Clean Development Mechanism
Designated National Authority

Saudi Arabia's Greenhouse Gas Crediting & Offsetting Mechanism (GCOM)

Methodology for Determining Emission Reductions Resulting from CCS/CCUS Activities

Designated National Authority (DNA), Ministry of Energy
IT 02, Digital City, An Nakheel, Riyadh 12382

Contents

Oil and gas sector: Carbon Capture, Utilisation and Storage (CCS/CCUS)

1. Background and environmental integrity

The methodology for determining emission reductions from oil and gas production via carbon capture, utilization and storage technologies developed for the Kingdom of Saudi Arabia's GHG Crediting and Offsetting Mechanism is designed to provide an easy-to-use set of equations and calculations, while at the same time ensuring environmental integrity in its application.

To ensure a good quality standard of the underlying approach, the methodology is based on CCS-principles and rules defined by the Clean Development Mechanism (CDM) Executive Board / Meth Panel (Decision 10/CMP7/2012). It should be noted that so far, no approved CCS-methodology exists under the CDM. However, the previously mentioned guidance defines clear and strong guidance with the objective to achieve highest possible security and minimise possible environmental backlash caused e.g., by non-permanence issues occurring during or after CCS operations.

This methodology includes approaches to calculating baseline, project and leakage emissions. The politically contested issue of seepage is comprehensively addressed. The monitoring, reporting and verification (MRV) requirements ensure comprehensiveness and accuracy while recognizing data availability issues. For maximising quality and sustainability, project developers should always work with project-specific data.

2. Generic considerations of CCUS carbon credit projects

Oil and gas production is a highly complex business, with many different emission sources. Monitoring of such emissions is not as simple as e.g., in case of a renewable energy project, where only a limited number of parameters is needed to determine corresponding emission reductions, such as the produced electricity and the grid emission factor. Contrary, in the oil and gas sector, one needs to monitor various emission sources such as wells, pipelines, processing facilities of flared and vented gases, potential losses during transport, as well as electrical and thermal energy consumption at various points (often not individually billed).

Therefore, a **project- or activity-specific approach** must be applied that considers the unique design of each specific project on an individual basis.

For carbon crediting of CCS/CCUS projects, the most important aspect is the **permanence of storage. Short term utilisation** of CO_2: e.g., in the soda drink industry, chemical industry, for the production of sport shoes, mattresses, etc. lead to the release of temporarily stored CO_2 to the atmosphere within a short period of time (i.e., within days to a few years). Due to the very temporary character of storage, this type of carbon utilisation is typically not suited for generating carbon credits (and would not attract buyers due to reputational risks). **Medium term utilisation** of captured carbon, e.g., in building materials, typically leads to a release of temporarily stored carbon to the atmosphere after longer periods (e.g., decades). Such projects may be partially suited for generating carbon credits, but the temporary character would require special attention. Finally, the **long-term storage in saline aquifers / depleted oil and gas reservoirs** – e.g., CCS and EOR, where no release to the atmosphere is planned, can be considered as generally suited for carbon credit generation. However, prevention of release of stored CO_2 to the atmosphere ("reversal") requires special attention in order to create carbon credits that the market considers decent quality.

Last but not least, one needs to note that **Enhanced Oil Recovery (EOR)** has been and continues to be heavily contested at international level due to the associated increase of fossil fuel production. Carbon credits from EOR-activities may therefore face political challenge by international buyers.

Reservations and criticism may also be expected for Carbon Capture and Storage activities due to non-permanence concerns – however, to a lower extent. Such concerns may be overcome by **being strictly conservative** in the methodological approach and quantification of carbon offsets.

3. Definitions

Carbon Capture and Storage (CCS)
The process of separation and capture of carbon dioxide from a point source or directly from the atmosphere, its transport (if applicable) and subsequent safe and permanent storage in deep underground geological formations.

Carbon Capture, Utilization and Storage (CCUS)
The process of separation and capture of carbon dioxide from a point source or directly from the atmosphere, its transport (if applicable) and, subsequent usage and safe and permanent storage.

Fugitive Emissions
Emissions including all intentional and unintentional CO_2 emissions (released to the atmosphere) from the capture, processing, transport and storage of CO_2. This includes emissions from flaring and venting.

Project closure
Means end of injection of CO_2-rich gases into the storage site.

Seepage
Emission of stored CO_2 from a storage complex to the atmosphere (or ocean/surface water). Seepage can arise as a consequence of subsurface processes occurring after injection such as diffusion (through cap rocks) and migration (along fault planes and fissures or through operational or abandoned wells).

Storage Complex
The geological storage complex consists of the geological reservoir and the related caprock/seals.

Storage Site
The storage site consists of the geological storage complex and associated surface and injection facilities.

Caprock
A layer of hard, relatively impermeable rock that forms a barrier or seal above and around the reservoir rock so that fluids cannot migrate beyond the reservoir.

4. Quantification of GHG offset-credits (overview)

GHG offset-credits will be quantified by comparing "(CCS/CCUS) project emissions" to "business-as-usual (BAU)" emissions. Equation (1) summarizes the generic quantification method.

$$\boldsymbol{ER_y = \left(BE_y - PE_y\right)} \tag{1}$$

Where:

ER_y	=	Emission reductions achieved by project
BE_y	=	Baseline emissions
PE_y	=	Project emissions, e.g., related to fossil fuel and electricity consumption for pumping, transport, etc. Project emissions also include seepage emissions, i.e., potential release of stored CO_2 to atmosphere at some point in time.

5. Eligibility requirements

1. This methodology applies to project activities that reduce GHG emissions to the atmosphere by capturing CO_2 or CO_2-rich streams from oil and gas production facilities or processes, transportation of captured CO_2 via a pipeline as applicable and injection into an appropriately selected and well-managed geological storage complex for long-term containment.

2. This methodology is applicable to both new and existing oil and gas exploration and production process.

3. The methodology is applicable under the following conditions:
   - The captured CO_2 is transported via pipeline from the capture site to the injection facility.
   - Capture facility, transport pipeline and storage complex are located in Saudi Arabia.
   - The storage complex does not expand beyond the borders of Saudi Arabia, neither on-shore nor off-shore. Subsurface storage complex should not stretch to offshore territories.
   - The storage complex is fed only with CO_2-rich streams from one or more facility/-ies under the control of the same Project Proponent;

4. Furthermore, the methodology is applicable if Project Proponents meet the following requirements:
   - The storage complex is selected in accordance with the procedures and characteristics described in Annex I, and the analysis suggests that with the proposed Mode of Operation (such as project-specific injections procedures that manage injection pressure appropriate to the injection formation porosity and diffusion rates, caprock fracture pressure or capillary entry pressure, etc.) seepage is very unlikely and that no significant negative environmental

or health impacts are likely to occur. The storage complex characterization and selection procedure and report shall be approved by the Saudi DNA.

- As part of the storage complex characterization and selection procedure described in Annex I, the potential for seepage is evaluated through development of three-dimensional static and dynamic geological earth models that predict the movement of the CO_2 over time. This identifies locations and features where seepage might occur. The model or set of models shall be approved by the Saudi DNA.
- An appropriate monitoring plan for the storage complex is defined and shall be approved by the Saudi DNA.
- A plan for systematic review of modelling exists. The review will compare results generated during storage complex characterization and selection against data collected during monitoring of the storage complex collected after the commencement of injection. The result(s) shall be submitted as part of the verification process and reviewed by the independent verification company and the Saudi DNA prior to issuance of carbon credits.
- A plan for corrective measures to counteract significant irregularities is defined. This plan and assessment shall be approved by the Saudi DNA.
- The Kingdom of Saudi Arabia agrees in writing to take over liability for the Storage Complex from the Project Proponent 10 years after end of injection (“project closure”) and if all conditions are met (see section 0). The agreement shall be issued prior to approval of the project activity by the Saudi DNA. The terms of liability transfer shall include inter alia: the performance basis upon which liability transfer could occur, for example, through provision of sufficient evidence to suggest that the stored CO_2 will be completely contained for several hundred years.
- The Project Proponent demonstrates that adequate provisions, by way of financial security (or equivalent) are made to ensure that potential seepage, occurring at any point of time, can be compensated by surrender of an equivalent number of permanent emissions certificates from the Saudi Mechanism or Article 6 of the Paris Agreement (ITMOs). This amount will be capped at the total number of Saudi carbon credits received by the project activity during the project’s lifetime.
- An appropriate storage complex management plan is developed. This is to include inter alia the procedures for injection of CO_2 into the storage complex, operation and abandonment of wells, and storage complex closure procedures. This management plan shall be approved by the Saudi DNA.

5. This methodology can be applied to the following onshore sub-surface formations/scenarios:
    - Saline aquifers
    - Depleted oil and gas- and/or gas fields

6. This methodology does not apply to
    - Activities related to CO_2-storage in oceans;
    - Activities related to enhanced oil- or hydrocarbon recovery (EOR/EHR) that would be conducted anyway with a view to increase incremental oil-/hydrocarbon production – as these will not lead to emission reductions in Saudi Arabia compared to baseline emissions;

7. Finally, this methodology is only applicable if it can be demonstrated that venting of the CO_2 to the atmosphere is the most plausible baseline scenario. In case any legal provisions, code of

conducts or other types of legally or morally binding obligations prohibit the venting of CO_2 to the atmosphere, no carbon credits can be generated.

6. Project boundaries

8. The **spatial extent** of the project boundary encompasses the facility capturing the CO_2 that would otherwise be vented, and the main fuel and power systems that have a direct bearing on emissions associated with the project activity, in addition to the project related facilities. These elements include:
   - The installation where the carbon dioxide is captured;
   - Any CO_2 treatment and conditioning facilities, such as dehydration and compression facilities;
   - Transportation equipment, including pipelines and booster stations along a pipeline or offloading facilities in the case of transportation by ship, rail or road tanker;
   - Any reception facilities or holding tanks at the injection site;
   - The injection facility;
   - Any fuel gas and/or power systems, on the basis that the project activity leads to changes in the net emissions from these sources due to changes in fuel and electricity demand associated with the project activity.
   - Subsurface components, including the geological storage complex and all potential sources of seepage, as determined during the characterization and selection of the geological storage complex.

9. The **spatial project boundary** also extends into the sub-surface to include the pre-defined storage complex and overburden. The project boundary in relation to the sub-surface can be summarized as:
   - Vertical boundary (which is the surface area of the geosphere directly above the Storage Complex and overburden).
   - Lateral boundaries (based on the lateral limits of the storage complex, which is an estimation based upon a characterization of the storage complex and predictive forward models of the CO_2 plume migration, potential seepage pathways and ultimate distribution of CO_2 in the targeted storage complex).
   - The boundaries of the storage complex and associated overburden are defined by the storage complex characterization procedures.

10. The **temporal project boundary** is relevant in the context of permanence of emissions reductions created by the project activity. There are four distinct phases/events of the temporal extent:

1. Development
2. Operation
3. Closure
4. Post Closure.

7. Calculation of baseline emissions

Baseline emissions represent the CO_2 captured and subsequently injected and permanently stored in geological reservoirs that would have been emitted to the atmosphere in the absence of the project activity. By using injected CO_2 as basis for calculating the baseline emission, the calculation of emissions from fugitive CO_2 emissions along the CCS/CCUS value chain can be avoided due to the fact that fugitive emissions have been automatically deducted from the quantification.

Baseline emissions from venting of CO_2 are calculated as follows:

$$BE_y = \sum_i Q_{CO2,injected,i,y} \qquad (2)$$

Where:

BE_y	=	Baseline emissions in year y (tCO_2/yr)
$Q_{CO2,injected,i,y}$	=	Mass of CO_2 equivalent captured and injected at injection point i in year y at the storage site (tCO_2/yr)

$Q_{CO2,injected,i,y}$ is calculated as:

$$Q_{CO2,injected,i,y} = FRGas_{\ injected,i,y} \times w_{CO2,injected,i,y} \qquad (3)$$

Where:

$Q_{CO2,injected,i,y}$	=	Mass of CO_2 injected at injection point i in the year *y* at the storage site (tCO_2/yr)
$FRGas_{CO2,injected,i,y}$	=	Mass flow rate of gas stream (tonnes/yr) that is injected within the project activity at injection point i in year y
$w_{CO2,injected,i,y}$	=	Concentration of CO_2 (tCO_2/tonne) in the injected gas monitored at injection point i in the year *y*

Note that the quantification method introduced above is a generic guidance that might need to be adjusted to fit the concrete project design. Baseline emissions (BE) need to be estimated ex-ante based on the planned project design and modelled CO_2 injection. The real benefit and resulting quantities of carbon credits will be determined by ex-post monitoring of baseline emissions by directly measuring the amount of injected CO_2. Project proponents must elaborate an appropriate MRV-plan, to be approved by the Saudi DNA.

8. Calculation of project emissions

Project Emissions (PE) need to be estimated ex-ante according to the quantification methods provided below, in order to get a realistic understanding of the net-benefits of the CCS project activity. The real benefit and resulting quantities of carbon credits will be determined by ex-post monitoring of parameters required to determine project emissions.

Project Emissions include i) emissions from use of fossil fuel for capture, treatment & conditioning, transportation, reception and injection of the CO_2-rich gas stream, ii) emissions from electricity use for capture, treatment & conditioning, transportation, reception and injection of the CO_2-rich gas stream, iii) fugitive methane (CH_4) emissions along the CCS process including transportation. CH_4 emissions are converted to CO_2 equivalent using a Global Warming Potential (GWP) of 28 tCO_2e/tCH_4, and, iv) potential seepage as a result of injected CO_2 being emitted from the storage site (if applicable)

Any heat use for the project activity is to be accounted based on the energy source used (e.g., fossil fuel use or electricity consumption).

Project emissions are calculated as follows:

$$PE_y = PE_{FC,y} + PE_{EC,y} + PE_{CO2e,CH4,y} + PE_{Seepage,y} + \quad (4)$$

Where:

PE_y	=	Project emissions in year *y* (tCO_2/yr)
$PE_{FC,y}$	=	Project emissions from fossil fuel combustion in year *y* (tCO_2/yr)
$PE_{EC,y}$	=	Project emissions from electricity consumption in year *y* (tCO_2/yr)
$PE_{Seepage,y}$	=	Project emissions from seepage in year y (tCO_2/yr)
$PE_{CO2e,\ CH4,y}$	=	Fugitive CH_4 emissions in year y, converted to CO_2e (tCO_2e/yr)

Project emissions are calculated in the following steps:

Step 1: Determination of project emissions from fossil fuel consumption

Step 2: Determination of project emissions from electricity consumption

Step 3: Determination of fugitive CH_4 emissions

Step 4: Determination of seepage project emissions

The four steps are now presented in more detail:

Step 1: Determination of project emissions from fossil fuel consumption

$$PE_{FC,j,y} = \sum_i FC_{i,j,y} \times COEF_{i,y} \tag{5}$$

Where:

$PE_{FC,j,y}$	=	Baseline emissions from fossil fuel combustion in process *j* during year y (tCO_2/yr)
$FC_{BL,i,j,y}$	=	Quantity of fuel type *i* that would have been combusted in process *j* during year *y* (mass or volume unit/yr) for project activity
$COEF_{i,y}$	=	CO_2 emission coefficient of fuel type *i* combusted in process *j* during the year *y* (tCO_2/ mass or volume of fossil fuel)
i	=	Fuel types combusted in process *j* during the year *y*

The CO_2 emission coefficient of fuel type *i* can be calculated using one of the following two options as per the *CDM tool 03: Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion*[1]:

1) Option A: the CO_2 emission coefficient is calculated based on the chemical composition of the fossil fuel type i via the following approach:

If $FC_{i,j,y}$ is measured in a mass unit:

$$COEF_{i,y} = w_{C,i,y} \times \frac{44}{12} \tag{6}$$

If $FC_{i,j,y}$ is measured in a volume unit:

$$COEF_{i,y} = w_{C,i,y} \times \rho_{i,y} \times \frac{44}{12} \tag{7}$$

Where:

$w_{C,i,y}$	=	Weighted average mass fraction of carbon in fuel type *i* in year *y* (tC/ mass or volume of fossil fuel)
$\rho_{i,y}$		Weighted average density of fuel type *i* in year y (mass unit/volume unit of the fuel)

[1] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-03-v2.pdf

2) Option B: The CO_2 emission coefficient is calculated based on net calorific value and CO_2 emission factor of the fuel type *i* via the following approach:

$$COEF_{i,y} = NCV_{i,y} \times EF_{CO2,i,y} \quad (8)$$

Where:

$NCV_{i,y}$	=	Weighted average net calorific value of the fuel type *i* in year *y* (GJ/mass or volume unit)
$EF_{CO2,i,y}$		Weighted average CO_2 emission factor of fuel type *i* in year y (tCO_2/GJ)

Step 2: Determination of project emissions from electricity consumption

Project emissions from electricity consumption are calculated as follows:

$$PE_{EC,y} = \sum_{j} EC_{PJ,j,y} \times EF_{EL,j,y} \times (1 + TDL_{j,y}) \quad (9)$$

Where:

$PE_{EC,y}$	=	Project emissions from electricity consumption in year *y* (tCO_2/yr)
$EC_{PJ,j,y}$	=	Quantity of electricity consumed by the project electricity consumption source *j* in year *y* (MWh/yr)
$EF_{EL,j,y}$	=	Emission factor for electricity generation for source *j* in year *y* (tCO_2/MWh)
$TDL_{j,y}$	=	Average technical transmission and distribution losses for providing electricity to source *j* in year *y*
j	=	Sources of electricity consumption in the project

$EF_{EL,j,y}$: Project proponents can use the latest grid emission factor for Saudi Arabia as published by the Saudi DNA.

$TDL_{j,y}$: Use a conservative assumption matching the project situation. The Saudi DNA has to approve the chosen value. *If no data is available, a default value of 20 % is recommended in accordance with CDM Tool 05*[2].

Note that if electricity is sourced from captive plants, the specific emission factor based on power output and related fossil fuel consumption shall be used instead of grid emission factors.

[2] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-05-v1.pdf

Step 2: Determination of fugitive CH_4 emissions

Injection of hydrocarbons (i.e., CH_4) must be designed to be less than 5 % molar composition of the total volume injected into one storage complex ($PE_{CO2e,CH4,y}$ can then be assumed to be negligible). Otherwise, fugitive methane emissions along the CCS process including transportation have to be quantified and accounted as project emissions using a Global Warming Potential of 28 tCO_2e/tCH_4 based on the following approach.

$$PE_{CO2e,CH4,y} = \sum_i Q_{CO2e,CH4\,captured,k,y} - \sum_i Q_{CO2e,CH4\,injected,i,y} \qquad (10)$$

Where:

$PE_{CO2e,CH4,y}$	=	Fugitive CH_4 emissions in year y, converted to CO_2e (tCO_2e/yr)
$Q_{CO2e,CH4\,captured,k,y}$	=	Mass of CO_2 equivalent of CH_4 in captured CO_2 stream from point source k in year y at the capture site (tCO_2e/yr)
$Q_{CO2e,CH4\,injected,i,y}$	=	Mass of CO_2 equivalent of CH_4 injected at injection point i in year y at the storage site (tCO_2e/yr)

$Q_{CO2e,CH4\,captured,k,y}$ and $Q_{CO2e,CH4\,injected,i,y}$ are calculated as:

$$Q_{CO2e,CH4\,captured,k,y} = FRGas_{captured,k,y} \times w_{CH4,captured,k,y} \times GWP_{CH4} \qquad (11)$$

$$Q_{CO2e,CH4\,injected,i,y} = FRGas_{injected,k,y} \times w_{CH4,injected,i,y} \times GWP_{CH4} \qquad (12)$$

Where:

$FRGas_{captured,k,y}$	=	Mass flow rate of gas stream that is captured from the project activity at capture point k in year y (tonnes/yr)
$FRGas_{injected,i,y}$	=	Mass flow rate of gas stream that is injected within the project activity at injection point i in year y (tonnes/yr)
$w_{CH4,captured,k,y}$	=	Concentration of CH_4 in the captured gas monitored at capture point k in the year *y* (tCO_2/tonne)
$w_{CH4,injected,i,y}$	=	Concentration of CH_4 in the injected gas monitored at injection point i in the year *y* (tCO_2/tonne)
GWP_{CH4}	=	Global warming potential of CH_4, 28 tCO_2e/tCH_4

Step 4: Avoidance, determination and calculation of seepage emissions

All potential seepage sources shall be effectively managed through good site selection and management, including effective monitoring during and post injection (which serves to support zero-seepage assumptions), and the use of corrective measures to control any significant irregularities in the subsurface behavior of the CO_2.

For ex-ante calculation, seepage project emissions ($PE_{Seepage,y}$) should be estimated as accurately and conservatively as possible, applying latest scientific expertise and a site-specific expert-evaluation based on predicting simulation models. Proper site selection and characterization shall ensure that $PE_{Seepage,y}$ can be assumed to be 0.

For ex-post calculation:

1. Potential seepage emissions are to be considered as project emissions if they occur within the crediting period.

2. In order to firstly avoid – and secondly determine and account for – such potential emission source(s), Project Proponents are required to implement a multi-step process as part of the overall storage complex development and management undertaken during project development, operation, closure and post-closure phases. This process serves to reduce the risk of seepage occurring to extremely low levels.

3. These steps are as follows:

   Sub-step 4a: Storage complex characterization, selection and management in accordance with procedures defined in Section 9;

   Sub-step 4b: Monitoring of the sub-surface storage complex for assurance purposes in accordance with procedures defined in Section 9;

   Sub-step 4c: Quantification of the mass of any CO_2 released to the atmosphere from the storage complex as a consequence of seepage;

   Sub-step 4d: Closure of storage site if monitoring and updated modelling confirms no seepage and long-term permanence of CO_2 storage.

   Further details on the procedures for each step are provided below and in the corresponding monitoring plan section.

Sub-step 4a – Storage Complex characterization, selection and management

See Section 10.

Sub-step 4b - Monitoring of the sub-surface storage complex

See Section 10.

1. If seepage is detected during the operational phase / crediting period, or could occur as a result of significant irregularities, no further carbon credits will be issued until corrective measures to stop further seepage have been carried out, and an updated storage complex assessment in combination with an updated monitoring and management plan indicates that further seepage is not anticipated. The Saudi DNA must approve continuation of carbon crediting.

2. If seepage occurs during closure- or post-closure period, the Project Proponent shall take the following measures:
   - To take all possible corrective measures to prevent the continuation of seepage;
   - To take all possible corrective measures to minimize harm to humans and the natural environment as a consequence of seepage, in line with prevailing national laws and regulations, and the risk assessment and environmental impact assessment prepared as part of the overall project approvals.

3. In addition, the amount of seepage emissions should be quantified following the procedure outlined in Sub-step 4c.

Sub-step 4c - Quantification of any mass of CO_2 emitted to the atmosphere due to seepage

1. The procedure outlined in Sub-step 4b provides the basis for detecting seepage emissions from a CO_2 Storage Complex. If application of the monitoring plan provides evidence of seepage emissions, the level of emissions should be calculated using the following formula:

$$\boldsymbol{PE_{Seepage,y}} = \left[\sum_{\boldsymbol{i}} \left(\boldsymbol{S_{FR,i}} * \boldsymbol{S_{T,y,i}}\right)\right] * \boldsymbol{10^3} \quad (13)$$

Where:

$S_{FR,i}$	=	Flux rate of seepage of source i ($kgCO_2e$/day)
$S_{T,y,i}$	=	Number of days seepage source i is estimated to have been occurring in year y

2. The procedure for determining flux rate and duration should be included in the Monitoring Plan developed by Project Proponents and approved by the Saudi DNA.

3. The quantification of seepage should take place according to the best available knowledge and technology at the time of occurrence. The obligation to replace the respective amount of carbon

credits must consider uncertainties related to this quantification. This is a conservative approach ensuring the environmental integrity of the Saudi GHG Crediting and Offsetting Mechanism.

4. If seepage is determined during the monitoring period (see section 10), an amount equal to the mass of seepage quantified following these procedures must either:
    - Be included as project emissions for the respective period since the last request for issuance (i.e., in the same way as for other project emissions); or
    - If the project emissions exceed the baseline emissions calculated for the given period, then the exceedance must be compensated by the Project Proponents by surrender of an equivalent number of permanent emissions certificates (including credits from the Saudi Mechanism, ITMOs or A6.4ERs);
5. These obligations shall rest with the Project Proponent up to the date when monitoring ceases and liability transfers from Project Proponent to the Kingdom of Saudi Arabia occurs, and with Saudi Arabia thereafter – see section 0.

Sub-step 4d: Closure of storage site and cessation of monitoring

See Section 0.

9. Calculation of carbon credits under the Saudi Mechanism

The number of carbon credits that may be issued under the Saudi GHG Crediting and Offsetting Mechanism are calculated as follows (see Equation (10)):

$$ER_y = (BE_y - PE_y) \tag{10}$$

Where:

ER_y	=	Emission reductions achieved by project
BE_y	=	Baseline emissions
PE_y	=	Project emissions, e.g., related to fossil fuel and electricity consumption for pumping, transport, etc. Project emissions also include seepage emissions, i.e., potential release of stored CO_2 to atmosphere at some point in time.

10. Monitoring plan

Project proponents need to elaborate a comprehensive monitoring plan, describing in detail how all technical parameters will be monitored (*Where? How? How frequent?*). This applies to all parameters listed in Equations (1) - (10) above, and further parameters required to accurately monitor the behaviour of the CO_2-plume in the storage complex, as well as potential seepage. As such, the monitoring plan shall also reflect the site selection process as follows:

Sub-step 4a – Storage Complex characterization, selection and management (as per Section 8)

1. Project Proponents shall employ appropriate Storage Complex selection in order to support assumptions regarding zero-Seepage in the short, medium and long term. This must be supported by good management of the Storage Complex following a prescribed Mode of Operation prepared based on the specific characteristics of the Storage Complex.

2. Project Proponents shall prepare a Storage Complex characterization report in accordance with procedure defined by Saudi Arabia as part of the overall project registration procedure. This shall be submitted to the Saudi DNA in conjunction with the project registration document for the proposed project. The Storage Complex characterization report shall be approved by the Saudi DNA (and/or a competent authority appointed by the DNA).

3. Project Proponents shall continuously monitor pressure in the primary geological storage formation. The pressure in the primary geological storage formation shall not exceed levels which could induce the following pressure driven processes in the formation which can affect security of storage: fracture propagation pressure (FPP); fault reactivation pressure (FRP); fault valving pressure (FVP); seal (caprock) capillary entry pressure (CEP). The inducing pressure levels of each in the Storage Complex shall be identified in the Storage Complex characterization report.

4. The storage characterization report shall determine the modes of operation for the Storage Complex so as to ensure that pressure-driven processes in the primary geological containment formation are within accepted levels of safety i.e., within levels that avoid the risk of activating pressure-driven Seepage processes within the Storage Complex. Safety margins for pressure in a primary storage formation should be determined using best available scientific expertise.

5. Project Proponents should continuously monitor down-well pressures ($P_{M,i}$) in each injection and observation well in the Storage Complex during both CO_2 injection operations and the post-closure phase. At no point should pressure in the primary geological storage formation exceed the maximum level as defined above.

Sub-step 4b - Monitoring of the sub-surface storage complex

1. Projects Proponent should design a monitoring plan based on serving the following purposes:
   - To provide an image of the subsurface behavior of the injected CO_2 plume within the storage complex so as to provide an image of the subsurface behavior to facilitate systematic review of the subsurface monitoring post commencement of injection operations; and;
   - To provide early signs of significant irregularities within and outside of the storage complex defined during storage complex characterization, including recognized migration & seepage pathways.

2. In the event that significant irregularities in the storage complex are detected, injection operations should cease and further investigations (monitoring and modelling) should be carried out to provide details of the irregularity and the reasons for it occurring. These investigations should serve:
   - To initiate any corrective measures required to restore the security of the storage complex to ensure long-term isolation of the CO_2 from the atmosphere through maintenance of the CO_2 trapping mechanisms in the storage complex;

To determine whether the significant irregularities could have or will lead to seepage of CO_2; and, if required, to initiate actions to quantify seepage, as described in Sub-step 4c in Section 8, in order to identify the seepage emission source(s).

The monitoring-plan will be highly activity- and site-specific. Project proponents also need to define reporting formats and details for all monitored parameters.

Monitoring of CCS project activities shall be undertaken to meet the following objectives:

(a) To provide assurance of the environmental integrity and safety of the geological storage site;

(b) To confirm that the injected carbon dioxide is contained within the geological storage site and within the project boundary;

(c) To ensure that injected carbon dioxide is behaving as predicted in order to minimize the risk of any seepage or other adverse impacts;

(d) To ensure that good site management is taking place, taking account of the proposed conditions of use set out in the site development and management plan;

(e) To detect and estimate the flux rate and total mass of carbon dioxide from any seepage;

(f) To determine whether timely and appropriate remedial measures have been carried out in the event of seepage;
(g) To determine the reductions in anthropogenic emissions by sources of greenhouse gases that have occurred as a result of the registered CCS project activity.

The Monitoring Plan shall contain precise information and requirement for the operational and the post-operational phase of the CCS activity. The monitoring of the geological storage site shall:

(a) Begin before injection activities commence, to ensure adequate time for the collection of any required baseline data;
(b) Be conducted at an appropriate frequency during and beyond the crediting period(s) of the proposed project activity;
(c) Not be terminated earlier than 10 years after closure of the storage site (= end of injection of CO_2-rich gases). Thereafter, monitoring will be continued by the Kingdom of Saudi Arabia, and eventual seepage included in the national emissions inventory as per the rules, modalities and procedures of the enhanced transparency framework of the Paris Agreement[3].;
(d) Only be terminated if no seepage has been observed at any time in the past 10 years and if all available evidence from observations and modelling indicates that the stored carbon dioxide will be completely isolated from the atmosphere in the long term.

Sub-step 4c: Closure of storage site and transfer of liability

1. Following the closure of the CO_2 Storage Complex for the project activity, Project Proponents must continue to monitor, report and undertake any remediation and corrective measures in the event of any significant irregularities and seepage until conditions for liability transfer to the Kingdom of Saudi Arabia are met. The terms of liability transfer shall be agreed with the Kingdom of Saudi Arabia prior to registration of the project activity. The terms of liability transfer should be performance-based (i.e., based on the performance of the CO_2 Storage Complex), and should follow the conditions proposed in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 5, Section 5.7.1, para. 4(v)*[4]. This requires that once the CO_2 approaches its predicted long-term distribution within the reservoir, and there is agreement between the models of CO_2 distribution and measurements made in accordance with the monitoring plan, it may be appropriate to decrease the frequency of (or discontinue) monitoring. On this basis, the convergence of observed and predicted behavior, and the reduction or cessation of monitoring should provide a basis for liability transfer.

2. Following liability transfer, the Kingdom of Saudi Arabia shall take over responsibility for the CO_2 storage complex, including the liability for undertaking sub-steps 4a, 4b and 4c for management of significant irregularities or seepage, if required. After liability transfer, the Project Proponent shall be absolved of these responsibilities.

3. Any potential seepage from closed storage sites of activities undertaken under the Saudi GHG Crediting and Offsetting Mechanism shall be accounted in the Kingdom's National Inventory as per the IPCC guidelines for national inventories to be applied under the Paris Agreement.

[3] See requirements defined under decision 18/CMA.1 as well as the "Guidance operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement" agreed by CMA3.

Moreover, seepage emissions are to be reported by the Kingdom of Saudi Arabia as per the requirements defined under decision 18/CMA.1 as well as the "Guidance operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement" agreed by CMA3.

4. Project Proponents shall be required to continue to undertake periodic verification of monitoring, including in the final liability transfer report, by an accredited independent verification company until the point of liability transfer.

11. Liability provisions

1. Liability for seepage rests with Project Proponents during the operational phase and until transfer of liability to the Kingdom of Saudi Arabia, as described in paras 3 and 4 of this chapter. After transfer of liability according to section 0c, the Kingdom of Saudi Arabia will be responsible.
2. Regardless of the time in which seepage occurs, the Kingdom of Saudi Arabia needs to report such emissions properly in its national inventory according to latest UNFCCC reporting rules[5].
3. In the event that seepage occurs during the operational phase (= injection of CO_2-rich gases) but after the crediting period of the activity (i.e., before liability transfer according to the provisions of Section 10 takes place), the amount of seepage emissions must be compensated by the Project Proponents by surrender of an equivalent number of permanent emissions certificates (such as ITMOs, A6.4ERs) of the UNFCCC.
4. In the event that seepage occurs after the end of the project closure and after liability transfer according to the provisions of Section 10 takes place, Project Proponents are not liable for surrendering an equivalent number of permanent emissions certificates (such as ITMOs, A6.4ERs) of the UNFCCC. The Kingdom of Saudi Arabia needs to report such emissions properly in its national inventory according to latest UNFCCC reporting rules[6].

[5] See requirements defined under decision 18/CMA.1 as well as the "Guidance operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement" agreed by CMA3.
[6] See requirements defined under decision 18/CMA.1 as well as the "Guidance operationalizing the modalities, procedures and guidelines for the enhanced transparency framework referred to in Article 13 of the Paris Agreement" agreed by CMA3.

Annex 1 - Selection and characterization of the geological storage site[7]

1. Geological storage sites shall only be used to store carbon dioxide as project activities under the Saudi GHG Crediting and Offsetting Mechanism if there is no significant risk of Seepage, no significant environmental or health risks exist, and the geological storage site will comply with all laws and regulations of the Kingdom of Saudi Arabia.
2. The geological storage site is not located in international waters.
3. The following shall be evaluated when determining whether geological storage sites are eligible:

   (a) All available evidence, such as data, analysis and history matching, indicates that the injected carbon dioxide will be completely and permanently stored such that, under the proposed or actual conditions of use, no significant risk of seepage or risk to human health or the environment exists;

   (b) Whether the geological storage site is suitable for potable water supply.

4. Project participants shall take the following steps to characterize the proposed geological storage site:

   (a) Step 1: data and information collection, compilation and evaluation. This step shall involve the collection of sufficient data and information to characterize the geological storage site and determine potential seepage pathways. The collected data and information shall be evaluated in order to make a preliminary assessment of the site's storage capacity and to assess the viability of monitoring. The data and information shall be evaluated for its quality and, where required, new data shall be collected;

   (b) Step 2: characterization of the geological storage site architecture and surrounding domains. This step shall involve the assessment of known and inferred structures within the injection formation(s) and cap rock formation(s) that would act as barriers to, or facilitators of, the migration of injected carbon dioxide. This step shall involve the compilation of (a) numerical three-dimensional static earth model(s) of the geological storage site. The uncertainty associated with key parameters used to build the model shall be assessed. The model shall be used to characterise, inter alia:

   (i) The structure of the geological containment;

   (ii) All relevant geological properties of the injection formation(s);

   (iii) The cap rock formation(s) and overburden;

   (iv) The fracture system;

   (v) The areal and vertical extent of the geological storage site (e.g., the injection formation, the cap rock formation, overburden, secondary containment zones and surrounding domains);

   (vi) The storage capacity in the injection formation(s);

   (vii) The fluid distribution and physical properties;

   (viii) Other relevant characteristics;

[7] In accordance with Decision 10/CMP7/2012, which constitutes the UNFCCC's definition of best practice for CCS projects under the CDM.

(c) Step 3: characterization of dynamic behaviour, sensitivity characterization and risk assessment. This step shall involve an assessment of how the injected carbon dioxide can be expected to behave within the geological storage site architecture and surrounding domains, with a particular focus on the risk of seepage. This step shall utilize numerical dynamic modelling of the injected carbon dioxide using the static model developed in step 2 above to assess coupled processes (i.e., the interaction between each single process in the model), and, where possible, reactive processes (e.g. the interaction of injected carbon dioxide with in situ minerals in the numerical model), and short- and long-term simulations. Such numerical modelling shall be used to provide insight into the pressure and extent of carbon dioxide in the geological storage site over time, the risk of fracturing the cap rock formation(s) and the risk of seepage. Multiple simulations shall be conducted to identify the sensitivity of the assessments to assumptions made. The simulations carried out in this step shall form the basis for risk and safety assessments (see below);

(d) Step 4: establishment of a site development and management plan. Drawing on steps 1–3 above, a site development and management plan shall be established. The plan shall address the proposed conditions of use for the geological storage site and include, inter alia, descriptions of:

(i) The preparation of the site;

(ii) Well construction, such as materials and techniques used, and the location, trajectory and depth of the well;

(iii) Injection rates and the maximum allowable near-wellbore pressure;

(iv) Operating and maintenance programmes and protocols;

(v) The timing and management of the closure phase of the proposed carbon dioxide capture and storage (CCS) project, including site closure and related activities.

5. A wide range of data and information shall be used in performing the characterization and selection of the geological storage site, including, inter alia:
   a. Geological information, such as descriptions of the overburden and cap rock formation(s) and injection formation(s), locations of mapped faults, subsurface well and wellbore information, permeability and porosity, which are important in determining the injectivity of the injection formation, and the cap rock formation containment capacity, and information about regional tectonics, including the stress field and historical seismic activity;
   b. Geophysical information, such as the thickness and lateral extent of the storage and cap rock formation(s), pressure, temperature, the existence of faults, and reservoir heterogeneity. Sources of data may include, inter alia, well logs, sonic logs and seismic surveys;
   c. Geomechanical information, such as the stress state and the rock fracture pressure within the injection formation(s) and the cap rock formation(s). Sources of data include borehole data, such as breakouts inferred from caliper and televiewer logs, minifrac results, information about anisotropy within the reservoir, and mud loss events;
   d. Geochemical information, such as information on rock and fluid properties and mineralogy. Fluid properties, such as the brine salinity, should also be used to determine dissolution trapping rates;
   e. Hydrogeological information, such as aquifer characteristics and aquifer flow direction and rates within the geological storage site, the overburden and surrounding domains.

Annex 2 - Risk and safety assessment[8]

1. A comprehensive and thorough risk and safety assessment shall be carried out in order to assess the integrity of the geological storage site and potential impacts on human health and ecosystems in proximity to the proposed CCS project activity. The risk and safety assessment shall also be used to inform environmental and socio-economic impact assessments.
2. The risk and safety assessment shall consider the following:

   (a) Specific risks associated with containment failure resulting in emissions of greenhouse gases from above-ground installations and seepage from subsurface installations, and the potential effects on, inter alia:

      I. The contamination of underground sources of drinking water;
      II. The chemical properties of seawater;
      III. Human health and ecosystems (e.g., as a result of carbon dioxide accumulations at dangerous levels in non-turbulent air);

   (b) The risk of continuous slow seepage from a geological storage site. This type of event can arise due to, inter alia:

      I. Seepage along (an) injection well(s) or abandoned well(s);
      II. Seepage along a fault or fracture;
      III. Seepage through the cap rock formation;
      IV. The risk of sudden mass release of carbon dioxide from surface CCS installations, for example due to pipeline rupture.
3. The risk and safety assessment shall:
   a. Cover the full chain of carbon CCS, including surrounding environments;
   b. Provide assurance of safe operational integrity regarding the containment of carbon dioxide, based on site-specific information about the geological storage site, potential seepage pathways, and secondary effects of storing carbon dioxide in the geological storage site, such as brine migration;
   c. Be used to determine operational data for the application of the site development and management plan, such as to set the appropriate maximums of injection pressure that will not compromise the confining cap rock formation(s) and the overburden of the geological storage site;
   d. Take account of the effects of potential induced seismicity or other geological impacts, as well as any other potential consequences for the environment, including on local ecosystems, property and public health, and global environmental effects on the climate directly attributable to the CCS project activity, including effects due to seepage;
   e. Be used to help prioritize locations and approaches for enhanced monitoring activities;
   f. Provide a basis for remedial measures, including plans for responses that can stop or control any unintended emissions from surface CCS installations and seepage of carbon dioxide, restore the integrity of a geological storage site, and restore long-term environmental quality significantly affected by a CCS project activity. Such measures and plans shall accompany monitoring plans;
   g. Include a communication plan.

[8] In accordance with Decision 10/CMP7/2012, which constitutes the UNFCCC's definition of best practice for CCS projects under the CDM.

4. In order to assess the potential risks of carbon dioxide capture, transportation and storage in a geological storage site, the project participants shall take the following steps:
    a. Step 1: hazard characterization. This shall include an analysis the following:

        (i) Potential hazards resulting from the capture, transportation and injection of carbon dioxide;

        (ii) Potential seepage pathways from the geological storage site;

        (iii) The magnitude of potential seepage for identified potential seepage pathways;

        (iv) Critical parameters affecting potential seepage, such as the maximums of injection formation pressure, injection rates and temperature;

        (v) The sensitivity to various assumptions made during numerical modelling;

        (vi) Any other factors which could pose a hazard to human health and the environment;

    b. Step 2: exposure assessment. This shall be based on the characteristics of surrounding populations and ecosystems, the potential fate and behavior of any seeped carbon dioxide, and other factors;
    c. Step 3: effects assessment. This shall be based on the sensitivity of species, communities or habitats linked to potential seepage events identified during the hazard characterization and the effects of elevated carbon dioxide concentrations in the atmosphere, biosphere and hydrosphere;
    d. Step 4: risk characterization. This shall comprise an assessment of the safety and integrity of the geological storage site in the short-, medium- and long-term, including an assessment of the risk of seepage under the proposed conditions of use set out in the site development and management plan;
    e. Step 5: contingency plan for large incidents, including seepage. This shall comprise all the necessary plans to be put in place in case of large incidents, including availability of trained personnel, materials and equipment and financial means to mitigate adverse impacts of the incident and teams prepared to act as swiftly as possible.