MCA4climate: A practical framework for planning pro-development climate policies

Mitigation Theme Report:
Encouraging Carbon Dioxide Capture and Storage

Contribution to the MCA4climate initiative

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Practical Note

For an overview of the MCA4climate initiative and a step-by-step guidance on how the theme-specific information reported below may be practically applied in countries wishing to develop pro-development climate policy planning, please see the main MCA4climate report and other associated documents (such as the case studies) available on www.mca4climate.info. For further information, please contact the UNEP team, Serban Scrieciu, Sophy Bristow, Daniel Puig or Mark Radka at unep.tie@unep.org.

1. Introduction

Carbon dioxide capture and storage (CCS) reduces greenhouse gas emissions by separating CO_2 from the flue gases of a large, stationary point source, transporting it, and isolating it from the atmosphere by injecting in a geological storage reservoir that is suitable for permanent storage (IPCC, 2005). Examples of CO_2 sources to which CCS could be applied are coal- or gas-fired power plants, iron and steel factories, refineries and bio-ethanol plants. CCS consists of techniques that are partly in use in the oil and gas industry. However, the technology still needs to be tested in real life. Several demonstrations in non-power sectors are taking place in Norway, Canada and Algeria. Various countries are planning a range of more full-scale demonstrations of CCS in various sectors (Global CCS Institute, 2010).

An advantage of CCS is that it can reduce greenhouse gas emissions by 70 to 85% compared to conventional technology (Viebahn et al., 2007), while continuing the use of fossil fuels for power or in other industries. Costs, however, are still high, technological risks are insufficiently covered, and in many jurisdictions, a regulatory framework for underground storage is still absent. In addition, there are concerns about public perception of underground CO_2 storage in inhabited areas, the significant energy penalty of the capture process, sufficient global and regional storage capacity, and the risks and impacts of CO_2 potentially seeping out of badly selected reservoirs.

2. The role of CCS in climate policy

CCS is considered as one of the options in a portfolio of mitigation actions. The IEA (2010) projects that in a cost-effective mitigation portfolio, CCS could achieve up to some 19% of global emission reductions required for a 450 ppm scenario by 2050. About half of the CCS emission reductions would be in the power sector and the other half in industry. The consideration of using CCS as a mitigation action, however, varies greatly between countries and local circumstances. In a few countries, in particular in the Middle East, CO_2 could be used for Enhanced Oil Recovery (EOR) and therefore could have a value-added in addition to climate change mitigation. In others, CO_2 capture technology and storage services could become export products. In most of the world, however, apart from climate change mitigation, there are few additional drivers for CCS. Unlike energy efficiency and renewable energy, it does not provide for other environmental or social benefits. Economic benefits arising from widespread CCS may in specific countries include employment and exports, but no studies that quantify potential economic benefits could be identified.

3. Approach

Governments considering long-term climate mitigation policies need to consider a number of issues: first, which mitigation options the country intends to use, and second, how those mitigation options should be realised. In this paper, the starting point is that a country has decided that it wants to reduce emissions, but that it needs to decide whether CCS should be part of its mitigation portfolio and how it should be realised. It takes the perspective of a country government; not of a project developer or operator.

This paper outlines the tools for governments to address the question whether to use CCS in the mitigation portfolio through a systematic multi-criteria analysis. It provides policy options and the criteria to contrast how different policy options enable CCS. The criteria are also linked to indicators.

4. Policy options for CCS

Table 1 below reviews a number of policy options to incentivise or enable CCS. It should be noted that:

- Most of these policy options, especially those in the awareness raising and public investment sections, will have to be implemented in order to allow for efficient implementation of CCS. Any soundly implemented CCS policy would include such policies; some options can therefore be seen as conditional rather than optional.
- Some economic instruments are complementary; others would be regulating the same problem. Especially those instruments addressing different technological maturity phases are considered complementary, even to the extent that the one is not effective without the other.
- For some disadvantages, no possible remedies exist as they are inherent characteristics of the policy option.

Table 1: Policy options to incentivise or enable CCS

Policy option	*Advantages*	*Disadvantages*	*Possible remedies*
Market-based instruments			
• Carbon price or tax	Incentive for CCS but only when it is the most cost-effective option	Unpredictable prices; unstable incentive Market failures – market underinvests in new technology Limited demonstration benefits	Additional policies Strong, credible cap
• Tax credits	Incentive for CCS projects Less visible as cost on government budget	Visibility and complexity for users Difficult in countries with unstable tax regime Uncertainty whether sufficient tax credit is given	
• Carbon emission standard	Firm signal to market Government budget neutral Adjustable standards	High electricity costs Inflexible policy	Combine with subsidies to ease the pain for operators
Command and control regulatory instruments			
• CCS mandate for coal- or fossil-fuelled installations	Firm signal to market Government budget neutral Phase-out unabated coal/fossil fuels	High costs implications Inflexible policy	Combine with subsidies to ease the pain for operators
Public investment			
• R&D support	Reduces costs of CCS through better technology Builds knowledge base for CCS in country	No incentive for deployment	Combine with other policies
• Demonstration subsidy	Direct, focussed demonstration subsidy	High costs for government Possible over-subsidising	Tender and competition Independent information providers on costs
• Funding pipeline network	Infrastructure investment best done by government Reduce upfront investment costs for CCS	High costs for government	Introduce increasing user fees

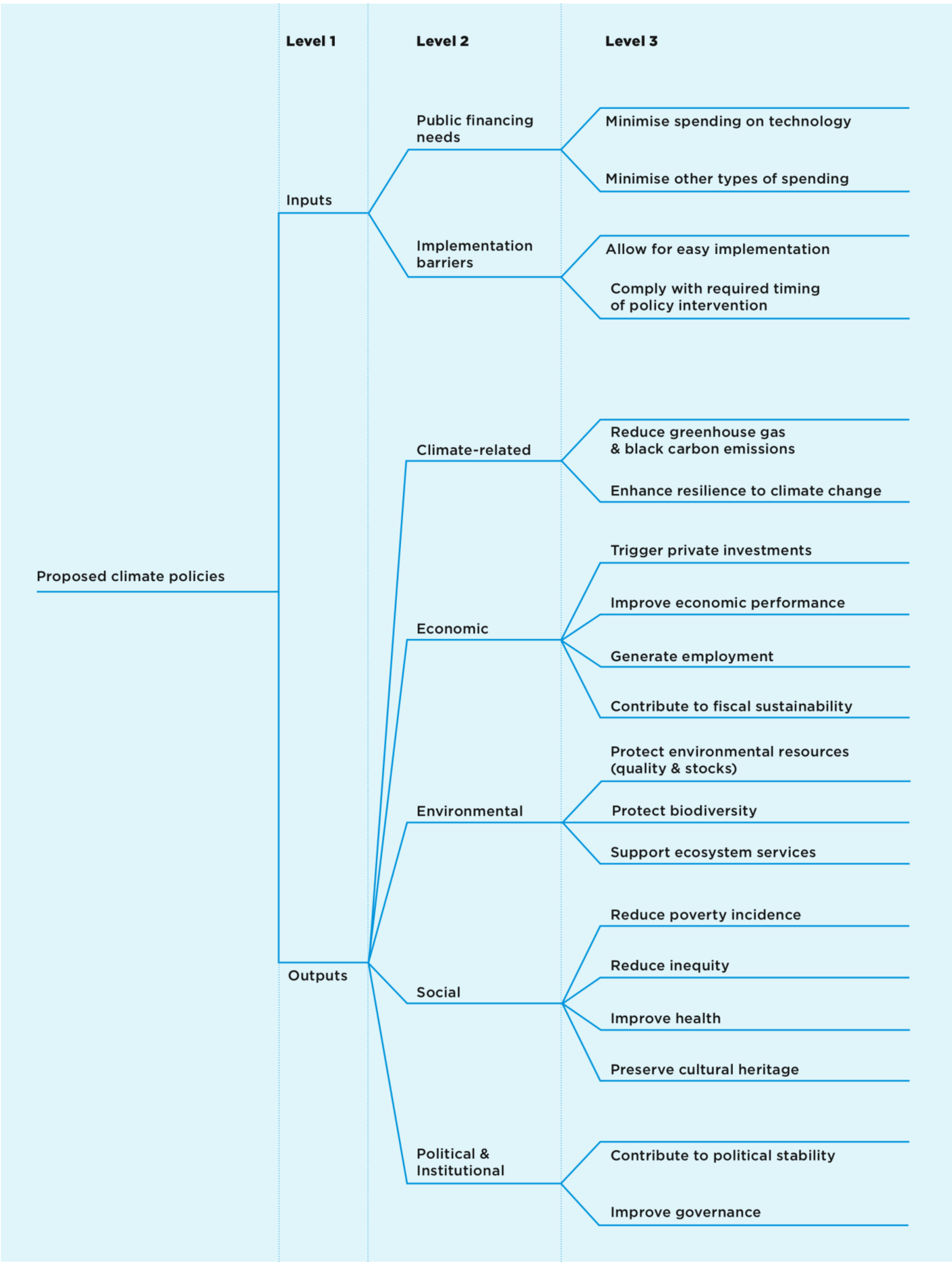
• Funding of storage assessments	Reduce upfront and uncertain investment for CCS project developers	Costs for government	Combine with international cooperation
Awareness raising and information			
• Academic education programmes (e.g. CCS centre of excellence)	Builds specialised human capacity on CCS	Transaction costs Diversion of capacity from other fields	Use of additional resources
• Regulatory capacity building	Awareness and knowledge with government Enabling safe management and regulation of CCS	Transaction costs Diversion of capacity from other fields	Combine with international cooperation Looking for synergies with other fields
• Public engagement programmes around projects	Public better informed about CCS Likely higher acceptance and less resistance	Costs Potential delays in project implementation	Use existing methodologies Early planning and start of public engagement
• Information portal and documentation	General public and media better informed about CCS	Transaction costs Risk of low usage	Good promotion and advertisement Make information demand-driven
International cooperation			
• Regional knowledge networks on CCS technology, public perception, economics and legislation	Knowledge exchange leading to lower learning costs	Transaction costs Exposure of underperforming countries	Create an open, fact-based atmosphere
• International demonstration fund for CCS	Level-playing field internationally Shared learning benefits	Hard to agree upon High costs and uncertain benefits for some countries	Attention to benefits for all but more for those investing more

5. Criteria and indicators for the CCS mitigation theme

The multi-criteria tree against which climate policies could be assessed is shown in Figure 1. This is hierarchical containing four levels. The first three levels are generic to all themes, and the fourth level is theme-specific. The latter criteria (together with their corresponding indicators) can be viewed mostly as descriptors of the generic criteria applied to each specific climate change theme, in this case encouraging carbon dioxide capture and storage. The generic criteria are grouped, at the first level, under inputs (the costs or efforts required to implement a climate policy option) and outputs (the impacts of a particular policy option). The input side is linked to two dimensions (or level-two criteria): public financing needs and implementation barriers, which are in turn disaggregated in “minimise spending on technology” and “minimise other types of spending” for the former, and “allow for easy implementation” and “comply with required timing of policy implementation” for the latter (these are the four level-three criteria on the input side). The output side refers to five dimensions (level-two criteria): climate-related, economic, environmental, social, and political & institutional to describe likely positive or negative impacts of a policy option. These are in turn broken down into 15 level-three criteria: two on climate-related, four on the economics, three on the environmental side, four on the social dimension, and two linked to the political and institutional dimension. A detailed discussion of the criteria tree at the generic level is described in the main report summarising the MCA4climate approach and its associated documents (available on www.mca4climate.info).

In the remainder of this section, each level-three criterion (the list on the far right side of Figure 1) is detailed further towards CCS-specific criteria (which can be regarded as level-four criteria or mere descriptors of the level-three criteria) and their associated indicators. Main characteristics of CCS are reflected in these generic criteria, for instance the relatively high costs, the need for suitable geological storage capacity, the human resources needs to implement and regulate projects for a technology that in most countries is still in its infancy, the deep greenhouse gas emission reductions that the option is capable of reaching, but also the general lack of co-benefits and its potential environmental impacts.

Figure 1: The generic criteria tree, part of the MCA4climate Policy Evaluation Framework



5.1 Input criteria: efforts required for implementing CCS-enabling policy options

Public financing needs

Criterion 1: Minimise spending on technology

Two sub-criteria are relevant here: investment costs and operational costs.

Investment costs: Investment costs associated with CCS include capture and compression installations, CO_2 transport infrastructure, and the injection and well installations associated with geological storage. These costs depend on the type of CCS project – the CO_2 source, the required CO_2 transport distance.

- Indicator: Capture and compression installation costs
- Indicator: Transport infrastructure costs
- Indicator: Storage exploration costs
- Indicator: Injection and well facilities costs
- Indicator: Proximity of sources and reservoirs
- Indicator: Investments in innovation, training, technical capacity and evaluation and expansion of consumer education and market-based initiatives.

Operational costs: CCS has considerable operational costs, such as energy costs for operating the capture installations. These costs are not included here as they are incurred by the project operator. For a country, operational costs associated with CCS include costs of enabling CCS.

- Indicator: Implementation costs, administration costs, enforcement costs (in case of regulation), programme costs (campaigns, training etc.), costs for monitoring and evaluation, subsidies, tax exemptions / deductions.

Criterion 2: Minimise other types of spending

This criterion may be further disaggregated into three sub-criteria applicable to the CCS theme: underground storage capacity; potential for enhanced oil recovery; and low-cost capture possibilities. These are further described below.

Underground storage capacity: For CCS, one needs to know whether there is sufficient underground storage capacity in the country or accessible elsewhere. Such an assessment can be costly, especially when geological exploration has not been conducted in the past. There needs to be human and institutional capacity to assess the underground storage capacity.

- Indicator: Costs of underground CO_2 storage assessments

Potential for Enhanced Oil Recovery: If a country is producing oil and/or has reservoirs that could yield revenues through CO_2-EOR, CCS could be a more cost-effective option for emission reduction.

- Indicator: estimated CO_2 storage and revenue generating potential for EOR

Low-cost capture possibilities: Capture of CO_2 is considered the most costly step, unless a source already emits high-purity CO_2. Sources that do that include natural gas processing and biomass conversion.

- Indicator: $MtCO_2$ emission from hydrogen production and associated cost-savings
- Indicator: $MtCO_2$ emission from gas processing and associated cost-savings
- Indicator: $MtCO_2$ emission from biomass, coal or gas to liquids and associated cost savings
- Indicator: unused $MtCO_2$ emission from ammonia production and associated cost savings

Implementation barriers

Criterion 3: Allow for easy implementation

Four aspects are worth considering when discussing the policy feasibility of CCS-enabling mitigation action that are difficult for quantifying in monetary terms: the institutional set-up, human capacity, public support, and the capacity for enforcement of legal framework.

Institutional set-up: in order to govern CCS safety and implementation, it helps if a institutional memory for the underground is present. That is often the case when the country has an oil and gas industry, and/or when there is existing legislation for mining activities. An important aspect is also that there is capacity for inspection and enforcement.

- Indicator: Presence of oil and gas industry OR Presence of mining law for deep underground
- Indicator: Existence of regulations related to safety and permanence

Human capacity developed related to CCS: CCS require a number of disciplines, such as geologists, geological engineers, chemical engineers, economists and mechanical engineers. In addition, before a CCS project is implemented, a country may feel the need to develop local capacities to understand, as well as develop and implement regulation related to safety and permanence.

- Indicator: number of specialised workers

Public support: Past experiences have shown that public resistance to CCS projects, in particular the storage site, can be strong. Such public resistance can be mitigated through early and sound communication about the project, and proper public engagement.

- Indicator: proximity of storage sites to inhabited areas
- Indicator: history of successful public engagement programmes

Capacity for enforcement of legal framework: if there is a legal framework for CCS present or under development, capacity for inspection and enforcement is necessary.

- Indicator: presence of inspection and enforcement of underground legislation
- Indicator: Identification of mandated competent authority
- Indicator: Number of trained specialists in competent authority

Criterion 4: Comply with required timing of policy implementation

There are two sub-criteria related to the time lag between when a policy action is agreed upon and when this becomes operational: timeline for human capacity development and time to develop the legal framework.

Timeline for human capacity development: As a new technology, any country, including developed countries, needs to ready itself for the technology. This involves building basic skills with practitioners, in universities, in technical schools and with legislators.

- Indicator: Human capacity gap

Time to develop a legal framework: In most countries, enacting legislation takes various years. Such time is also needed for the development of a legal framework for CCS in the European Union, for instance, the process for CCS legislation was started in 2006 and is likely to be finalised in 2011, and this was considered very fast.

- Indicator: time needed to issue the respective laws/regulations

5.2 Output criteria: possible impacts of a CCS-enabling option

Climate-related

Criterion 5: Reduce greenhouse gas & black carbon emissions

Greenhouse gas emission reductions compared to the baseline, taking into account the energy penalty and upstream emissions. CCS is unlikely to significantly impact black carbon emissions as these mainly result from old coal-fired power, to which the application of CCS is uneconomical.

- Indicator: Emission reduction in tCO_2 avoided

Criterion 6: Enhance resilience to climate change

This is not applicable to the CCS mitigation theme

Economic impacts

Criterion 7: Trigger private investments

While initially CCS may need public funding, in the longer run, under a carbon-constrained regime, the presence of a CCS industry in a country could entice business to invest in the country and in CCS.

- Indicator: Over time development of ratio of public/private investment in the technology

Criterion 8: Improve economic performance

Entrepreneurial activities for CCS technology, knowledge or services: Various entrepreneurial activities and industry activities result from relevant industries. These include underground service companies, pipeline manufacturers, solvent producers or gasification installation builders.

- Indicator: CCS-related turnover

Criterion 9: Generate employment

CO_2 capture and storage is an additional activity with implications on direct and indirect local jobs during construction, operation and aftercare of the CCS project.

- Indicator: Amount of jobs created as a consequence of CCS

Criterion 10: Contribute to fiscal sustainability

This refers to the balance of public spending and revenues over time as a result of CCS.

- Indicator: Projected (and realised) public spending on CCS
- Indicator: Projected (and realised) tax income resulting from CCS

Environmental impacts

Criterion 11: Protect environmental resources (quality and stocks)

Environmental resource impacts of CCS mitigation action may relate to the reduction of air pollution and the environmental safety of storage operation.

Reduction of air pollution compared to plant without CCS, taking into account the energy penalty and upstream emissions.

- Indicator: Emission reduction of SOx, NO_x, particulate matter, mercury

Safety of storage operations

- Indicator: Risk (probability x impact)

Criterion 12: Protect biodiversity

Storage potential and nature reserves: storage potential may be located in nature reserves, which may suffer as a consequence of storage operations.

- Indicator: Location of storage potential in nature reserves

Criterion 13: Support ecosystem services

Water reservoirs: If a country is very dependent on underground drinking water reservoirs, and storage of CO_2 might be taking place close to that, CCS may pose an unacceptable risk. Legislation and sound site selection should prevent leakage, but political and public acceptance of CCS may be reduced anyhow.

- Indicator: dependence on groundwater resources for human consumption
- Indicator: projected leakage rate into groundwater resources for human consumption under legislative scenarios

Social impacts

Criterion 14: Reduce poverty incidence

This criterion is not applicable to the CCS theme unless when specifically related to employment issues (already covered under criterion 9 on generating employment)

Criterion 15: Reduce inequity

Stakeholder empowerment: If CO_2 storage sites are planned near inhabited areas, research suggests that it is advisable to engage the inhabitants of that area into the planning process. Such engagement would enhance civil empowerment, whereas the absence of such engagement would increase inequity. So a question is: would stakeholders be genuinely engaged?

- Indicator: Inclusion of appropriate stakeholder engagement guidelines or obligation in CCS legal framework

Criterion 16: Improve human health

Potential health impacts of reduced air pollution: Some CCS technologies can have reduction of air pollution as a side-effect, as with CO_2 other pollutants are stripped.

- Indicator: Changes in health expenditures
- Indicator: Incidence of respiratory diseases
- Indicator: Mortality or DALYs

Criterion 17: Preserve cultural heritage

Storage potential and cultural assets: storage potential can be located in or near cultural assets that may suffer as a consequence of storage operations.
Indicator: Location of cultural assets close to storage potential

Political and institutional impacts

Criterion 18: Maintain or improve political stability

Two sub-criteria are relevant in this category: dependency on fossil fuels and energy security of supply.

Fossil fuels: A political reason for CCS is that it reduces the immediate need to reform a fossil-fuel-based energy system when carbon constrains are enacted. Does CCS allow the continued use of affordable and available fossil fuels?

- Indicator: dependence on fossil fuels (in particular coal)

Energy penalty: in particular the capture of CO_2 is, for most CO_2 sources, an energy-intensive process. Therefore, CCS may affect energy use and energy security of supply.

- Indicator: Additional fuel use (GJ)/reduced power supply as a consequence of CCS

Criterion 19: Improve governance

Community engagement programmes incentivised by CCS projects may lead to improved contact between government and public.

- Indicator: Community engagement is undertaken around CO_2 transport and storage projects

6. Relation to other themes

CCS relates to other themes in a number of ways. Primarily it interacts with other energy technologies.

- CCS in power plants and industrial facilities costs energy and therefore affects energy efficiency targets negatively. The IPCC (2005) and IEA (2009) indicate that CCS on a power plant reduces the output of a power plant by 15 to 20% compared to the original output. Overall, the energy efficiency of the economy will therefore decrease.

- If mitigation options are considered simultaneously, they may compete for the same funding. If CCS is seen as attractive, this may result in less funding for another option, such as renewable energy.

- In the context of an electricity market, power plants with CCS may primarily be used as a baseload option. This may affect the deployment of nuclear power, which will be competing with CCS for baseload power supply.

- If water reservoirs are affected by CO_2 storage operations, this may reinforce vulnerability of dry areas (potentially increasing adaptation costs in areas such as water management, vulnerability of agricultural systems or infrastructure resilience).

7. Identification and description of methods of assessment

Tools, techniques, models that can be used to determine the value of the indicators (including qualitative descriptions) are suggested below across all indicators in section 6.

Table 2 Methods of assessments and characteristics for all indicators.

Indicator	Model / method / tool	Characteristics
Capture and compression installation costs	Cost estimate	Quantitative
Transport infrastructure costs	Cost estimate	Quantitative
Storage exploration costs	Cost estimate	Quantitative
Injection and well facilities costs	Cost estimate	Quantitative
Proximity of sources and reservoirs	Source-sink matching analysis. For examples, see specialised consultancy firms such as www.Geogreen.fr	Quantitative but with many qualitative elements as possible
Investments in innovation, training, technical capacity and evaluation and expansion of consumer education and market-based initiatives.	Cost estimate	Quantitative, although there are many uncertainties.
Implementation costs, administration costs, enforcement costs (in case of regulation), programme costs (campaigns, training etc.), costs for monitoring and evaluation, subsidies, tax exemptions / deductions.	Cost estimate	Quantitative, although there are many uncertainties.
Costs of underground CO_2 storage assessments	Cost assessment	Quantitative
Estimated CO_2 storage and revenue generating potential for EOR	Geological atlas, either through a quick-scan or through reservoir-specific assessment. Examples include methodologies for South Africa (Council for Geoscience, 2010)	Qualitative with as many quantitative elements as possible
$MtCO_2$ emission from hydrogen production	Greenhouse gas inventory or CO_2emissions database (IEA GHG, 2010)	Quantitative
$MtCO_2$ emission from gas processing	Greenhouse gas inventory or CO_2 emissions database (IEA GHG, 2010)	Quantitative

Indicator	Model / method / tool	Characteristics
$MtCO_2$ emission from biomass, coal or gas to liquids	Greenhouse gas inventory or CO_2 emissions database (IEA GHG, 2010)	Quantitative
Unused $MtCO_2$ emission from ammonia production	Greenhouse gas inventory or CO_2 emissions database (IEA GHG, 2010)	Quantitative
Presence of oil and gas industry OR Presence of mining law for deep underground	Check whether this is the case	Qualitative
Presence of inspection and enforcement of underground legislation	Quality of environmental compliance	Qualitative
Existence of regulations related to safety and permanence	Check in legal framework	Qualitative
Human capacity gap	Difference between the required staff by project developer and supply of skilled personnel	Quantitative but many uncertainties
Proximity of storage sites to inhabited areas	- GIS analysis (if tool is available) - Combination of map and geological mapping	Quantitative Qualitative
History of successful public engagement programmes	Check whether this is the case	Qualitative
Identification of mandated competent authority	Check in legal framework	Qualitative
Number of trained specialists in competent authority	Review of competent authority staff background and experience	Qualitative
Time needed to issue the respective laws/regulations	- Average time for legislation to pass - Experience with underground and environmental legislation	Qualitative
Emission reduction in tCO_2 avoided	Evaluate on a plant level in the engineering modelling. E.g. through ASPEN	Quantitative
CCS-related turnover	Requirement for publishing cost data Monitoring of expenditure	Quantitative
Over time development of ratio of public/private investment in the technology	Requirement for publishing cost data Monitoring of expenditure	Quantitative
Amount of jobs created as a consequence of CCS	Employment analysis, e.g. with employment models	Quantitative but many uncertainties
Number of specialised workers	Identify the required skills and education level Add up the qualified experts in the country	Quantitative but many uncertainties
Projected (and realised) public spending on CCS	Budget review	Quantitative
Inclusion of appropriate stakeholder engagement guidelines or obligation in CCS legal framework	Check on legal framework	Qualitative

Indicator	Model / method / tool	Characteristics
Changes in health expenditures	See Health chapter in MCA	
Incidence of respiratory diseases		
Mortality or DALYs		
Location of cultural assets close to storage potential	- GIS analysis (if tool is available) - Combination of map and geological mapping	Quantitative Qualitative
Location of storage potential in nature reserves	- GIS analysis (if tool is available) - Combination of map and geological mapping	Quantitative Qualitative
Dependence on groundwater resources	Data analysis on water origin	Quantitative
Emission reduction of SOx, NOx, particulate matter, mercury	Evaluate on a plant level in the engineering modelling. E.g. through ASPEN	Quantitative
Risk	Outcome of risk assessment/environmental impact assessment	Combination of quantitative and qualitative
Dependence on fossil fuels (in particular coal)	Share of fossil fuels (coal, gas, oil) in the energy mix. Sources include databases by the International Energy Agency or the US DOE Energy Information Administration.	Quantitative
Additional fuel use (GJ) as a consequence of CCS	Evaluate on a plant level in the engineering modelling. E.g. through ASPEN	Quantitative
Community engagement is undertaken around CO_2 transport and storage projects	Whether community engagement has taken place, number and nature of meetings. Tools for community engagement: see for instance WRI (2010) and http://www.esteem-tool.eu/esteem-tool/	Qualitative

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