Environmental Impact Assessment of Carbon Capture & Storage in the Netherlands.

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Abstract
This paper provides a concise insight into the application of Environmental Impact Assessment (EIA) procedures for future Carbon Capture and Storage (CCS) projects. Main environmental impacts allocated to the three parts of a CCS chain (capture of CO_2 from power plants, transport through pipelines and onshore geological storage) are identified by reviewing analogue EIA's.
Furthermore, bottlenecks regarding the assessment of environmental impacts and current environmental legislation are discussed. Finally, suggestions to overcome these bottlenecks and recommendations for future research are made.

Keywords: policy, environmental impact, regulation, implementation.

Introduction
One of the possible options to reduce CO_2 is the implementation of carbon capture and storage (CCS) projects. To realize such projects, legal requirements should be fulfilled in order to obtain an environmental permit. In the Netherlands, the permit for a CCS project requires in most cases an Environmental Impact Assessment (EIA) procedure. Given that plans are currently being drafted for CCS (pilot) projects, the need for clarity on administrative, juridical and environmental implications of these projects is growing. This demand is driven by both market parties and legislators.
This paper aims to provide a framework for EIA's for CCS projects in the Netherlands. The focus of this paper lies on the Environmental Impact Statement (EIS), which is an obligatory element of the EIA procedure. We will provide insight in some legal aspects (e.g. environmental standards, legal procedures and licenses) regarding the EIA. Next, specific issues and impacts (e.g. safety, ground contamination and disturbance, emissions and biodiversity) that are expected to be addressed in an EIA concerning CCS activities are discussed. Finally, methods for analyzing the possible environmental impacts are proposed.

The Environmental Impact Assessment procedure
The Dutch EIA procedure (see Figure 1) and the guidelines for setting up an EIS are defined in Dutch and EU guidelines which are stated in the Environmental Management Act (EmA) and the Environmental Impact Assessment Decree [1-3].
The EIA is used to assess the environmental impacts of specific activities in order to include the environment in the decision making process on permits and investments of the involved parties (e.g. governing bodies and initiators of CCS project).

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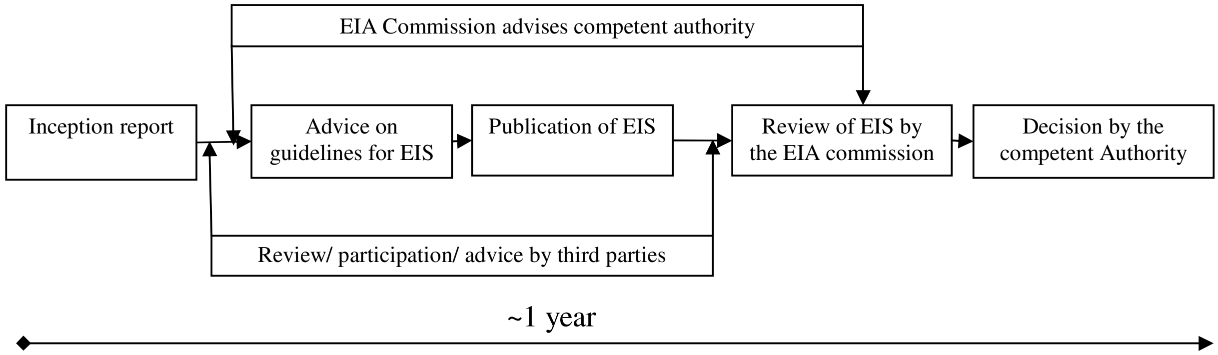

Figure 1 Simplified scheme of the EIA procedure in the Netherlands.

A similar assessment procedure to EIA, the Strategic Environmental Assessment (SEA) and related EU guidelines [4] will be implemented in national legislation in the near future. The SEA procedure is applicable for plans and programs[2] which include/foresee activities subjected to EIA obligation. In an EIA, various decision making procedures for obtaining permits or exemptions are incorporated into one single procedure (Article 14.5 EmA). Both procedures can be influenced by third parties by requesting additional information, challenging information or adding information. This possibility of public participation may play a key role in the public perception and rules of acceptation of CCS. The average costs of EIA procedures range between 70 000 and 100 000 Euro and normally takes about 1 year to conclude. These figures are indicative as cost and duration are highly dependent on the type of project. Due to added complexity and novelties, it is expected that these figures are significantly higher for an EIA applied on a CCS chain.

The goal of the EIA is to evaluate different project alternatives and find the 'best' option in environmental terms. To achieve this, the assessment comprises the identification of possible impacts, followed by measuring, predicting, evaluating and subsequently suggesting possibilities for mitigation of each impact. In general, all possible effects on the ecological, sociological and economic environment of a project should be assessed, including possible linkages between these categories of effects [3]. However, in practice, the impacts as well as the used methods which are included in the assessment do not seem to be standardized, because they have been developed location and project specific [5].

Approach

The mentioned guidelines are used to construct the general outline of the EIA for CCS projects in the Netherlands. The application of the procedure on CCS projects is dealt with in this paper by studying the three distinctive process steps of a CCS project, namely the power plant with capture, the transport of captured CO_2 and finally the underground storage. EIA's which have been performed for analogue projects in the Netherlands provide the main input for this paper. The analogue EIA's, 10 in total, for coal fired power plants, natural gas pipelines and natural gas storage facilities are analysed to obtain an overview of the most notable regulations, assessed impacts, methods and quality of the assessments.

Most notable environmental regulations

Activities or projects in the CCS chain where an EIA is obligated are depicted in Table 1. Next to EIA obligated activities there are also activities which require a decision from the competent authority (last column), in which the necessity of an EIA has to be determined. Finally, there is the possibility to perform a voluntary EIA.

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[2] Plans and programs are, for example, in the case of spatial planning: key planning decisions, regional and municipal zoning plans.

Table 1 EIA obligated activities in the Netherlands [2].

Process in CCS chain	Activity	EIA obligated	Decision obligated by competent authority*
Power plant	Establishing an installation for producing electricity, steam of heat (not nuclear).	Capacity ≥ 300 MW_{th}	Alteration or expansion: -increase capacity of ≥ 20% -change of fuel mix.
Transport	The construction of a pipeline for the transportation of oil, gas or chemicals.	Diameter > 80 cm Length > 40 km	Length ≥ 1 km in sensitive areas (≤ 3 nautical miles offshore).
Storage **	Extraction of oil and natural gas – in case of enhanced oil/gas recovery	Oil > 500 ton / day Gas > 500.000m^3 /day	
	Deep drilling or altering or expanding a current activity for searching or extraction of salt, gas or oil.		No threshold set.
	Establishing an installation for storing of non-dangerous wastes in the underground.	≥ 500.000 m^3	
	Altering or expanding a waste management installation.		≥ 250.000 m^3 100 tonne waste /day

* The competent authorities for power plants are the Ministry of Transport, Public Works and Water Management and the Province.
For transport: the Ministry of Transport, Public Works and Water Management and 'affected' municipalities.
For storage projects the Ministry of economic affairs is the main competent authority.
** An environmental license is in any case obligated for obtaining a license for storage activities according to the Mining act (Art. 40), also when an activity does not exceed the threshold set in the Environmental Management Act.

The initiator has to consider a vast array of acts, regulations, decrees, guidelines, standards and governmental programs when commencing and fulfilling the EIA. From which two issues regarding legislation applicable to CCS can be pointed out:

1. The European Commission [5] states that for some EIA obligated projects a tactic is used to split up one project[3] into various (not EIA obligated) sub-projects to evade the EIA obligation. In the Netherlands, it is set in regulations that, if related activities can be foreseen they are considered to be part of the project and consequently, they must be included in the EIA. The question remains if power plants with capture technology, transport and underground storage are inherently linked to each other and can be considered as one installation.
2. According to the mining act, a storage plan is obligated for a permit which includes the plan for measuring earth movement up to 30 years after closure of a storage site. However, monitoring of CO_2 leakage into the atmosphere is not specifically addressed in current regulation, nor is the maximum allowable flux from the soil (leakage) determined.

Environmental Impacts

The activities and associated environmental impacts ideally should be considered for each phase of a project life cycle: the construction, operation and decommissioning phases. The reviewed EIA's indicate that the impacts given in Table 2 will be assessed in an EIA applied to a CCS project.
We found that the emphasis in the procedures for the power plants lies on assessing the environmental impact of the operation phase and down stream impacts of emissions. The most important emission assessed is that of CO_2 in the operational phase. The second target is to consider the energy efficiency, use of waste heat and other end of pipe emission control technologies.

[3] Article 1.1: 4 of Environmental Management Act: 'One facility is considered to be the collection of accompanying installations that have a technical, organizational or functional bound and are in each others direct vicinity belonging to the same company or institution.'

Table 2 Environmental impacts relevant in an EIA for CCS in the Netherlands.

Impact	Power Plant	Transport through pipeline	Storage in underground, on-shore
Land use	Area (in hectares) occupied by the installation and surrounded regulated zones (e.g. safety zones).		
Archaeological, and cultural heritage	Destruction of archaeological artefacts in the ground during construction, destruction of typical geomorphologic occurrences in the landscape or cultural heritage.		
Biodiversity	General: destruction, disturbance and dispersion of habitat during construction, operation and dismantling.		
		Heat flux to soil (pipeline).	
Raw materials resources and Water use	-Use of materials (e.g. MEA) for emission reduction (SCR, FGD). -Process and cooling water use.	Construction materials.	Construction materials.
Visual impact	Impact of installation (e.g. stack) considering its surroundings.	Visual impact due to construction and decommissioning activities.	Impact of above ground Injection facility.
Energy requirement	Total capacity and energy requirement of components, gross production, net production, efficiencies of alternatives.	Compression energy requirement.	Energy requirement for injection, monitoring and abandonment.
Gaseous emissions and immission	CO_2, NOx, SOx, hydrocarbons, Particulate Matter, Volatile Organic Compounds and heavy metals.	Leakages/ blow off in case of emergencies.	Leakages of CO_2 from installation (leakage rates), hydrocarbons (injection in oil or gas fields).
Waste management	Solid waste handling, quality and quantity of waste flows.	Handling of waste produced during construction (steered drilling and drilling fluids).	Handling of waste produced during construction (drilling).
Socio-economic		Soil temperature (heat flux) and agricultural activities, other economic or social activities affected.	Agricultural (CO_2 leakage to soil), tourism, competition with storage of natural gas and earth heat recovery.
Noise, light and odour nuisance	-Noise zoning. -Light emissions/immission. -Odour emissions/immission.	-Noise emissions/immission surrounding compression station. -Disruption during construction.	-Noise emissions/immission surrounding injection station. -Disruption during construction.
Soil disruption	Soil disruption during construction and dismantling phase.	Soil disruption during construction and dismantling phase.	-Soil subsidence/inclination and induced damage. -Seismicity (similarities with natural gas storage). -Drilling during construction.
Soil contamination	Leaching of substances from waste/fuel storage.	-In case of leakage of CO_2 to soil.	-Mobilization of heavy metals, increase of soilCO_{2i}.
Safety	Internal/External safety for area: -Ammonia storage (SCR). -Solvent storage (amines/selexol).	-Individual risk (risk contours). -Group risk (F/N curve).	-Individual and group risk of aboveground installation. -Chance of CO2 leakage → possible exposure and related effects on human and ecosystems.
Groundwater and surface water disturbance/contamination	Cooling water discharge: water withdrawal, heating of water and mix zone effects. -Contaminants: emissions and immission effects in receiving water system. -Groundwater disturbance/withdrawal during construction.	-Disturbance of groundwater flow and level during construction and operation. -Extraction of groundwater during construction.	-Groundwater disturbance/contamination during construction. Risk of groundwater contamination through leakage: -Increase of pH. -Increase heavy metals.

The shaded boxes indicate probable gaps in knowledge and consequently, a limited availability of tools.

The design of the power plant should be benchmarked against BREF's[4] (issued under the IPPC Directive) for energy efficiency, pollution control and cooling water discharge.

The reviewed EIA procedures for natural gas pipelines indicate that the most environmentally friendly alternative should be determined by optimizing the route, design of the pipeline, construction techniques, timing of construction activities (e.g. breeding seasons, and nuisance for local residents), abandonment plan and mitigation possibilities. Optimizing the variants should be done by minimizing the most important impacts: a possible heat flux to soil[5], disturbance of groundwater flow and ecosystem during construction, operation and decommissioning, contamination of the soil, noise nuisance of the compressor station and risks due to pipeline failure.

Storage of natural gas in gas fields and in salt caverns and EOR can provide a benchmark for the EIA procedure for CO_2 storage. The procedures for these projects show that in the assessment emphasis lies on the stability and integrity of the sink including monitoring and abandonment plan, external safety of the installation, harmonization of above ground installations with the landscape, timing of construction, nuisance (light, noise) during the use phase and possible mitigation measures incorporated in the design of the installation to reduce possible impacts mentioned above.

Methods for Impact Assessment

The EIA provides a framework in which several methods for assessing impacts (quantitative or qualitative) are integrated. Methods currently used in EIA's are for example Life Cycle Assessment, Acoustical models, Geodetic deformation analysis, Risk analysis, Water discharge (thermal and waste substances) analysis and various forms of surveys (Ecological, Archaeological, Geohydrological). Although most of these methods provide the possibility for quantitative assessment of impacts, the nature of the environmental information presented in an EIS is in general often highly descriptive. Specifically for CCS, a problem with assessing and evaluating impacts quantitatively is expected in the field of external safety for transport and storage of CO_2 as methods and/or input for these methods are still lacking or under development.

Discussion and Conclusion

Regarding the information presented in this paper, it is expected that power plants with CO_2 capture and transport through pipelines can be assessed within the current EIA framework. However, when applying the EIA on CCS, specific aspects will require the adaptation or development of regulation, methods and assessment tools related to the EIA procedure. Some of these aspects are:

- Experience gained from capture projects should be used to gradually expand and improve the BREF for Large Combustion Plants regarding capture options and its relation with other emission reduction techniques.
- It is not clear yet if the CCS chain will be defined as one installation. By dividing the project into three separate processes it is possible that, separately, the parts are not EIA obligatory. This could result in neglecting environmental impacts and limiting participation of third parties in the decision making procedure. This issue should be carefully considered by regulators, competent authorities and project initiators in an early stage to avoid delaying legal procedures in the future.
- Current regulations and guidelines do not specifically prescribe a monitoring plan for possible CO_2 fluxes from the soil as it does for seismicity and soil movement. A framework which combines current legislation for seismicity and soil movement (measuring before, during and up to 30 years after closure) and experiences with monitoring techniques used in recent projects[6] [6, 7] can be used

[4] BREF stands for Best Available Technology Reference documents. Applicable are the BREF for Large Combustion Plants (LCP) (not yet formally adapted), for industrial cooling systems and for monitoring. CO_2 capture techniques are now roughly described in the appendix of the BREF for LCP.

[5] Assuming that CO_2 is transported in supercritical state at > 72.8 bar and >31°C.

[6] Weyburn, Canada; NASCENT; Rangely, USA and In Salah, Algeria.

as a first approach to overcome this gap in regulations.

- High uncertainty in the EIA procedure is expected to be in the storage of CO_2. Methods are lacking for quantitative risk assessment of the underground and are under development. As a consequence, no regulation or guidelines exist which prescribe such methods. Therefore, it is suggested that experiences with risk assessment for underground CO_2-storage will be included in national guidelines on Quantitative Risk Assessment. This could provide a progressing knowledge base for all participants in the EIA procedure.
- From a spatial planning point of view, implementing a CCS project is very complex. SEA-like[7] procedures have been used in spatial planning decisions to determine possible locations for projects (i.e. designation of possible locations for power plants). This approach should be applied on the appointment of possible CO_2 storage locations as well. This would bring forward the need for a SEA in which (source and sink) locations for CCS are identified at an early stage and included in strategic decision making regarding spatial planning. This to avoid conflict with other spatial functions (e.g. gas storage, earth heat, oil/gas extraction) and incorporate possible environmental impacts as criteria in strategic decision making.
- Considering the mentioned points, it is recommended to conduct an EIA procedure for the entire chain when planning a CCS (pilot) project in the Netherlands as this could (1) provide further insights into possible neglected environmental burdens of the whole chain; (2) provide a benchmark of the procedure and related assessment tools for CCS projects for competent authorities and initiators; (3) identify inadequacies in current regulations; (4) bring relevant stakeholders together in an early phase of the planning of a CCS project and (5) possibly ease the planning and implementation of future (commercial) CCS projects.

This paper shows an overview of the EIA procedure in the Netherlands, depicting the possibilities for establishing a framework for the assessment of CCS in the context of environmental impacts and accompanying regulations. The preliminary findings presented above form the starting point of future work to unravel these issues further, in order to provide more detailed insights into the environmental impacts of CCS projects and the adequacy of the EIA procedure to assess them.

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7 An environmental license and thus an EIA is obligated for the partial revision of a zoning plan (issued by central, provincial and municipal government) when this includes EIA obligated activities.