TRUST

High resolution monitoring, real time visualization and reliable modeling of highly controlled, intermediate and up-scalable size pilot injection tests of underground storage of CO_2

Contract #309067

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Executive summary

CO_2 capture and storage (CCS) is a promising solution to reduce the CO_2 emissions caused by the human kind in order to reduce greenhouse gas effects on the environment. The CO_2 has to be captured at the place of its genesis and brought to a suitable place for storage. This storage place has to fulfill several criteria, e.g. good injectivity, high storage capacity, tightness during its long life cycle (up to hundreds of years). Of course, several risks are related to the geological deep storage of CO_2, which have to be identified and treated in a comprehensive evaluation, (i) framework requirements, (ii) risk assessment including risk identification, risk analysis, and risk evaluation, (iii) risk handling and treatment, (iv) Risk Tackling (v) risk monitoring and controlling (vi) risk communication and exchange of information, which have to be passed through iteratively, either if new findings are made during the operation of the CO_2 injection facility or in case of any changes in the process, but at all events at least once a year.

During the previous MUSTANG Project (EU No. 227286), guidelines for risk management for CO_2 storage in deep saline aquifers have already been developed and described for the topics (i) Reservoir, (ii) Geochemistry, (iii) Well Engineering (Drilling, Integrity), (iv) Geo-mechanics, (v) HSE, and (vi) Hydrogeology. These topics have been evaluated qualitatively and it was recommended to quantitate them as soon as reliable data are available within the progress of the following Projects (in this case: TRUST). This will be done in the comparative study for Heletz and Hontomin in deliverable D7.3.

The topic "operation of the CO_2 injection facility and expected performance" has not yet been addresses and evaluated. This gap will be filled by applying the present risk management strategy, which completes the risk assessment for the on-ground installations for the CO_2 injection and their operation including the interfaces in D7.2, in co-operation of KIT with the local users EWRE.

Keywords	Risk management strategy, risk assessment, CO_2 geological storage, ISO 31000, HAZOP

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1. Introduction

For the effective control of greenhouse gases, especially to reduce the emission of CO_2 into the atmosphere, one opportunity is the geological deep storage in deep saline aquifers. This method requires the construction of suitable injection sites, which have to be safe during operation, but also during the very long time of storage lasting from hundreds to thousands of years. Hence, there are many risks in this process concerning safe operation of the injection facility, but moreover the tightness of the storage to ensure that no uncontrolled releases may happen. Yet, a standardized, comprehensive, site independent, commonly accepted, clear and transparent methodology for risk assessment is still missing. Hence it is absolutely essential to develop a qualified risk management method covering all existing risks in a qualitative and (if data are available) also in a quantitative way.

Risk management covers in general the complete risk assessment cycle consisting of risk identification, analysis, evaluation, and treatment, controlling, monitoring, reviewing, identifying and handling residual risks and ensuring communication and exchange of information. These, universally applicable, principles and generic guidelines on risk management have been defined since 2009 in ISO 31000 and the related documents [Brüh-2012].

The challenge in the present Project TRUST is to adapt these general tools to the specific needs of risk management according to the CO_2 storage demands in TRUST.

- Risk Assessment:
  - Risk identification;
  - Risk analysis;
  - Risk evaluation;
- Risk treatment:
  - Risk controlling;
  - Risk monitoring;
  - Risk reviewing;
- Identifying and handling of residual risks;
- Ensuring communication and exchange of information about the risk management procedure.

Therefore, a systematic approach is necessary to establish a practically applicable specific risk management tool, which covers all specific risks concerning CO_2 handling above and under the ground, which means both the injection and the fate of the stored CO_2 as well. The whole procedure has to be in a well-understandable format and formulation for the experts and the non-expert as well. At the end of the TRUST Project, it will further be extended to break down protocols and guidelines for CO_2 storage site licensing and certification, but also establish a practical data base for decision-makers and stakeholders.

2. Objective

The main objective of this Deliverable is to develop a *Strategic Risk Management Approach for CO_2 injection*. The main task of KIT in this Deliverable is the compilation of results achieved so far from MUSTANG and other CCS projects to provide a solid base to develop a strategic risk management plan using generally available tools referring to DIN ISO 31000.

All risks concerning the handling, injection and the fate of the stored CO_2 should be identified, defined and structured, either qualitatively or quantitatively. Also, tools for controlling, monitoring and reviewing the risk assessment process need to be evaluated. The handling of residual risks has also to be addressed as well as the way of communication and exchange of information.

The central aim is to provide a general risk management strategy, which can be applied directly to the site specific application for Heletz, which will be reported in Deliverable D7.2.

For the MUSTANG project [Dias-2010, Guen-2014] and also in some other CCS projects [Futu-2007, IEA-2009a, IEA-2009b, Metz-2005, Sava-2004] scoping for risk assessment tools has already been carried out. From these results, guidelines for risk management of deep saline aquifer storage sites have been delineated, especially with focus on geological and geophysical aspects concerning the reservoir engineering and behavior for CO_2 storage and the tightness of cap rock formations with risks of leakage. These data [Dias-2010, Guen-2014] are available for further use in the comparative study for Heletz and Hontomin in D7.3.

Within TRUST, however, a strategic risk management plan using generally available tools referring to DIN ISO 31000 will be developed with a special focus on all risks concerning the handling and injection of CO_2, which has not yet been considered in the other studies. Methods for controlling, monitoring and reviewing of the risk assessment process have to be evaluated. The handling of residual risk will be addressed as well as the way of communication and exchange of information.

In general, the risk management strategy will be described in a way which is clearly understandable by both experts and non-experts.

3.The Risk Management Process

DIN ISO 31000 is a generic norm providing fundamental applicability for all types of businesses and all types of risks. In the present case, this generalized procedure will be described first and then be adapted to the local needs within the Project TRUST.

The **risk management process** is a cycle, which is passed through iteratively, as shown in Figure 1 [Brüh-2012].

It consist of the following points, which have all to be addressed thoroughly during the risk management process.

In general, there are four different types of risk management:

- **Strategic risk management**: Top-Down-Process with focus on basic aspects without any operative or dispositive details.
- **Dispositive risk management**: Bottom-Up-Process concerning technical and organizational risks
- **Operative risk management**: balance between strategic and dispositive risk management assessing product and project risks
- **Process-based risk management**: bottom-up-process e.g. analysis of hazardous work or Failure Mode and Effects Analysis (FMEA)

For the comprehensive risk management plan in carbon capture and storage (CCS) all these mentioned topics have to be addressed and evaluated. The general procedure, as shown in Figure 1, is as follows:

3.1 Framework Requirements

In a first step, the **framework requirements** have to be analyzed completing the internal and external influencing factors as well, which can have an impact on the development of risk criteria and finally the risk handling.

The external influencing factors could be for example:

- the surrounding conditions of the project;
- the organizational structure;
- laws and regulations;
- Interests of different involved groups (partners, stakeholders, politicians).

The internal influencing factors take aims and strategies of the project into account, but also already available data.

3.2 Risk Assessment

The **risk assessment** consists of 3 steps:

- **Risk identification:** The reference points, which allow the evaluation of risks for the project have to be deduced from the external and internal points of the framework requirements as well as from standards, laws, rules and principles, but also from special application fields. The probability of occurrence and the case frequency have to be addressed.

- **Risk analysis:** The identified risks are described, their origins, the probability of the respective event and the frequency are analyzed.

- **Risk evaluation:** The results from the risk analysis are evaluated.

3.3 Risk Handling and Treatment

The next step is **Risk handling and treatment,** which covers the selection and implementation of one or more methods and options in order to handle the risks. Cyclic processes are necessary to assess the methods used for risk handling and treatment for its efficiency. If the remaining risk is still too high to be tolerated, further methods have to be elaborated and evaluated until the remaining risk is under the given limit. The following possibilities for risk handling and treatment, which do not exclude each other and are also not suitable for all situations:

- Avoiding of risks by avoiding activities causing risks;
- Enhancement of the tolerable risk limit, as long as concerning only business risks and no hazards to humans, tangibles, and environment;
- Removing of risk sources;
- Change of probability of occurrence of risks;
- Change of impact of risks;
- Sharing of risks between different parties;
- Voluntary underwriting of risks.

3.4 Risk Tackling

For **risk tackling**, **risk management plans** have to be prepared and implemented in order to document the selected methods and how their efficiency will be checked and proofed. A risk management plan should contain:

- Expected achievable benefit.
- Performance measurement and restrictions.
- Responsibilities for clearance and implementation of risk management plans.
- Suggested actions.
- Requirements on reporting and risk monitoring.
- Time schedule and plan for implementation.

3.5 Risk Monitoring and Controlling

Accompanying to the risk management process, an iterative **risk management controlling** is necessary.

3.6 Risk Communication and Exchange of Information

Risk communication and **exchange of information** with and for experts and the public as well are essential for a successful application of the established risk management.

A special part of the risk management are **emergency and crisis management** enforcing a fast and right reaction as response to a serious event. It is followed directly by a business continuity management in order to find back to standard operation as soon as possible.

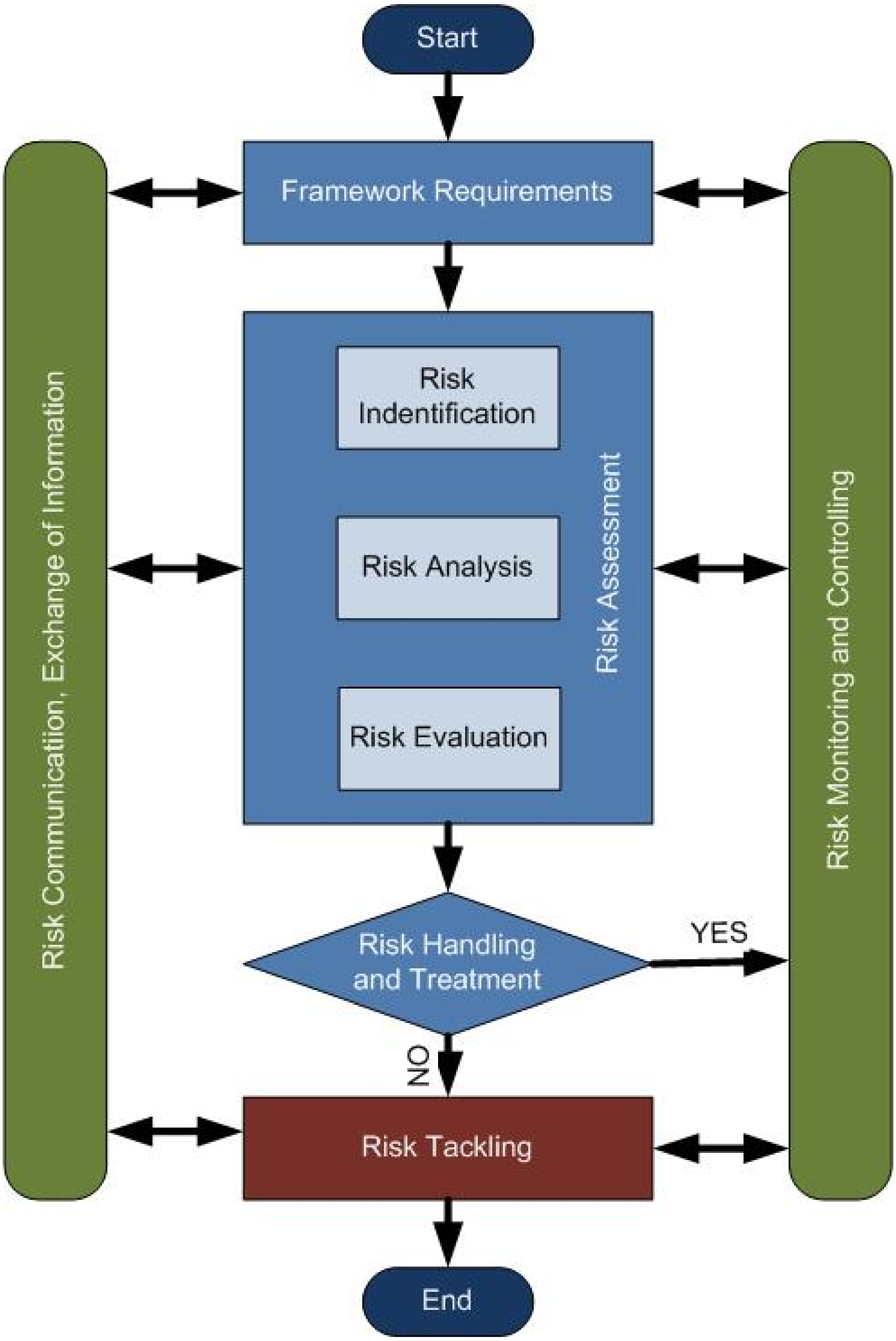

Figure 1: Schematic of Risk Management Process according to ISO 31000 [Brüh-2012]

4. General Results

The risk management process according to ISO 310000, as described above, has to be applied to the CCS storage site in Heletz, Israel.

During the MUSTANG Project (EU No. 227 286), guidelines for risk management for CO_2 storage in deep saline aquifers have already been developed and described [Dias-2010, Guen-2014]. Here, already the main disciplines involved in a CO_2 storage project have been identified as:

- **Operation**: Expected performance (safety, CO_2 injection …);
- **Reservoir**: Understand flow within reservoir (gas, liquid ….) within CO_2 storage operations;
- **Geochemistry**: geochemical interactions between injected or resident fluids, well materials, cements, rocks and fluids in the near Geophysicist wellbore environment;
- **Well Engineering (Drilling, Integrity):** Procedures for drilling, construction and permanent abandonment of wells; Materials/, integrity management chemical and physical properties of different fluid and cement types interpretation of evaluation logs;
- **Geomechanics**: potential geomechanical impacts on well cements and the near wellbore environment that may stem from CO2 storage operations;
- **HSE**: HSE management and requirements in applicable regulations;
- **Hydrogeology**: Understand fluid flow within geological system Within CO_2 storage operations.

Besides operation, all other topics have been evaluated qualitatively and it was recommended to quantitate them as soon as reliable data are available within the progress of the following Projects (in this case: TRUST). This will be done in the comparative study for Heletz and Hontomin in D7.3.

The focus of the present study is to fill the gap for the previously not considered topic **"operation"**, which completes the risk assessment for the on-ground installations for the CO_2 injection and their operation.

According to the risk management process described above and shown in Figure 1, for the topic "**operation**" a Process-based risk management as bottom-up-process has been selected.

First of all, the framework requirements for the internal and external influencing factors have to be analyzed. They are:

1. the CO_2 injection facility;
2. the interfaces to the CO_2 supply and the well head;
3. the location of the CO_2 injection facility;
4. the surroundings of the location;
5. the organizational structure for operation and maintenance of the CO_2 injection facility;
6. The installation and handling of the CO_2 tank and the well head.

These identified framework requirements are the column heads in Table 1 providing a summary of all steps necessary for a comprehensive risk assessment of the entire CO_2 injection facility. Also the interfaces to the CO_2 tank and the well head, the location itself and the surroundings, but a safe operation and maintenance of the facility are considered. The results of the risk assessment will be used to determine how to handle the identified risks and to develop a risk management plan to provide a safe operation of the injection facility.

Table 1: Summary of risk assessment and management for the CO_2 injection facility

1. Framework requirements	CO_2 injection facility	Interfaces to the CO_2 supply (tank) and the injection site (well head)	Location of the CO_2 injection facility	Surroundings of the facility location	Organizational structure for operation and maintenance of CO_2 injection facility	Installation and handling of CO_2 tank and well head
2. Identification of risks, analysis and evaluation	HAZOP study available	HAZOP study available	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE
3. Risk handling and treatment	HAZOP study available	HAZOP study available	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE
4. Risk tackling and management plans	Evaluation of the HAZOP study	HAZOP study available	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE
5. Risk management controlling and monitoring	To be done by KIT with support of EWRE	HAZOP study available	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE	To be done by KIT with support of EWRE
6. Risk communication	Has to be discussed, not yet decided					

This risk management strategy will be used for the practical risk assessment analysis for the experiments at Heletz, which will be carried out for reporting in Deliverable D7.2.

For the topics "CO_2 injection facility" and "Interfaces to the CO_2 supply (tank) and the injection site (well head)" already a HAZOP study is available and can be directly used to develop a risk management plan for the experiments at Heletz in D7.2.

All other topics f (2. to 6.) have to be assessed and evaluated in the practical risk assessment in D7.2 in co-operation of KIT with the local users EWRE.

The topic "communication of risks" has not yet been discussed within the working group; this has to be done during the work concerning Deliverable D7.2 to take a decision for the further handling.

It has to be indicated, that the list in Table 1 has to be updated, if new findings are made during the operation of the **CO_2** ***injection facility or in case of any changes in the process, but*** **at all events at least once a year in close connection with the annual safety instruction*****.***

5. Next Steps

The present risk management strategy will be applied to Heletz site, Israel, with focus on the filling the gap regarding the safe operation of the CO_2 injection facility (from the CO_2 tank to the well head, including all interfaces).

A comprehensive risk assessment process will be performed for the operation of the injection facility itself, but also for the CO_2 storage tanks and their connection to the injections facility on one side and the connection to the well head on the other side. For this purpose, a comprehensive HAZOP study prepared by the CO_2 injection facility distributer TRIMERIC CORP. and the operator EWRE is available. For the documentation in D7.2 some pictures and also a 3D-plan of the entire arrangement of all components from the tank to the well head is needed.

The actual risk situation will be described and also how to minimize and to handle the residual risks for Heletz site, Israel.

The controlling and monitoring tools for the CO_2 injection facility including the interfaces will be derived from the risk assessment results.

The communication of information will be discussed and the number one way will be decided and determined.

All results will be reported in Deliverable D7.2.

6. Expected Innovation and Exploitation-Outlook

The findings for Heletz site resulting from the present risk management approach as well as from the practical risk assessment for operating the CO_2 injection facility in Heletz to be reported in the next Deliverable D7.2 will be compared with the approaches for Hontomin injection site in Spain. Here also the results from MUSTANG Project will be quantitated as far as possible. The complete evaluation will be reported in Deliverable D7.3.

All risk management findings will be used as basic input for further applications such as the development of guidelines, protocols for site licensing and certification, liability issues and others, which will be reported in Deliverable D07.4. On the basis of the lessons learned for the injection experiments and the risk analysis a methodology for a procedure for the certification and licensing Heletz for CO_2 storage will be developed. It should become a template for other sites. Active participation of regulators and stakeholders will allow tailoring this procedure to their critical needs and requirements.

7. References

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