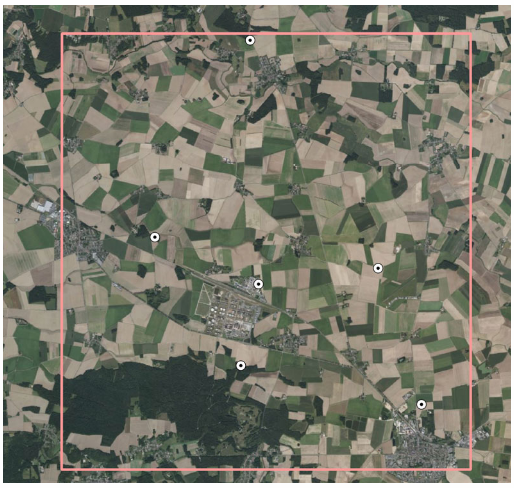

Figure 4.1 Legacy wells within the project area (dots)

In the area of interest within the Paris basin (**Erreur ! Source du renvoi introuvable.**), there are six legacy wells and only three within a 3-kilometre radius from the CO_2 emission plant and one on the CO_2 emission plant premises.

4.1.2 Prepare/develop a pilot for commercial development (e.g., attract project developers)

The prepare/develop pilot for commercial development strategy is aimed at attracting interest and commitment from industrial CO_2 emitters in the area, which might be connected to the storage location through a newly built pipeline network. The pilot design should target a commercial rate of about 0.3 Mtpa. Consequently, the high peak rate should be confirmed during the pilot period (5 years and 100 kt) to test formation behaviour, plume monitoring, and ensure proper future storage profile management in case of positive results. The financial investment is significant and should be financed by the industrial joint venture, complemented by national or European funds.

Table 4.1.2: Prepare a pilot for commercial development strategy of French region.

Strategies	**DECISIONS**											
	CO2 Source	***CO2 Transport***	***Supply***	***Total CO2 quantity***	***Surface facilities***	***Power supply***	***Well design***	***Monitoring***	***next phase Funding***	***Project duration***	***Project budget***
	LAT NITRO	Onsite (3)	Continuous	< 100 k tons (4)	No facilities (7)	power grid	Vertical (10)	4D seismic	UE	5 years	< 10 M€
2. commercial develop	Total Grandpuits	Trucks	Intermittent	Min. (5)	Temporary (8)	solar / wind	Deviated, (11)	DAS	State initiative	Min. 3 years (13)	< 20 M€
	Large CO2 emitters (1)	Train		Commercial scale (6)	Permanent (9)	geothermal		New wells (12)	consortium public/private	Commercial (14)	Commercial (15)
	Distant CO2 emitters (2)	Pipeline						legacy O&G wells	Private equity		
	CO_2 market										

(1) Waste incinerators, large CO_2 emitters nearby Paris (as identified in STRATEGY CCUS).
(2) Distant CO_2 emitters (e.g. steel industry in Northern France).
(3) Onsite (injection well within CO_2 plant).
(4) Research permit (< 100 kt)
(5) Minimum to obtain meaningful results (~30 kt).
(6) Amount to achieve commercial scale ("autorisation environnementale unique").
(7) No facilities i.e. manifold hooked up to injection well.
(8) Temporary surface facilities with reduced footprint.
(9) Permanent injection facility.
(10) Vertical, basic completion.
(11) Deviated, enhanced completion design.
(12) New surveillance wells
(13) Minimum to obtain results (30 kt) i.e. 3 years
(14) Commercial design life e.g. 30 years
(15) Commercial scale (~100 M€)

The CO_2 source is assumed to be from the three industrial sites located a few kilometres from the storage site; the industrial relevant injection rate should be considered; high peak rates, e.g., 10 kg/s, during a long enough period would require a connection to the pipeline or temporary surface storage tanks during the pilot testing. Such peak rates will be determined by ongoing characterization and modelling studies. The pipeline transport is in line with the expected commercial outcome.

The power supply to the injection well site will come from the power grid to minimise the cost of equipment at the injection site, while the pipeline pressure should be high enough to enable supercritical CO_2 injection. The well will be vertical or slightly deviated to minimise drilling costs and complexity, but the design of its completion and material is not finalized. The estimated cost of this pilot for commercial development strategy is expected to be around 100 M€.

The MMV plan has yet to be outlined since the risk analysis has not yet been performed at this report delivery date, but it is foreseen to be significant with likely 4D seismic and DAS in addition to monitoring wells.

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In the area of interest within the Paris basin (**Erreur ! Source du renvoi introuvable.**), there are six legacy wells and only three within a 3-kilometre radius from the CO_2 emission plant and one on the CO_2 emission plant premises.

4.1.3 Minimise the project footprint on local communities

The strategy to minimise the project footprint on local communities is based on reducing the impact of the pilot operations through an injection located within the premises of a CO_2 emission plant where there is a disposal well in the formation of interest. To ensure relevant results, the pilot is expected over a 3-year period to test formation behaviour, plume monitoring, and ensure proper future storage profile management in case of positive results. The financial investment is limited, with the possibility of being financed by national or European funds.

Table 4.1.3: Minimise the project footprint on local communities strategy of French region.

Strategies	DECISIONS										
	CO2 Source	***CO2 Transport***	***Supply***	***Total CO2 quantity***	***Surface facilities***	***Power supply***	***Well design***	***Monitoring***	***next phase Funding***	***Project duration***	***Project budget***
	LAT NITRO	Onsite (3)	Continuous	< 100 k tons (4)	No facilities (7)	power grid	Vertical (10)	4D seismic	UE	5 years	< 10 M€
	Total Grandpuits	Trucks	Intermittent	Min. (5)	Temporary (8)	solar / wind	Deviated, (11)	DAS	State initiative	Min. 3 years (13)	< 20 M€
3. Minimise footprint	Large CO2 emitters (1)	Train		Commercial scale (6)	Permanent (9)	geothermal		New wells (12)	consortium public/private	Commercial (14)	Commercial (15)
	Distant CO2 emitters (2)	Pipeline						legacy O&G wells	Private equity		
	CO_2 market										

(1) Waste incinerators, large CO_2 emitters nearby Paris (as identified in STRATEGY CCUS).
(2) Distant CO_2 emitters (e.g. steel industry in Northern France).
(3) Onsite (injection well within CO_2 plant).
(4) Research permit (< 100 kt)
(5) Minimum to obtain meaningful results (~30 kt).
(6) Amount to achieve commercial scale ("autorisation environnementale unique").
(7) No facilities i.e. manifold hooked up to injection well.
(8) Temporary surface facilities with reduced footprint.
(9) Permanent injection facility.
(10) Vertical, basic completion.
(11) Deviated, enhanced completion design.
(12) New surveillance wells
(13) Minimum to obtain results (30 kt) i.e. 3 years
(14) Commercial design life e.g. 30 years
(15) Commercial scale (~100 M€)

There will be a limited amount of up to 30 kt of CO_2, which could be injected intermittently and combined with water injection. No CO_2 transport is required as there is only a limited pipe connection between the capture plant and the well head.

The power supply to the injection well site will come from the power grid to minimise the cost of the pilot project. The well will be vertical or slightly deviated to minimise drilling costs and complexity, but

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the design of its completion and material is not finalised. The estimated cost of this strategy of minimal footprint on local communities is expected to be less than 10 M€.

The MMV plan has yet to be outlined since the risk analysis has not yet been performed at this report delivery date, but it is foreseen to use DAS monitoring.

In the area of interest within the Paris basin (**Erreur ! Source du renvoi introuvable.**), there are six legacy wells and only three within a 3-kilometre radius from the CO_2 emission plant and one on the CO_2 emission plant premises.

4.1.4 Foster local economy and nearby communities development

The strategy to foster local economy and nearby communities development is aimed at attracting interest and commitment from industrial CO_2 emitters in the area and beyond, which might be connected to the storage location through a newly built local pipeline network and national CO_2 transport backbone. The pilot design should target an industrial rate of about 1 Mtpa. Such peak rates will be determined by ongoing characterization and modelling studies. Consequently, this rate should be confirmed during the pilot period (5 years and 100 kt) to test formation behaviour, plume monitoring, and ensure proper future storage profile management in case of positive results. The financial investment is significant and should be financed by the industrial joint venture, complemented by national or European funds.

Table 4.1.4: Foster local economy and nearby communities development strategy of French region.

Strategies	**DECISIONS**										
	CO2 Source	***CO2 Transport***	***Supply***	***Total CO2 quantity***	***Surface facilities***	***Power supply***	***Well design***	***Monitoring***	***next phase Funding***	***Project duration***	***Project budget***
	LAT NITRO	Onsite (3)	Continuous	< 100 k tons (4)	No facilities (7)	power grid	Vertical (10)	4D seismic	UE	5 years	< 10 M€
	Total Grandpuits	Trucks	Intermittent	Min. (5)	Temporary (8)	solar / wind	Deviated, (11)	DAS	State initiative	Min. 3 years (13)	< 20 M€
	Large CO2 emitters (1)	Train		Commercial scale (6)	Permanent (9)	geothermal		New wells (12)	consortium public/private	Commercial (14)	Commercial (15)
4. Foster local economy	Distant CO2 emitters (2)	Pipeline						legacy O&G wells	Private equity		
	CO_2 market										

(1) Waste incinerators, large CO_2 emitters nearby Paris (as identified in STRATEGY CCUS).
(2) Distant CO_2 emitters (e.g. steel industry in Northern France).
(3) Onsite (injection well within CO_2 plant).
(4) Research permit (< 100 kt)
(5) Minimum to obtain meaningful results (~30 kt).
(6) Amount to achieve commercial scale ("autorisation environnementale unique").
(7) No facilities i.e. manifold hooked up to injection well.
(8) Temporary surface facilities with reduced footprint.
(9) Permanent injection facility.
(10) Vertical, basic completion.
(11) Deviated, enhanced completion design.
(12) New surveillance wells
(13) Minimum to obtain results (30 kt) i.e. 3 years
(14) Commercial design life e.g. 30 years

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(15) Commercial scale (~100 M€)

The CO_2 source is assumed to be from local and distant industrial sites; the relevant industrial injection rate should be considered; high peak rates, e.g., about 32 kg/s, during a long enough period would require a connection to the pipeline. The pipeline design is in line with the expected commercial outcome.

The power supply to the injection well site will come from renewable electricity (likely wind farms) while the pipeline pressure should be high enough to enable supercritical CO_2 injection with minimal site equipment, e.g., an electric pump. The well will be vertical or slightly deviated to minimise drilling costs and complexity, but the design of its completion and material is not finalised. The estimated cost of this strategy to foster the local economy and nearby communities development is expected to be above 100 M€.

The MMV plan has yet to be outlined since the risk analysis has not yet been performed at this report delivery date, but it is foreseen to be significant with 4D seismic and DAS in addition to monitoring wells.

In the area of interest within the Paris basin (**Erreur ! Source du renvoi introuvable.**), there are six legacy wells and only three within a 3-kilometre radius from the CO_2 emission plant and one on the CO_2 emission plant premises.

4.1.5 Build a world-class CCS demonstrator

The strategy to showcase CCS solutions and associated advantages, e.g., build a world-class CCS demonstrator, is aiming at demonstration of the benefits of CCS through an injection located within the premises of a CO_2 emission plant where there is a disposal well in the formation of interest. To ensure relevant results and demonstration, the pilot is expected over a 5-year period to test formation behaviour, plume monitoring, and ensure proper future storage profile management in case of positive results. The financial investment is limited, with the possibility of being financed by European and national funds.

Table 4.1.5: Built a world – class CCS demonstrator strategy of French region.

Strategies	**DECISIONS**										
	CO2 Source	***CO2 Transport***	***Supply***	***Total CO2 quantity***	***Surface facilities***	***Power supply***	***Well design***	***Monitoring***	***next phase Funding***	***Project duration***	***Project budget***
	Borealis	Onsite (3)	Continuous	< 100 k tons (4)	No facilities (7)	power grid	Vertical (10)	4D seismic	UE	5 years	< 10 M€
	Total Grandpuits	Trucks	Intermittent	Min. (5)	Temporary (8)	solar / wind	Deviated, (11)	DAS	State initiative	Min. 3 years (13)	< 20 M€
	Large CO2 emitters (1)	Train		Commercial scale (6)	Permanent (9)	geothermal		New wells (12)	consortium public/private	Commercial (14)	Commercial (15)
	Distant CO2 emitters (2)	Pipeline						legacy O&G wells	Private equity		
5. Show case CCS	CO_2 market										

(1) Waste incinerators, large CO_2 emitters nearby Paris (as identified in STRATEGY CCUS).
(2) Distant CO_2 emitters (e.g. steel industry in Northern France).

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(3) Onsite (injection well within CO_2 plant).
(4) Research permit (< 100 kt)
(5) Minimum to obtain meaningful results (~30 kt).
(6) Amount to achieve commercial scale ("autorisation environnementale unique").
(7) No facilities i.e. manifold hooked up to injection well.
(8) Temporary surface facilities with reduced footprint.
(9) Permanent injection facility.
(10) Vertical, basic completion.
(11) Deviated, enhanced completion design.
(12) New surveillance wells
(13) Minimum to obtain results (30 kt) i.e. 3 years
(14) Commercial design life e.g. 30 years
(15) Commercial scale (~100 M€)

There will be a limited amount of up to 30 kt of CO_2, which could be injected intermittently and combined with water injection. No CO_2 transport is required as there is only a limited pipe connection between the capture plant and the well head.

The power supply to the injection well site will come from a geothermal plant. The well will be vertical or slightly deviated to minimise drilling costs and complexity, but the design of its completion and material is not finalised. Temporary surface storage tanks would be required to enable demonstration of a high peak injection rate, e.g., 2 kg/s, for a long enough period. The installation should be designed to be easily dismantled at the end of the demonstration. The estimated cost of this strategy is expected to be less than 20 M€.

The MMV plan has yet to be outlined since the risk analysis has not yet been performed at this report delivery date, but it is foreseen to use 4-D seismic and DAS monitoring in addition to monitoring wells.

In the area of interest within the Paris basin (**Erreur ! Source du renvoi introuvable.**), there are six legacy wells and only three within a 3-kilometre radius from the CO_2 emission plant and one on the CO_2 emission plant premises.

4.2 Lusitanian Basin (Portugal) conceptual scenarios

As results of the discussion, six (6) strategies and corresponding alternatives have been defined:

1) Minimum cost.
2) Social engagement, awareness, local development.
3) Regulatory gaps understanding and research.
4) Schedule and accelerating the pilot development.
5) Enhance the commercial development.
6) Limit HSE risk and reduce territorial impacts.

4.2.1 Minimum cost

Minimum investment strategy is based on reducing (financial) risks due to geological uncertainty by minimising capital costs at front, based on a 3-years pilot injection to test formation behaviour, including 3D seismic acquisition (as part of the baseline monitoring plan), and ensuring proper future storage profile management in case of positive results. The financial investment is limited to 20 M€

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for the storage component, and it is considered to have possibility of being financed by national (public and/or private) or European funds.

Table 4.2.1: Minimum cost strategy of Portuguese region.

Strategy (*)	Decisions							
	CO_2 Source	***Transport***	***CO_2 Quantity***	***Supply Continuity***	***Monitoring***	***Power Supply***	***Well Design***	***Project Duration***
Min. Cost	Market	Pipeline	100Kt (Permit max)	Continuous	4D seismic (monitor CO_2 plume)	Powergrid	Vertical	5 years: Monitoring during injection and post-injection
	Cement & lime plant	Truck/ship	CO_2 availability at the source	Intermittent	Monitoring along the well	Renewables: Offshore Wind	Deviated	Min. for monitoring (30 Kt) / 3 years
	Pulp plant	Train/ship	Min. For monitoring (<100 kt)		Near-Seabed (e.g., piston cores, ROV's)			Upscale to commercial storage site.
	Glass industry							
	Oil Refinery							

The CO_2 source is assumed to be from the closer point (cement/lime, glass, and paper and pulp industries) from 50 to 80 km of storage site; a limited amount of 30 kt CO_2 per year (minimum to be monitored); CO_2 transported by ship/truck/train to be defined the best option; there is no need to ensure continuous injection (small reception tanks). This transport is considered a flexible and cheaper solution that minimise the risk of costly infrastructure that would be evaluated later in the project.

The power supply for the injection well site will be provided from the power grid to guarantee a continuous power supply at competitive prices, reducing the complexity of the project evaluation. The well design will be vertical; however, specific aspects such as alloys, completions, and diameters are still being discussed, as well as considering alternative (directional) well designs to optimise storage injection. Nevertheless, vertical wells used to be less complicated, cheaper to drill, and easier to complete.

The MMV plan has yet to be outlined since the risk analysis is being performed at this report delivery date. So far, for all the scenarios in this area, the MMV plan will consist of the recommended procedures for these projects. In the Lusitanian basin, there are a few legacy wells in the area of interest, and the closest well is the Dourada-1, which is located within the P50 prospect outline. This legacy well is being taken into account in the ongoing dynamic simulations, ensuring that the plume does not reach the well in the long term.

4.2.2 Social engagement, awareness, local development

The social engagement and local development strategy aims to enhance the positive impacts on the local community in terms of development and the positive perception of the project among the citizens.

The CO_2 source for this strategy should come from the nearby pulp plant and glass industry. The negative impact of carbon emission reduction in these factories and facilities would be reduced, and the business adaptation to future emissions restrictions would be granted, therefore extending their lifecycle. At the pilot scale, CO_2 transport would be made by truck to the temporary storage site at the Figueira da Foz port, and from there by ship to the storage site. The total volume to be injected must be below 100,000 metric tonnes (the maximum volume for a pilot well permit) and be injected

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continuously. Temporary CO_2 storage at the Figueira da Foz port (CO_2 offloading terminal) may be needed to compress and pressurise CO_2 while guaranteeing a continuous flow.

Strategy	Decisions							
	CO2 Source	*Transport*	*CO2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*project duration*
	market	pipeline/ship	**100kt (permit max)**	**intermitent**	**4D seismic (to monitor CO2 plume)**	power grid	**vertical**	**5 years (injection, monitoring during injection, monitoring post-injection)**
Social Engagement, Awareness, Local development	cement & lime plant	truck/ship	CO2 availability at the source		**monitoring along well**	**Renewable: offshore wind**	**deviated**	min. for monitoring (30ktons): 3 years (check QUEST)
	pulp plant	**train/ship**	min. for monitoring (<100 kton)		**near-seabed (e.g. piston cores, ROV inspection)**			Upscale to commercial storage site
	glass industry							
	refinery							
	others							

Table 4.2.2: Social engagement, awareness, local development of Portuguese region.

The MMV plan, as above, has not yet been outlined; despite there is a legacy well in the vicinities of the storage site (Dourada-1), this well was P&A in the 1970's, and it is not being accounted for to be used as a monitoring point. So far, no new observation wells have been included in this scenario; although they can increase economic activity while they are drilled, they would largely impact the project costs, and there are other alternatives to be considered offshore to properly monitor the storage site.

In terms of power supply, the most suitable "green" alternative that can be considered to maximise the project's CO_2 emission reduction is the connection to the offshore wind farms that are being promoted by the government in the AOI. This would help to create new job opportunities in the area linked to this project.

About the project funding, duration, and budget, it is considered that the most advantageous alternatives for this strategy are a sound budget for a pilot development project with funding that can come from the EU and/or private equities, including the mixing alternative of consortia EU/private partners.

4.2.3 Regulatory gaps understanding and research

This strategy will address the problems that a potential carbon storage operator could face. Those problems could be related to regulation, a lack of knowledge on reservoir behaviour, and technical and economic issues. So, this strategy should help to understand the issues as deeply as possible, as well as address recommendations and solutions for the industry or lawmakers.

In this scenario, the CO_2 source comes from cement/lime, pulp and paper plants, glass industry, or eventually a refinery. This CO_2 will be transported by ship to the injection site up to 100,000 CO_2 metric tonnes (the actual limit of a pilot well permit). The CO_2 should be injected intermittently in order to conduct the operation in the safest possible way while controlling the pressure buildup at the reservoir scale (CO_2 storage at the site should be available).

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Strategy	Decisions							
	CO2 Source	*Transport*	*CO2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*project duration*
	market	pipeline/ship	100kt (permit max)	intermitent	4D seismic (to monitor CO2 plume)	power grid	vertical	monitoring during injection, monitoring post-injection)
	cement & lime plant	truck/ship	CO2 availability at the source		monitoring along well	Renewable: offshore wind	deviated	min. for monitoring (30ktons): 3 years (check QUEST)
Regulatory Framework Gap Understanding / Research	pulp plant	train/ship	min. for monitoring (<100 kton)		near-seabed (e.g. piston cores, ROV inspection)			Upscale to commercial storage site
	glass industry							
	refinery							
	others							

Table 4.2.3: Regulatory gaps understanding and research of Portuguese region.

Although the MMV plan has yet to be defined in this scenario, 4D seismic would be key to monitor the CO_2 plume evolution at depth. Additionally, monitoring along well and seabed monitoring stations (e.g., piston cores, ROV inspection) will be highly considered in the MMV plan. Drilling observation wells might be considered at a later stage to help better understand the reservoir behaviour, although it poses a significant cost to the project.

A deviated well can increase the injectivity of CO_2 especially in low-permeability rocks, increasing the efficiency of the injector well in the commercial upscaling phase. This alternative well design would only be considered at a later stage, after proving the storage concept. This strategy would be slightly more expensive, and it would probably require financial incentives from joint public/private funding to make the project feasible.

Regarding the gap in regulation in this project, the potential connection to offshore wind farm energy generation would be something to be defined for the future. The current uncertainties about the timing of the development of this initiative can only allow for a conceptual consideration at this stage.

4.2.4 Schedule and accelerating the pilot development

The strategy for scheduling and accelerating the pilot development will strongly rely on a secured supply of CO_2, preferably from local sources to stimulate carbon capture and transport from emitters close by, but alternatively from other available sources in the future, such as CO_2 carrier ships.

Table 4.2.4: Schedule and accelerating the pilot development of Portuguese region.

Strategy	Decisions							
	CO2 Source	*Transport (onshore to port/offshore)*	*CO2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*project duration*
	market	pipeline/ship	100kt (permit max)	intermitent	4D seismic (to monitor CO2 plume)	power grid	vertical	5 years (injection, monitoring during injection, monitoring post-injection)
	cement & lime plant	truck/ship	CO2 availability at the source		monitoring along well	Renewable: offshore wind	deviated	min. for monitoring (30ktons): 3 years (check QUEST)
	pulp plant	train/ship	min. for monitoring (<100 kton)		near-seabed (e.g. piston cores, ROV inspection)			Upscale to commercial storage site
Schedule & accelerate the pilot development	glass industry							
	refinery							
	others							

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During the pilot phase, CO_2 transportation from emitters to the temporary receiving terminal at the port of Figueira da Foz can be made either by truck or eventually by ship. Incoming CO_2 at the onshore facility would undergo pressurisation (~15 bar), a process that can take approximately 5 days to build up the required pressure before injection.

Given the uncertainties with reservoir deliverability and seal containment, MMV strategies to accelerate the pilot development would require monitoring along well. Well-based monitoring research and development has been gaining attention in recent years, including petrophysical measurements, core plugs, and permanently deployed sensors that can be used in repeated geophysical surveys to assess temporal changes in the subsurface. Furthermore, coupled subsurface processes, including hydrological, mechanical, and geochemical, must be understood to ensure the permanence of the stored CO_2 throughout the project's lifecycle.

Pilot development would only rely on a vertical well injection to secure cheaper CAPEX costs, and access to the power grid is still to be addressed. The offshore setting poses additional constraints during the CO_2 injection operation, can increase the project costs; however, the available options will still be discussed in the storage development plans.

4.2.5 Enhance the commercial development

The commercial upscaling would preferentially be an extension of the more efficient and proven results from the pilot phase.

To ensure the economics and stakeholder engagement of the project, CO_2 sources would preferably rely on local emitters that already had some contribution in the past pilot injection phase. However, this would rely on the ability and investment of local industry emitters to secure the capture and transport of their CO_2 emissions to the receiving terminal at the Figueira da Foz port. To reduce the risk of intermittent CO_2 supply and to promote a higher influx into the storage site, the project would benefit from other CO_2 sources available elsewhere, namely by ship (this ensures flexibility and scalability of the project).

Table 4.2.5: Enhance the commercial development of Portuguese region.

Strategy	**Decisions**							
	CO2 Source	***Transport***	***CO2 Quantity***	***Supply continuity***	***Monitoring***	***Power Supply***	***well design***	***project duration***
	market	**pipeline/ship**	100kt (permit max)	**intermitent**	**4D seismic (to monitor CO2 plume)**	**power grid**	vertical	5 years (injection, monitoring during
	cement & lime plant	truck/ship	**CO2 availability at the source**		monitoring along we	Renewable: offshore wind	**deviated**	min. for monitoring (30ktons): 3 years
	pulp plant	train/ship	min. for monitoring (<100 kton)		near-seabed (e.g. piston cores, ROV			**Upscale to commercial storage site**
	glass industry							
Enhance the commercial development	refinery							
	others							

Commercial development would require baseline monitoring, with long-term 4D seismic acquisition as a main requirement to observe the plume evolution in the subsurface from before the pilot injection until the end of the operation.

Upscaling the injection operation would also disregard transport by ship (from the Figueira da Foz terminal to the offshore platform) for a more efficient and cost-effective solution of a dedicated

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pipeline. The CO_2 flow rate would have to be decided depending on the ongoing dynamic simulations to ensure reservoir capacity under safe conditions. Optimisation of the storage site would also benefit from the drilling of a second (directional) well, although this option must be aligned with the injection simulation results still ongoing as well as the results of the pilot injection well.

4.2.6 Limit HSE risk and reduce territorial impacts

Finally, some general indications were also included as a consideration to limit HSE impacts on the affected territory.

Table 4.2.6: Limit HSE risk and reduce territorial impacts of Portuguese region.

Strategy	Decisions							
	CO2 Source	*Transport*	*CO2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*project duration*
	market	pipeline/ship	100kt (permit max)	**intermitent**	4D seismic (to monitor CO2 plume)	**power grid**	**vertical**	5 years (injection, monitoring during injection, monitoring post-injection)
	cement & lime plant	truck/ship	CO2 availability at the source		**monitoring along well**	Renewable: offshore wind	deviated	**min. for monitoring (30ktons): 3 years (check QUEST)**
	pulp plant	**train/ship**	**min. for monitoring (<100 kton)**		**near-seabed (e.g. piston cores, ROV inspection)**			Upscale to commercial storage site
	glass industry							
	refinery							
Limit HSE Risk & Reduce territorial impacts	others							

CO_2 transport from the source to the injection site is a transversal issue considered for mainland Portugal, and so it must be taken into account as a potential HSE risk. Generally, it is more efficient and cost-effective to compress and purify CO_2 at the source. Removing impurities, such as water, sulphur, and other contaminants, would result in higher quality CO_2, as well as meeting the specifications for safe and effective storage and reducing the associated environmental footprint, as it allows for larger quantities to be transported in fewer shipments. As an example, it is relevant to mention that The Navigator Company is addressing the possibility of implementing carbon capture in their pulp plant in Figueira da Foz. This operation and the connection to the designated storage site would help to ensure a reliable and continuous carbon source for a future CCS site.

Apart from the identified above-ground risk to be mitigated, the critical HSE topic to be considered is ensuring CO_2 plume monitoring in the short and long term. The minimum volume that is being considered as a baseline for monitoring is 30 kt for the entire pilot duration (3 years). Nonetheless, the 100 kt volume is the threshold value being considered in European regulation to discriminate between pilot CCS projects and commercial projects, and this is the amount to be counted in this project. So far, baseline monitoring in this offshore setting would preferably contemplate monitoring along-well, with CO_2 sensors placed in different sections to continuously measure CO_2 leakage, seabed monitoring (e.g., piston cores and ROV's inspections), and, most importantly, regular 3D seismic acquisition. 3D seismic would be key to assessing the evolution of plume dispersion through time, even after the CO_2 injection period. The regularity of seismic acquisition, acquisition parameters, area of acquisition (and other monitoring techniques) would need to comply with the regulatory standards to be implemented by the authorities. Detailed MMV recommendations will be addressed in the later stages of the project as soon as the optimised storage site and development plans are complete.

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4.3 Ebro Basin (Spain) conceptual scenarios

Five (5) alternatives have been defined according to five desirable strategies following the proposed methodology:

1) Minimum investment
2) Social engagement and local development
3) Regulatory gaps identification for best practices and recommendations
4) Enhance commercial development (potential commercial development after pilot)
5) Minimum uncertainty on HSE risks (well-known practices)

4.3.1 Minimum investment

Minimum investment strategy is based on reducing (financial) risks due to the geological uncertainty by minimising capital costs at front, based on a 3-years pilot injection to test formation behaviour, plume monitoring and ensuring proper future storage profile management in case of positive results. The financial investment is limited to 20 M€ and it is considered the possibility of being financed by national or European funds.

Table 4.3.1: Minimum investment of the Spanish region.

Strategy	Decisions									
	CO_2 Source	*Transport*	*CO_2 Quantity*	*Supply Continuity*	*Monitoring*	*Power Supply*	*Well Design*	*Next Phase funding*	*Project Duration*	*Project Budget*
1. Min. Investment	Market	Pipeline	100Kt (Permit max)	Continuous	4D seismic	Powergrid	Vertical	Private Equity	5 Years	Up to budget (<20M€)
	Waste Incineration plant	truck	Min.to monitor	Intermittent	New observation wells	Solar/wind	Deviated	EU	Min. For monitoring (30 Kt) / 3 years	Max. for commercial development
	Paper plant	train			Legacy observation wells	Geothermal Project		Consortia Public Private	Not limited	
	Others									

The CO_2 source is assumed to be from the closer point (paper industry) at 30 km of storage site; a limited amount to 10,000 CO_2 tonnes per year (minimum to be monitored), which could be combined with water injection, CO_2 transported by truck; there is no need to ensure continuous injection (small reception tanks). This transport is considered a flexible solution that minimise the risk of costly infrastructure that could be evaluated later in the project.

The power supply for the injection well site will be provided from the power grid, to guarantee a continuous power supply at competitive prices reducing the complexity of the project evaluation. The well design will be vertical; however, specifics (alloys, completions, diameters, etc.) are still being discussed. Nevertheless, vertical wells used to be less complicated, cheaper to drill, and easier to complete.

The MMV plan has yet to be outlined since the risk analysis is being performed at this report delivery date. So far, for all the scenarios in this area, the MMV plan will consist of the recommended procedures for these projects. In the Ebro basin, though, there are no legacy wells in the area of

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interest; actually, the closest well is Lopin-1 which is located some kilometres to the south, outside the area of interest.

4.3.2 Social engagement and local development

The social engagement and local development strategy aims to enhance the positive impacts on the local community in terms of development and the positive perception of the project among the citizens.

Table 4.3.2: Social engagement and local development strategy in the Spanish region.

Strategy	Decisions									
	CO_2 Source	***Transport***	***CO_2 Quantity***	***Supply Continuity***	***Monitoring***	***Power Supply***	***Well Design***	***Next Phase funding***	***Project Duration***	***Project Budget***
	Market	Pipeline	100Kt (Permit max)	Continuous	4D seismic	Powergrid	Vertical	Private Equity	5 Years	Up to budget (<20M€)
2. Social Engagement	Waste Incineration plant	truck	Min.to monitor	Intermittent	New observation wells	Solar/wind	Deviated	EU	Min. For monitoring (30 Kt) / 3 years	Max. for commercial development
	Paper plant	train			Legacy observation wells	Geothermal Project		Consortia Public Private	Not limited	
	Others									

The CO_2 sources for this strategy will be waste incinerators and the nearby paper plant, increasing the positive impact of these factories and facilities since their emissions will be reduced and the business adaptation to future emissions restrictions will be granted, therefore their future permanence. CO_2 transport will be made through pipelines considered to be safer and with less long-term impact than other transport alternatives. To build up a new pipeline and its operation, monitoring and maintenance may increase economic activity in the area during the project lifecycle. The total volume to be injected must be below 100,000 metric tonnes (the maximum volume for a pilot well permit) and be injected continuously. On-site CO_2 storage may be needed to guarantee this continuous flow. This alternative will increase the long-term knowledge of geological storage.

The MMV plan, as above, has not yet been outlined; there are no legacy wells close by that could be used for monitoring. No new observation wells have been included in this scenario; although they can increase economic activity while they are drilled, they may require more land use and a bigger visual impact. In terms of power supply, a “green” alternative is considered to reduce the project's CO_2 footprint and create new job opportunities in the area linked to this project: the area is surrounded by wind farms and solar plants, and the geothermal resources will be evaluated.

About the project funding, duration, and budget, it is considered that the most advantageous alternatives for this strategy are a sound budget for a commercial development project with funding that can come from the EU and/or private equities, including the mixing alternative of consortia EU/private partners.

4.3.3 Regulatory gaps identification for best practices and recommendations

This strategy will address the lack of developed regulation that a potential carbon storage operator could face. So, this strategy has to help to understand the issues as deeply as possible, as well as address recommendations and solutions for the industry or lawmakers based on national legal frame and international knowledge (for example, the current reviewed guidelines for UE Directive of CO2 storage application).

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Table 4.3.3: Regulatory gaps identification for best practices and recommendations of the Spanish region.

Strategy	Decisions									
	CO_2 Source	***Transport***	***CO_2 Quantity***	***Supply Continuity***	***Monitoring***	***Power Supply***	***Well Design***	***Next Phase funding***	***Project Duration***	***Project Budget***
	Market	Pipeline	100Kt (Permit max)	Continuous	4D seismic	Powergrid	Vertical	Private Equity	5 Years	Up to budget (<20M€)
	Waste Incineration plant	truck	Min.to monitor	Intermittent	New observation wells	Solar/wind	Deviated	EU	Min. For monitoring (30 Kt) / 3 years	Max. for commercial development
3. Gaps understanding	Paper plant	train			Legacy observation wells	Geothermal Project		Consortia Public Private	Not limited	
	Others									

In this scenario, the CO_2 sources are the waste incineration and paper plants nearby. This CO_2 will be transported through a pipeline to the injection site up to 100,000 CO_2 metric tonnes (the limit of a pilot well permit). The CO_2 should be injected continuously (CO_2 storage at the site should be available).

Although the MMV plan has yet to be defined in this scenario, it is considered to drill observation wells to help better understand the reservoir behaviour. The number of observation wells should be defined. The use geothermal resources as energy supply will cover also the needs for regulatory development of this green energy as well as looking for synergies between both development from a regulatory point of view (development permits, well permits and needs, …).

A deviated well can increase the injectivity of the CO_2 especially in low permeability rocks, increasing the efficiency of the project. This strategy will be expensive and with some bigger uncertainties than other strategies, it may need a join public/private funding to make the project suitable. Due to the main objective of the project which is not intended to be a commercial development the timing should be reduce enough to get the data, 5 years.

4.3.4 Enhance commercial development (potential commercial development after pilot)

To enhance the commercial development after the pilot project it will be considered all the decisions that eventually ease a future CCS storage implementation by a third party, i.e., to initiate the pilot development as a pre-commercial phase and it will be considering the economic parameters that could make this project attractive for private equities, reliable and constant quality CO_2 sources, good knowledge of reservoir characteristics (capacity, permeability, pressures, sealing, etc.), sound and reliable technology, etc.

In the area the CO_2 sources are the waste incineration and paper plant as the present bigger emitters in the area, other emitters potentially interested should be considered. The most valuable infrastructure for transport to the injection site is a pipeline that should allow a continuous injection rate into the reservoir that maximise the efficiency. Efficiency wises the most convenient well design may be a deviated well to override low permeability issues or simply increment the injection efficiency. The maximum injected volume is limited to the pilot permit allowance (100,000 metric tonnes of CO_2), but studies should state the biggest volume that can be injected in the reservoir with a threshold of uncertainties.

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Table 4.3.4: Enhance commercial development (potential commercial development after pilot) in the Spanish region.

Strategy	Decisions									
	CO_2 Source	***Transport***	***CO_2 Quantity***	***Supply Continuity***	***Monitoring***	***Power Supply***	***Well Design***	***Next Phase funding***	***Project Duration***	***Project Budget***
	Market	Pipeline	100Kt (Permit max)	Continuous	4D seismic	Powergrid	Vertical	Private Equity	5 Years	Up to budget (<20M€)
	Waste Incineration plant	truck	Min.to monitor	Intermittent	New observation wells	Solar/wind	Deviated	EU	Min. For monitoring (30 Kt) / 3 years	Max. for commercial development
	Paper plant	train			Legacy observation wells	Geothermal Project		Consortia Public Private	Not limited	
4. Commercial Development.	Others									

Like above scenarios, MMV has to be consistent with the risk assessment that is being done by this project WP5 team. It will be especially relevant to determine probabilities of events that can drive to an undesired project closure as well as the cost of this MMV plans before to transfer the storage site to the government.

To power up the facilities it can be convenient to have alternative power sources coming from "green" sources, that could reduce power supply budget, as well as the power grid that guarantee a stable prizing and continuous supply.

Funding must contemplate all available alternatives that can help to move to a commercial development (public funding, partnerships, private investors, etc.).

About duration and budget this scenario is based in long term operation which is linked to a strong project value analysis.

4.3.5 Minimum uncertainty on HSE risks (well-known practices)

This strategy is focused on reducing, to the minimum, any HSE issues. That is important for showing a safe and mature technology and ensure citizens engagement. It is considered an extra budget for over monitoring as a needed investment for technology settling and future implementation. The strategy will use the industry's best-available-techniques (BAT's) to reduce or minimise the risk linked to this project.

Table 4.3.5: Minimum uncertainty on HSE risks (well-known practices) of the Spanish region.

Strategy	Decisions									
	CO_2 Source	***Transport***	***CO_2 Quantity***	***Supply Continuity***	***Monitoring***	***Power Supply***	***Well Design***	***Next Phase funding***	***Project Duration***	***Project Budget***
	Market	Pipeline	100Kt (Permit max)	Continuous	4D seismic	Powergrid	Vertical	Private Equity	5 Years	Up to budget (<20M€)
	Waste Incineration plant	truck	Min.to monitor	Intermittent	New observation wells	Solar/wind	Deviated	EU	Min. For monitoring (30 Kt) / 3 years	Max. for commercial development
	Paper plant	train			Legacy observation wells	Geothermal Project		Consortia Public Private	Not limited	
	Others									
5. Min. risks.										

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This strategy is limited in terms of volume to inject into the reservoir; here, it is preferred to reduce pressures and volumes and then minimise any risk. So that limited volumes should come from the CO_2 market, preferably they must come to the injection site through a pipeline. The volume must be just enough to be monitored (10,000 t/year) and flow in a continuous way. The option of a deviated well should decrease injection pressure. The facility's power supply will come from the power grid, minimising impacts in the area.

The MMV plan for transport and storage must be upgraded using the BAT's, including observation wells.

Project duration, funding, and budgeting are linked to the objective of this strategy. So, public funding is more suitable for this strategy, as is the limited duration of 3 years to monitor the project impact in the area. The budget has to comply with this objective; there is no specific limitation in this matter.

4.4 Upper Silesia Basin (Poland) conceptual scenarios

Upper Silesia team carried out a framing session during its 1st Regional Stakeholder Committee in October 2023 and its results are included in annex 1.

Finally, four (4) strategic lines have been defined:

1. Pilot fast track development at minimal cost to prove technical feasibility.
2. Pilot for commercial development to attract investors.
3. Minimise negative impact on local communities (social + environmental).
4. Foster local economy.

4.4.1 Pilot fast track development at minimal cost to prove technical feasibility.

The first scenario aims to implement the technology in a pilot plant to demonstrate technical feasibility.

Table 4.4.1: Pilot fast track development at minimal cost of the Polish region.

DECISIONS									
CO_2 Source	Transport	CO_2 Quantity	Supply continuity	Monitoring	Power Supply	well design	next phase Funding	project duration	project budget
Power plants (1)	trucks	research project - to 100 kt	continuous	according to law	Polish power grids	new vertical	EU funding	pilot 5 years	Pilot – 100 M Euros
Heating plants	pipeline	commercial - to capacity of deposit 40-60 Mt	intermittent		renewables	new deviated	national funding	min to obtain results (3 years)	Commercial - 500 M Euros
Waste incineration plants		min. to obtain results ~30kt			power generators		private	commercial 30-40 years	<10 M Euros
Other industrial emitters (2)							public/ private consortium		

(1) Power plants (Tauron, PGE Rybnik, Bełchatów, Enea Połaniec)
(2) other industrial emitters nearby: Steel mill Dąbrowa Górnicza; cement plants (Holcim Małogoszcz, Dyckerhoff, Cemex Rudniki, Warta, Górażdże); Chemical plants (Synthos, Azoty)

A probable source of CO_2 may be a cement plant located near brine deposits because the cement industry in Poland has been heavily involved in the development of CCUS technology for some time, or a power plant, because power plants have been testing the technology using mobile capture

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installations. The scale of such an installation would be as small as possible, provided that stable conditions are achieved, and monitoring is carried out - 30 kt CO_2 was assumed and the duration was up to 3 years. It was assumed that such an installation would be funded from the EU budget (less than 10M €).

4.4.2 Pilot for commercial development to attract developers.

In the second scenario it was assumed the implementation of CCS technology in a pilot installation on a scale of up to 100 kt, and, after that, attracting investors and transforming the pilot into a commercial installation.

Table 4.4.2: Pilot for commercial development to attract developers of Polish region.

DECISIONS									
CO_2 Source	**Transport**	**CO_2 Quantity**	**Supply continuity depending on source**	**Monitoring**	**Power Supply**	**well design**	**next phase Funding**	**project duration**	**project budget**
Power plants (1)	road – during pilot	research project - to 100 kt	continuous	according to law	Polish power grids	new vertical	EU funding	pilot 5 years	Pilot – 100 M Euros
Heating plants	pipeline – commercial scale	commercial - to capacity of deposit 40-60 Mt	intermittent		renewables	new deviated	national funding	min to obtain results (3 years)	Commercial - 500 M Euros
Waste incineration plants		min. to obtain results ~30kt			power generators		private	commercial 30-40 years	<10 M Euros
Other industrial emitters (2)							public/ private consortium		

(1) Power plants (Tauron, PGE Rybnik, Bełchatów, Enea Połaniec).

(2) other industrial emitters nearby: Steel mill Dąbrowa Górnicza; cement plants (Holcim Małogoszcz, Dyckerhoff, Cemex Rudniki, Warta, Górażdże); Chemical plants (Synthos, Azoty).

In the long term, industry representatives who need to remove process emissions and who do not have an alternative may be interested, e.g. steelworks, cement plants, chemical plants, large waste incineration plants. Continuous CO_2 injection was assumed in commercial phase. During pilot phase road transport is expected, and after increasing the scale, transport by pipeline. In the initial phase, it can be considered using existing wells for injection (after well extended integrity assessments). Ultimately, in order to achieve the maximum capacity of the deposit, it was planned to build a new well with optimized geometry. Financing from national or EU funds was assumed at the pilot stage, and then on a commercial scale from private funds.

4.4.3 Minimise impact on local communities (social + environmental)

The third scenario assumes that the CCS process is conducted in such a way as to minimise local negative social and environmental impacts.

Similarly, to the previous scenario, in the long term, industry representatives who need to remove process emissions and who do not have an alternative may be interested in CO_2 capture. Additionally, CO_2 capture can help reduce other harmful emissions of gaseous substances into the air from industrial installations. CO_2 transport by pipeline was assumed because increased road transport is associated with negative social and environmental effects (accidents, destruction of road infrastructure, increased traffic intensity and traffic jams, air pollution with exhaust gases, noise emissions). The use of grid electricity was adopted as it did not impact the local community. The

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drilling site may be far from the power grid, so it may be necessary to install a local power source. In such a situation, the best solution is renewable energy sources - a wind turbine or PV cells, which will not only contribute to a smaller carbon footprint of the project but will also have a positive impact on the social factor by creating additional jobs. Long lasting project is more beneficial for the area development and the social engagement.

Table 4.4.3: Minimise impact on local communities (social + environmental) of Polish region.

DECISIONS									
CO_2 Source	**Transport**	**CO_2 Quantity**	**Supply continuity depending on source**	**Monitoring**	**Power Supply**	**well design**	**next phase Funding**	**project duration**	**project budget**
Power plants (1)	road – during pilot	research project - to 100 kt	continuous	according to law	Polish power grids	new vertical	EU funding	pilot 5 years	Pilot – 100 M Euros
Heating plants	pipeline – commercial scale	commercial - to capacity of deposit 40-60 Mt	intermittent		renewabl es	new deviated	national funding	min to obtain results (3 years)	Commercial - 500 M Euros
Waste incineration plants		min. to obtain results ~30kt			power generator s		private	commercial 30-40 years	<10 M Euros
Other industrial emitters (2)							public/ private consortium		

(1) Power plants (Tauron, PGE Rybnik, Bełchatów, Enea Połaniec)

(2) other industrial emitters nearby: Steel mill Dąbrowa Górnicza; cement plants (Holcim Małogoszcz, Dyckerhoff, Cemex Rudniki, Warta, Górażdże); Chemical plants (Synthos, Azoty)

4.4.4 Foster local economy

In the fourth scenario, it was assumed that the CCS process would be conducted in such a way as to maximise the development of the local economy and provide jobs for the local community.

Table 4.4.4: Foster local economy strategy of Polish region.

DECISIONS									
CO_2 Source	**Transport**	**CO_2 Quantity**	**Supply continuity depending on source**	**Monitoring**	**Power Supply**	**well design**	**next phase Funding**	**project duration**	**project budget**
Power plants (1)	road – during pilot	research project - to 100 kt	continuous	according to law	Polish power grids	new vertical	EU funding	pilot 5 years	Pilot – 100 M Euros
Heating plants	pipeline – commercial scale	commercial - to capacity of deposit 40-60 Mt	intermittent		renewables	new deviated	national funding	min to obtain results (3 years)	Commercial - 500 M Euros
Waste incineration plants		min. to obtain results ~30kt			power generators		private	commercial 30-40 years	<10 M Euros
Other industrial emitters (2)							public/ private consortium		

(1) Power plants (Tauron, PGE Rybnik, Bełchatów, Enea Połaniec)

(2) other industrial emitters nearby: Steel mill Dąbrowa Górnicza; cement plants (Holcim Małogoszcz, Dyckerhoff, Cemex Rudniki, Warta, Górażdże); Chemical plants (Synthos, Azoty)

It was assumed that the local economy could benefit from construction activities related to the construction of the pipeline, the installation of renewable energy sources and the design and

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construction of new wells. It was assumed that a real impact on the local economy could be achieved in the long term and on a commercial scale financed mainly from private and EU funds.

4.5 Macedonia Basin (Greece) conceptual scenarios

Greece has also carried out a framing session in September 2023 following the Ebro Basin strategies and adapting them to Macedonia reality. Five (5) alternatives have been defined according to five desirable strategies following the proposed methodology:

1) Minimum investment
2) Social engagement and local development
3) Regulatory gaps identification for best practices and recommendations
4) Enhance commercial development (potential commercial development after pilot)
5) Minimum uncertainty on HSE risks (well-known practices)

There is still in process better understanding how to realize each of selected strategies and more development is expected in the next steps. So far, the exercise was reviewing and adapting to West Macedonia region proposed strategies by the other areas.

Table 4.5.1: Minimum investment of Greek region.

Strategy	Decisions									
	CO2 Source	*Transport*	*Co2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*next phase Funding*	*project duration*	*project budget*
Minimum Cost	**external market**	pipeline	**< 100kt (no permit)**	continous	4D seismic data acquisition	**power grid**	**vertical**	**European Funding**	5 years	**up to budget (20M$)**
Social Engagement , Inclusiveness, Local development	thermal power plant	**truck**	**> 100kt (permit required)**	**intermitent**	**fiber optics (continuous monitoring)**	**solar / wind**	deviated	consortia public private	**min. for monitoring (30ktons) 3 years**	maximum for commercial development
Regulatory Framework Gap Understanding / Research	**cement factories**	train	**min. for monitoring**		new obs wells			**JV**	no limit	
Enhance the comercial development	**refineries**	**ship**			**legacy obs wells**					
Limit HSE Risk at maximumand Reduce territorial impacts	**steel**	**combination**								

Table 4.5.2: Social engagement and local development of Greek region.

Strategy	Decisions									
	CO2 Source	*Transport*	*Co2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*next phase Funding*	*project duration*	*project budget*
Minimum Cost	**external market**	pipeline	**< 100kt (no permit)**	continous	4D seismic data acquisition	**power grid**	**vertical**	**European Funding**	5 years	**up to budget (20M$)**
Social Engagement , Inclusiveness, Local	thermal power plant	**truck**	**> 100kt (permit required)**	**intermitent**	**fiber optics (continuous monitoring)**	**solar / wind**	deviated	consortia public private	**min. for monitoring (30ktons) 3 years**	maximum for commercial
Regulatory Framework Gap Understanding / Research	**cement factories**	train	**min. for monitoring**		new obs wells			**JV**	no limit	
Enhance the comercial development	**refineries**	**ship**			**legacy obs wells**					
Limit HSE Risk at maximumand Reduce territorial impacts	**steel**	**combination**								

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Table 4.5.3: Regulatory gaps identification for best practices and recommendations of the Greek region.

Strategy	Decisions									
	CO2 Source	*Transport*	*Co2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*next phase Funding*	*project duration*	*project budget*
Minimum Cost	external market	pipeline	< 100kt (no permit)	continous	4D seismic data acquisition	power grid	vertical	European Funding	5 years	up to budget (20M$)
Social Engagement , Inclusiveness, Local	thermal power plant	truck	> 100kt (permit required)	intermitent	fiber optics (continuous monitoring)	solar / wind	deviated	consortia public private	min. for monitoring (30ktons) 3 years	maximum for commercial
Regulatory Framework Gap	cement factories	train	min. for monitoring		new obs wells			JV	no limit	
Enhance the comercial	refineries	ship			legacy obs wells					
Limit HSE Risk at maximumand	steel	combination								

Table 4.5.4: Enhance commercial development (potential commercial development after pilot) of Greek region.

Strategy	Decisions									
	CO2 Source	*Transport*	*Co2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*next phase Funding*	*project duration*	*project budget*
Minimum Cost	external market	pipeline	< 100kt (no permit)	continous	4D seismic data acquisition	power grid	vertical	European Funding	5 years	up to budget (20M$)
Social Engagement , Inclusiveness, Local	thermal power plant	truck	> 100kt (permit required)	intermitent	fiber optics (continuous monitoring)	solar / wind	deviated	consortia public private	min. for monitoring (30ktons) 3 years	maximum for commercial
Regulatory Framework Gap Understanding /	cement factories	train	min. for monitoring		new obs wells			JV	no limit	
Enhance the comercial development	refineries	ship			legacy obs wells					
Limit HSE Risk at maximumand Reduce	steel	combination								

Table 4.5.5: Minimum uncertainty on HSE risks (well-known practices) of Greek region.

Strategy	Decisions									
	CO2 Source	*Transport*	*Co2 Quantity*	*Supply continuity*	*Monitoring*	*Power Supply*	*well design*	*next phase Funding*	*project duration*	*project budget*
Minimum Cost	external market	pipeline	< 100kt (no permit)	continous	4D seismic data acquisition	power grid	vertical	European Funding	5 years	up to budget (20M$)
Social Engagement , Inclusiveness, Local development	thermal power plant	truck	> 100kt (permit required)	intermitent	fiber optics (continuous monitoring)	solar / wind	deviated	consortia public private	min. for monitoring (30ktons) 3 years	maximum for commercial
Regulatory Framework Gap Understanding / Research	cement factories	train	min. for monitoring		new obs wells			JV	no limit	
Enhance the comercial development	refineries	ship			legacy obs wells					
Limit HSE Risk at maximum and Reduce territorial impacts	steel	combination								

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5. Conclusions

The scenarios show the different strategies selected by every region and, although every region has different situation, there are some common strategies in all the regions:

- Focused on minimum investments,
- Enhance positive local impacts,
- Better alternatives for later commercial development or trigger future CCS development projects,
- Minimum HSE impact in the area, and
- Strategies that pretend to fill up the gaps these projects could face before further developments.
- Eventually, a demonstration project.

At this time of the project, all those scenarios are based on desirable strategies, with a lack of relevant data. Specifically, the dynamic model will constrain the reservoir characteristics and capacities, and therefore it will help with the scenario analysis. On the other hand, the scenarios help to set up several issues linked to every desired strategy, and then they can be analysed in the later techno-economic assessment.

However, the objective of this task is to identify required information, to take specific decisions when it is possible, and to cover as wider (but manageable!) range of possibilities for the storage site development to ensure the best option for each region is selected.

The reduced project's cost scenarios aim at project validation with a minimum budget. In these cases, the limited budget reduces the project timing and development, using alternatives that are temporary in most cases. This strategy is focus on pilot (in the research meaning) with no commercial consideration after it.

The commercial developments and local economy-enhancing alternatives are longer-lasting, considering the pilot development as a pre-commercial phase. These scenarios consider tens of years' developments that need more data acquisition and upgraded infrastructure. The geological risk at this time is hight and to make possible and successful a commercial development it would be required industry, government, and local community involvement.

Reducing to the minimum the impacts HSE-wise increases the cost of the project since, in general, it is linked to a comprehensive HSE analysis and tight limitations, but it is a necessary current step for a technology stelling and increasing society engagement. This extra costs for overdesigning the MMV needs, and communication activities make a scenario in which public funding is essential.

Finally, those strategies that pretend to evaluate the gaps in the CCS developments will address the lack of developed regulation that a potential carbon storage operator could face. So, this strategy has to help to understand the issues as deeply as possible, as well as address recommendations and solutions for the industry or lawmakers based on national legal frame and international knowledge (for example, the current reviewed guidelines for UE Directive of cO2 storage application).

Understanding potential scenarios for each region, we are ready for next step: tecno-economic evaluation for prioritization (task 4.4).

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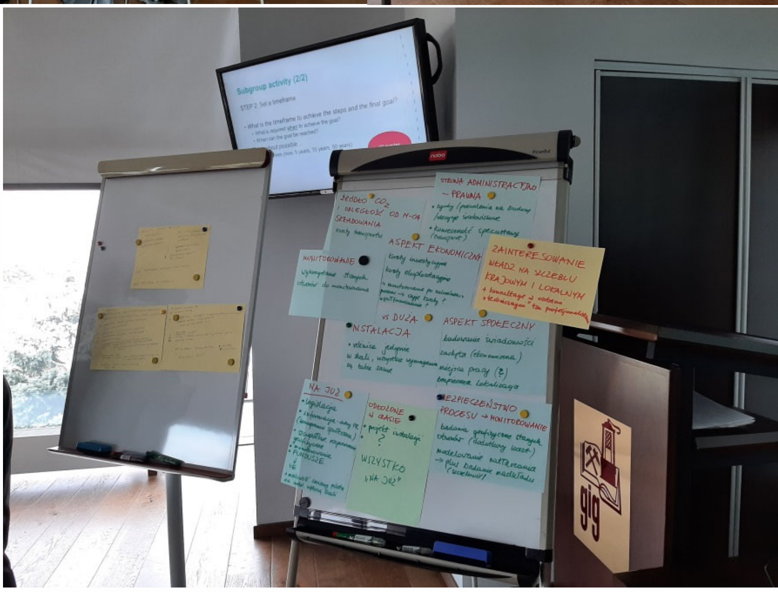
6. Annex 1: WP4 workshop performed along with 1st Regional Stakeholders Committee. Upper Silesia (Poland) on the 5th of October 2023

WP4 workshop was performed during the RSC meeting concerned with the development of CCS technology in the region - transformation paths and strategies. The main focus of the discussion was the issue of the common goal ‘Planning of a potential CCS pilot in Upper Silesia‘. What are the key steps and resources required to achieve the goal, and when will it be achieved. Workshop participants were randomly divided into two groups. After brainstorming, each group selected its representative who presented the most important conclusions on the board. The discussion was followed by a short summary (take-home messages) presented by the workshop moderator. The results presented during the summary by representatives of each group were very similar.



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6.1 Brainstorming

Thirteen participants representing various branches (industry – power sector, mining sector, public administration, local authorities, policy makers, civil society organisations, and scientific community – six participants from GIG) took part in the discussion. Below is a summary of the topics and comments discussed.

- The most important issue is the change in national regulation. The current provision in the annex to the regulation allows the offshore storage of carbon dioxide.
- Due to the current mining operations in the region and their seismic effects, there are social concerns related to the potential effects of storage - the impact on the seismicity of the rock mass. Microseismic monitoring during and after congestion is important.
- Local politicians from the towns located at the injection site were not interested in the meeting. Before starting the pilot, it is important to involve the local community - offices, mayors, as well as reach relevant departments, e.g., mining, geology, environmental protection and, management.
- It can be important to use the national language, because its greater accessibility for small communes and local governments.
- A very important factor is conducting a large-scale social campaign aimed at providing residents with reliable information about CCS issues. The information should be specific and provided by reliable people who enjoy social trust and, due to their competences, may constitute an authority for people.
- Benefits for the commune should be sought. Using the experience of mining exploitation, propose to municipalities a share of the benefits and savings due to ETS.
- It is crucial to complete geological modelling research. Then, 3D seismic surveys and additional drilling are needed.
- The final location of the holes has not yet been decided. After narrowing down the area and selecting the location, it will be necessary to conduct another survey among residents.
- Work related to modelling and the social campaign should be carried out simultaneously.
- The choice of emission source may have a positive impact on social acceptance by emphasising the socio-economic benefits of CCUS, i.e., maintaining industry in Silesia - steelworks and waste incineration plants. Stored carbon dioxide should not be imported from other countries, as this may have a negative impact (negative association with the storage of nuclear waste from Germany in Poland without the benefits of having nuclear energy).
- Before starting work in small towns, it is necessary to build preliminary infrastructure, e.g., roads for transporting drilling rigs.
- The scale of the pilot installation is limited by law - up to 100.000 t.
- An industry representative had doubts about increasing the pilot scale to an industrial scale in the same deposit - performing pilot tests in a deposit does not guarantee that injecting a larger amount of gas into the same deposit will result in the same gas spread and tightness.
- The requirements and preparation path are the same when considering a pilot or commercial installation; however, the scale of the project impacts the financing mechanism.

6.2 Decision hierarchy

The meeting participants decided that the vast majority of activities should be started as soon as possible (especially activities related to legislation, a social and information campaign aimed at creating good PR regarding CCS, detailed geophysical reconnaissance of the area, the possibility of monitoring, obtaining EU funds, or other sources of financing (unlikely), to identify whether a CCS pilot installation could be upgraded to a larger-scale installation). Regulation of legal issues and involvement of national and local authorities in the development of CCS technology are crucial. The delayed action may be the installation design.

Following stages of planning a CCS installation were proposed:

I. Within 5 years – CCS pilot on a scale 100,000 tons of CO_2/5 years (limited due to current legislation), i.e. approx. 60 tons per day:
   - Geological modelling - completion of research; 3D seismic research; narrowing the area; additional wells.
   - Effective cooperation with local politicians, involvement of the local community (representatives of offices, residents).
   - A social campaign combined with repeated surveys of the population from storage sites (conducting a social information campaign, necessarily in Polish, which guarantees greater accessibility for residents of small communes and local government employees; involvement of staff from the departments of mining, geology, environmental protection, and environmental management).
   - Identification of the socio-economic benefits of CCUS for the local municipality (based on mining experience; fee share, ETS savings vs. tax losses).
   - Risk identification (mining exploitation in the Upper Silesia region - felt rock bursts, visible mining damage, and destruction of buildings caused by current and completed coal mining - significant impact on public fears regarding storing CO_2 underground; necessary microseismic monitoring during and after CO_2 injection).
   - Identification of potential losses (impact on local property prices).
   - Selection of a CO_2 emission source aimed at maintaining industry in Upper Silesia (steelworks, waste incineration plants) and contributing to increasing social acceptance of the investment.
   - Preparation of initial infrastructure (road construction) necessary to transport heavy equipment (drilling rigs, then CO_2 tanks).
   - Transport modelling; pipelines – social acceptance of the pipeline route (underground); pipeline monitoring.
   - Construction of a pilot installation.

II. Within 10 years – the same deposit, scale up the pilot to the deposit capacity (industrial installation) and the monitoring activity.

III. Within 50 years – monitoring after closure of a CCS landfill

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6.3 Focus decision table: options

CO_2 **Source**	**Transport**	CO_2 **Quantity**	**Supply continuity depending on source**	**Monitoring**	**Power Supply**	**well design**	**next phase Funding**	**project duration**	**project budget**
Steel mill Dąbrowa Górnicza	road – during pilot	pilot - to 100 ths Mg	continous	according to law	Polish power mix	reconstruction of existing wells	EU funding	pilot 5 years	Pilot - several hundred million Euros
Power plants	pipeline – commercial scale	commercial - to capacity of deposit	intermitent		power plant (where capture located)	new	small scale national fund		Commercial - half a billion euros
Heating plants					RES		private		
Waste incineration plants									
Chemical plants									

6.4 Desirable Strategies boundaries

It was found that of the available options, most are determined by the stage (pilot or commercial installation), regulatory requirements, and existing conditions (reservoir capacity and existing wells). The definition of alternatives depends on the **choice of** CO_2 **source.**

6.4.1 Transport

- During pilot – construction of pipeline wouldn't be reasonable, road transport is expected.
- Commercial plant – only pipeline can be considered for such volume of CO_2

6.4.2 CO_2 quantity

- Pilot up to 100.000 tons of CO_2/ 5 years (limited due to current legislation)
- Commercial installation: up to capacity of deposit

6.4.3 Supply continuity

- Determined by the choice of CO_2 source

6.4.4 Monitoring

- requirements described in law

6.4.5 Well design

- Where possible, use of existing holes to reduce investment costs
- Choice of location

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6.4.6 Funding

- The pilot must be financed by an external body, e.g. from the EU, and the commercial installation is carried out by a profit-oriented investor.

6.4.7 Project duration

- Pilot – c.a. 5 years

After analysing the proposed methodology, participants concluded that several decisions will be determined by the choice of source and location, for example, transport and continuity. Another issues are restricted by legal regulations, for example, scale and monitoring. Thus, in our region, we propose limitation of alternatives and consideration of options related to CO_2 sources and well design.

7. Annex 2: WP4 Framing session for onshore CO_2 storage- Greece (September 2023)

The event took place on the HEREMA premises, with experts from CERTH and HEREMA itself attending the meeting. The discussion focused on technical and regulatory aspects while also included feedback from stakeholders based in West Macedonia. The latter was a synthesis of stakeholders workshops conducted during the StrategyCCUS and PilotStrategy projects.

7.1 Formulating the case for CCS in Greece overall and emphasis in West Macedonia

This first step was to bring the experts together, to share their professional experience, and to formulate a framework for CCS deployment in Greece. These, for simplicity reasons, are presented in bullet points below:

- The energy transition in West Macedonia left a vacuum in the area from a social and financial point of view.
- Social acceptance for heavy industry in West Macedonia is quite high.
- CO_2 storage is a non-visible technology with no visual pollution or any other form of contamination/pollution offering an alternative for economic growth in the area.
- CCS is very interesting but currently in a low maturation stage for Greece due to limited oil and gas exploration in the past.
- Not all data is publicly available or available for projects. There are exploration surveys taking place in Greece, but the data is owned by companies.
- Need to identify reservoirs with the right characteristics, thus need for further research.
- Current utilisation of the data available from the digitisation of geophysical (seismic data) will shed light on the prospective of the area. This will be complemented by the mapping survey from CERTH and laboratory investigation.
- Current data from the sample collection conducted in West Macedonia is very promising for the cap layers. These have practically low porosity and are impermeable. Thus, leakage will be non-existent and provide an extremely insignificant risk, making it easy to commercially finance the project in the future.

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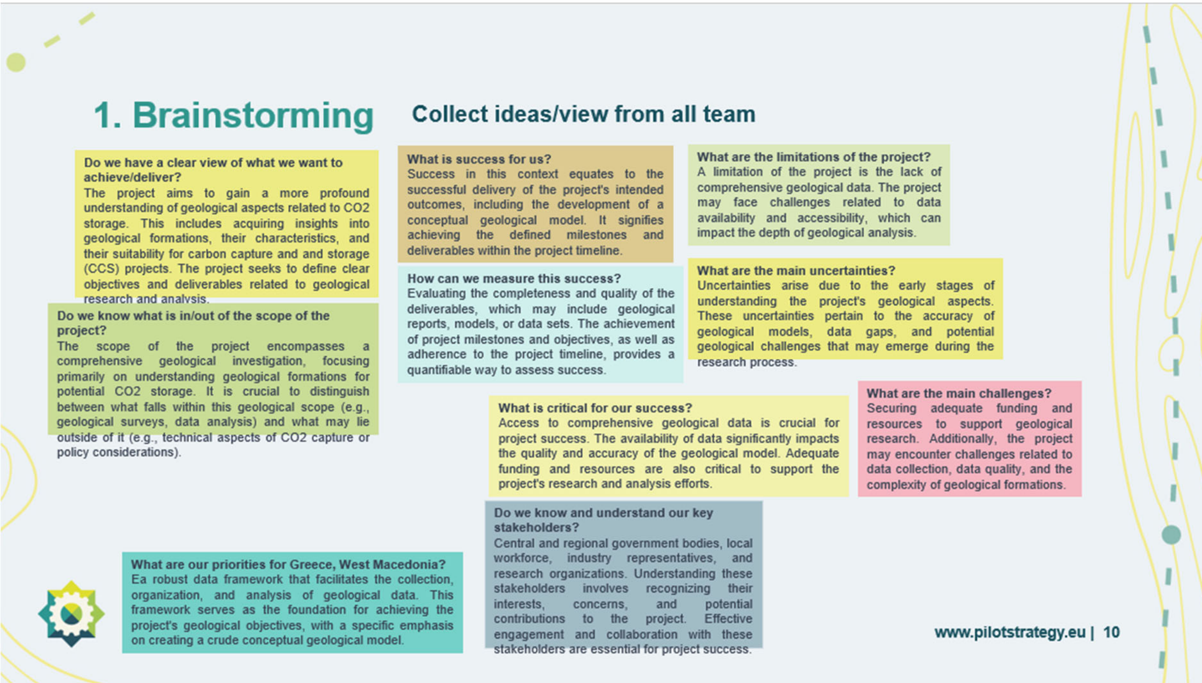
- Need to identify the formation beds and areas with the appropriate reservoir properties
- Large gas pipeline distribution networks are available in the area, with more to be constructed in the future. This makes the whole idea even more promising. The Trans Adriatic Pipeline connects Greece with Italy.
- Greece has dispersed heavy industry. Part of the CO_2 can come from Greece, but storage will be provided mostly for companies/countries that do not have the appropriate geology/infrastructure/social acceptance.
- Due to the current situation in West Macedonia, a window of opportunity is present for CCS deployment on a large scale. This technology has the prospect of mitigating climate change while also offering the prospect of well-paid jobs.
- HEREMA is involved in a more mature project related to offshore CO_2 storage in the oil and gas depleted field of Prinos. Technical details cannot be shared, but experience acquired by HEREMA can.



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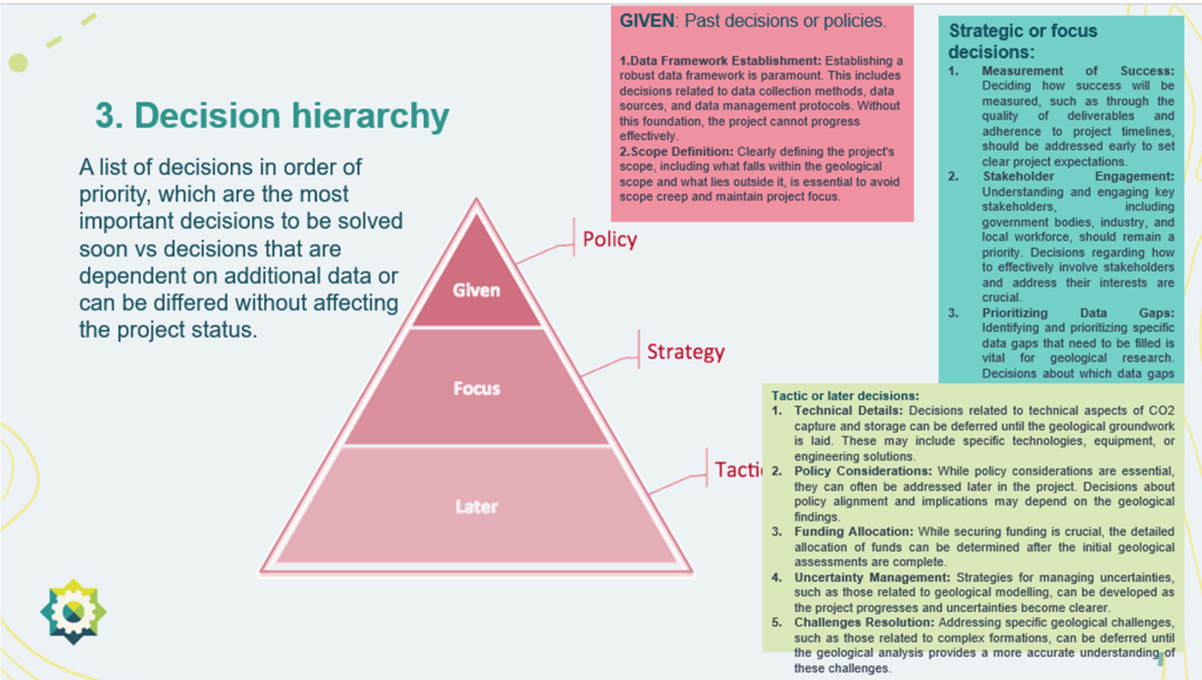

7.2 Decision Hierarchy

This was based on maturing the CCS technology framework in Greece.

7.2.1 Given:

1. Stakeholder engagement

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2. Social acceptance
3. Regulatory framework

7.2.2 Focus

1. Data acquisition
2. Sample collection
3. Ground investigation
4. Further laboratory investigations
5. Identification of CAPEX and OPEX
6. Campaigns for maintaining social acceptance
7. Educating the local authorities and population
8. Refine the regulatory framework and the permit process
9. Establish a standardised procedure for Environmental Impact assessments and any other related work as prerequisite for the permit process
10. Transport modelling
11. Market strategy – national and international transboundary clients
12. Initial business model
13. Map clients (national and international). Invite them to understand their needs

7.2.3 Later

1. Refinement of conceptual modelling
2. Installation of a borehole – some 20 M€ investment. This can become a laboratory for various data collection purposes, monitoring, data analysis. Geophysical monitoring along the borehole length, CO_2 injection and monitoring
3. Proof of concept based on the borehole
4. Refinement of Business model
5. Refinement of market strategy

7.3 Strategies Boundaries

This is quite similar to the Polish CCS development presented above. Apart from the offshore Prinos field, everything else is determined by the availability of suitable reservoirs, CO_2 (clients base), transport, social acceptance, and permit framework.

7.3.1 Suitable reservoirs:

Further research is needed to identify suitable reservoirs in all of Greece, not just in West Macedonia. Areas close to ports might present a competitive advantage, given that Greece has a tradition of sea transport. West Macedonia needs further data acquisition supported either by a national or a European project due to its low maturity level and the limited availability of data from previous oil and gas exploration in the area. Further geophysical investigation is needed, coupled with geochemical and geological mapping.

7.3.2 CO_2 sources:

Mostly international clients with a strong industrial base but no storage solutions available. Economies of scale to provide the right logistics and financial attractiveness.

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7.3.3 Transport:

During future pilots – construction of pipeline branches will not be reasonable due to permit restrictions and costs involved unless the operator becomes a partner of the project and provides either access or feedback prior to implementation. However, during that time, the permit procedure may be initiated together with relevant reports. Road transport will be deployed.

Commercial storage – a combination of ship transport and pipeline can be considered for economies of scale which will secure the project's viability.

7.3.4 CO_2 quantity

Pilot up to capacity of deposit, although less is expected.

Commercial installation: up to capacity of deposit

Supply continuity is determined by the choice of CO_2 source, but if the client base is established as international, then the prospect of multiple clients will offer higher sustainability and a longer prospect.

7.3.5 Monitoring

requirements as described by the current legislation

7.3.6 Well design

Choice of location

7.3.7 Funding

The pilot must be financed by an external body, e.g. from the EU, and the commercial installation is carried out by a profit-oriented investor

7.3.8 Project duration

Pilot – c.a. 5 years

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