European Energy and Environmental Law Review

Wolters Kluwer
Law & Business

Published by Kluwer Law International
P.O. Box 316
2400 AH Alphen aan den Rijn
The Netherlands

Sold and distributed in North, Central and South America by Aspen Publishers, Inc.
7201 McKinney Circle
Frederick, MD 21704
United States of America

Sold and distributed in all other countries by Turpin Distribution
Pegasus Drive
Stratton Business Park, Biggleswade
Bedfordshire SG18 8TQ
United Kingdom

ISSN 0966-1646

This journal should be cited as:
(2015) 24 EEELR

The European Energy and Environmental Law Review is published 6 times per year.
Subscription prices for 2015 [Volume 24, Numbers 1 through 6] including postage and handling:
Print subscription prices: EUR852/USD1,136/GBP626
Online subscription prices: EUR789/USD1,051/GBP579 (covers two concurrent users)

This journal is also available online at www.kluwerlawonline.com. Sample copies and other information are available at www.kluwerlaw.com. For further information at please contact our sales department at +31 (0) 172 641562 or at sales@kluwerlaw.com.

For Marketing Opportunities, please contact marketing@kluwerlaw.com

Printed on acid-free paper

European Energy and Environmental Law Review

The European Energy and Environmental Law Review invites the submission of unsolicited articles from scholars, practitioners and students of energy and environmental law. The Editors are willing to consider proposals for articles but is unable to make any commitment as to publication prior to submission of the final script. Book reviews are also welcome. Letters in response to articles can only be considered for publication if they do not exceed a maximum of 500 words.

Aims and Scope

European Energy and Environmental Law Review is a bimonthly journal which presents comprehensive coverage of the latest developments in energy and environmental law throughout Europe. In addition to this, European Energy and Environmental Law Review contains concise, accessible articles which explore and analyse significant issues and developments in energy and environmental law and practice throughout Europe.

European Energy and Environmental Law Review enables the reader to keep abreast of significant and topical aspects of energy and environmental law, including the legal issues relating to renewables, energy security, energy efficiency, energy competition law, energy liberalisation process, electricity and gas markets, climate change; sustainable energy, land, air, fresh water, oceans, noise, waste management, dangerous substances, and nature conservation. Its succinct, practical style makes it ideal for the busy professional, while the authority, scope,and topicality of its coverage make it an invaluable research tool.

An Assessment of CCS Risk Analysis Mechanisms used by EU Commission

*Behdeen Oraee-Mirzamani**

I. Introduction

The following is the way in which the European Commission currently performs risk analysis and risk management for geological storage of CO_2 and therefore recommends the CCS industry to do so too. The EU Commission, in its Guidance Document 1 (GD1),[1] recognises that the current level of knowledge with respect to the risk analysis of CO_2 storage sites is limited and as a result states that: "the overall approach is to identify and mitigate any significant risks; The CA should recognise that operators must undertake site-specific approaches in their risk assessment and management (European Parliament 2011a)".[2]

However, in order to provide a benchmark and a basis for risk analysis and risk management for the storage site operators and the insurance industry, the EU Commission makes use of the approach used in the CO2QUALSTORE report[3] which has been adapted in accordance with the needs of the CCS Directive.

According to the CCS Directive, CO_2 storage sites should only be selected, used and operated where there is no significant risk of leakage and that the stored CO_2 should be permanently contained (European Commisson 2009).[4] Significant risk is defined in the CCS Directive's Article 3(18) as meaning "a combination of probability occurrence of damage and a magnitude of damage that cannot be disregarded without calling into question the purpose of the Directive as far as the storage site is concerned".[5]

Therefore, according to the CCS Directive, the risks have to be analysed and determined as to how significant they are and if deemed significant, to what extent do they need to be addressed by storage site operators and considered by the insurance industry when insuring CO_2 storage sites.

II. Risk Analysis Methods Proposed by the European Commission in Guidance Documents 1 and 4

As mentioned previously, the CCS Directive makes use of a modified version of risk assessment and risk management technique used by the CO2QUALSTORE report in order to perform risk assessment for the lifecycle of CO_2 storage sites in general.

The proposed risk analysis and risk management approach used in the CCS Directive is divided into three steps, Overall Risk Management Process, Interaction between Operator and Competent Authorities and Risk Management at different project phases.

The following framework has then been provided for the overall risk management process in geological storage of CO_2 (European Commission, 2009):[6]

- Risk identification and assessment
- Risk ranking
- Risk management measures

Risk identification and assessment entails the identification, assessment and characterisation of potential hazards and risks towards the containment of CO_2 in underground storage sites, exposure and effects assessment (European Parliament, 2011a).[7]

Furthermore, risk ranking means to rank and categorise the identified risks and hazards based on a

* Doctoral Researcher at Imperial College London. email: b.oraee@imperial.ac.uk

[1] European Parliament 2011a. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 1 (GD1): CO_2 Storage Life Cycle Risk Management Framework. In: Commission, E. (ed.). *Official Journal of the European Union*: European Commission.

[2] European Parliament 2011. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 1 (GD1): CO2 Storage Life Cycle Risk Management Framework. In: Commission, E. (ed.). *Official Journal of the European Union*: European Commission.

[3] Det Norske Veritas (DNV) 2010. Co2qualstore Report – Guideline for Selection, Characterization and Qualification of Sites and Projects for Geological Storage of CO_2.

[4] European Commission 2009. Directive 2009/31/EC of the European parliament and of the council of 23 April 2009 on the geological storage of carbon dioxide and amending council directive 85/337/EEC, European parliament and council directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and regulation (EC) no 1013/2006. In: Commission, E. (ed.). *Official Journal of the European Union*.

[5] European Commission 2009. Directive 2009/31/EC of the European parliament and of the council of 23 April 2009 on the geological storage of carbon dioxide and amending council directive 85/337/EEC, European parliament and council directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and regulation (EC) no 1013/2006. In: Commission, E. (ed.). *Official Journal of the European Union*.

[6] European Commission 2009. Directive 2009/31/EC of the European parliament and of the council of 23 April 2009 on the geological storage of carbon dioxide and amending council directive 85/337/EEC, European parliament and council directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and regulation (EC) no 1013/2006. In: Commission, E. (ed.). *Official Journal of the European Union*.

[7] European Parliament 2011a. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 1 (GD1): CO2 Storage Life Cycle Risk Management Framework. In: Commission, E. (ed.). Official Journal of the European Union: European Commission.

CCS Risk Analysis Mechanisms

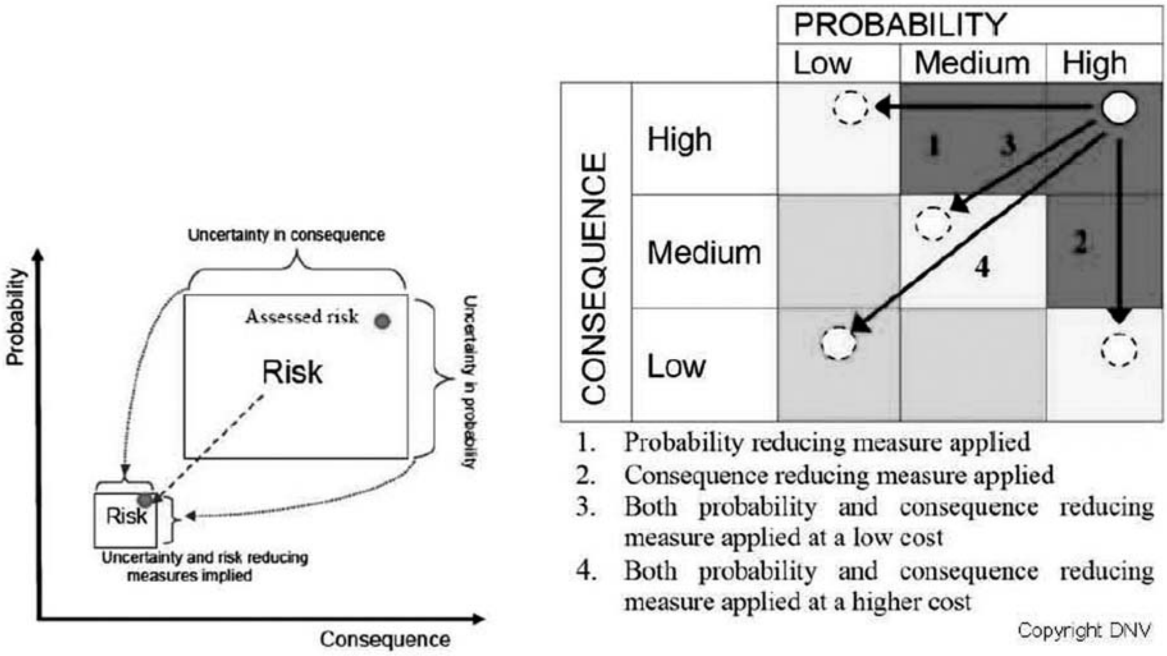

Figure 1: Risk Management Framework used in CCS GD1 (Det Norske Veritas (DNV), 2010)

standard matrix of probability and severity of outcome. This step consists of two options: Significant or Insignificant. The next step is to describe and evaluate preventive and corrective measures that can be used to manage the risks (Det Norske Veritas (DNV), 2010).[8]

The EU Commission recognises and mentions in GD1 that while its risk analysis framework is based on a modified version of the CO2QUALSTORE guideline, operators can also use other risk analysis and risk management methods, as long as they comply with the requirements of the CCS Directive.

2.1 EU Commission Guidance Document 1 (GD1) Risk Ranking Mechanism

Risk ranking is one of the most important elements in risk analysis since it enables the storage facilities' operators to be able to identify which risks are significant and which ones are insignificant. In addition, this also enables insurance companies to assess the risks of CO_2 storage more effectively at any given storage facility and therefore devise insurance policies that are more in favour of the CCS industry.

The EU Commission's CCS GD1 already provides a risk ranking mechanism that can be used by the CCS industry. This mechanism is described below.

The proposed method for ranking the risks associated with CO_2 storage is to categorise the risks using a standard matrix of probability and impact/severity of occurrence (shown in Figure 1).

The initial ranking, based on the risk identification stage, may be supported by the analysis carried out in the risk assessment step. The aim of this process is to characterize the potential significance of each risk along with its probability of occurrence and consequences should it occur. The relative significance of each risk should then be characterized, prioritised and placed in either the significant or insignificant categories. GD1 describes insignificant risks as "ones that are broadly regarded as not posing a significant danger to human health or environment" (European Parliament, 2011b).[9] Furthermore, it describes significant risks as "ones that must be reduced to insignificant through implementation of risk reducing measures in order to gain project approval, or to meet anticipated conditions for site closure (European Parliament, 2011b).[10]

In general, it is recommended by the GD1 that in order to avoid disappointment, the ranking takes place conservatively owing to the fact that there is a high

[8] Det Norske Veritas (DNV) 2010. CO2QUALSTORE Report – Guideline for Selection, Characterization and Qualification of Sites and Projects for Geological Storage of CO_2.

[9] European Parliament 2011b. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 2 (GD2): Characterisation of the Storage Complex, CO2 Stream Composition, Monitoring and Corrective Measures. In: Commission, E. (ed.). European Commission.

[10] European Parliament 2011b. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 2 (GD2): Characterisation of the Storage Complex, CO2 Stream Composition, Monitoring and Corrective Measures. In: Commission, E. (ed.). European Commission.

level of uncertainty with regards to the probability of leakage and the likelihood effects that a potential leakage may entail. Furthermore, the pessimistic end of severity and probability of occurrence scale have to be taken into account in order to ensure avoidable leakages of CO_2 from the storage reservoirs do not occur.

On the other hand however, one has to make sure that they avoid being biased when analysing and assessing the risks. Moreover, the risks have to be managed and downgraded effectively as more knowledge about particular CO_2 storage sites becomes available and uncertainties are reduced.

2.2 Addressing Risks in EU Commission Guidance Document 4 (GD4)

By virtue of the inclusion of geological storage sites under Annex I of the Emissions Trading Directive, installations will be required to surrender allowances for any emissions from the site (including leakage) as calculated pursuant to the Monitoring and Reporting Guidelines for CCS. The amount of the Financial Security for this obligation can be based on the potential total tons of emissions, including due to leakage(s), multiplied by the market cost of purchasing an equivalent amount of allowances. This calculation will require estimates for the total tons of emissions that may be released (including due to leakage(s)), the timing of emissions, and cost of allowances when releases occur.

It is worth noting that European Commission's GD4 has exercised language that specifically did not recommend the determination of Financial Security (FS) (for the surrender of allowances due to leakages) by multiplying the estimated amount of funds by the probability that the scenario occurs. Now, a "realistic and appropriate middle ground scenario taking into account of all available evidence of the site-specific risk profile is used" is recommended. In addition, GD4 contains a method for the "calculation of the potential leakage amount based on a probability distribution of the amount of leakage from the storage complex" where "there is a proposed use of probability distribution for determining the size of a leakage (not the probability that it will occur)". Furthermore, it gives regulators the choice of choosing a risk percentile for the size of the leakage to be used instead as an estimate, instead of an inflexible 25% default contingency for FS. Furthermore, there is specific mention of the fact that FS amounts may now be updated "in case of leakage or significant irregularities, or where the monitoring plan is updated pursuant to Annex II of the CCS Directive". For example, in the UK, the Environment Agency adds a contingency of about 40-50% in determining the minimum amount of the FS for trans-frontier movements of hazardous waste (European Parliament, 2011d).[11] Owing to the fact that there is little experience in the field of geological storage of CO_2, GD4 suggests for the storage site operators to estimate the said amount of FS based on the following:

A conservative estimate of the maximum portion of CO_2 that can be leaked from storage sites, which in most scenarios would be less than 100%;

A calculation of the potential leakage amount based on a probability distribution of the amount of leakage from the storage site taking into account the geological characteristics of the site, facility design, monitoring programme and statistical modelling (European Parliament, 2011d).[12]

2.3 An Industry View of EU Commission CCS Guidance Document 4 (GD4)

Financial Security and Contribution Articles are of particular concern. Guidance interpreted as requiring uncapped, uncertain liability which would be a major barrier to industry participation. Provision of security for worst case scenario as well as 25% contingency would make operator risk entirely disproportionate especially as the Competent Authority (CA) would have already assessed the operator as being fit and proper as well as commented on the suitability of the proposed storage site as part of the permitting process. They propose required security and additional contingency measures to be assessed on a site-by-site basis. Also highlighted is the need to distinguish liabilities between the demonstration and commercialization phases as demonstration projects will be facing first-of-a-kind issues.

Probabilistic risk management is already being used in evaluating energy sector technologies by both industry and government. Furthermore, any risk to the CA would be spread to many storage sites; therefore having a financial security based on worst case scenario for each storage site is disproportionate to the risk. Alternatively, arrangements can be made that would take into account risk exposure and each storage site operator would pay a risk adjusted payment based on storage site assessment. Money would go into a central fund held by CA.

Propose that if Member State has issued a permit to the operator, assume that there is very low risk of that site leaking (issues of oil wells past and access to information is made public).

Inclusion of storage sites within ETS exposes

[11] European Parliament 2011d. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 4 (GD4): Financial Security and Financial Mechanism. In: European Commission (ed.). *Official Journal of the European Union*: European Commission.

[12] European Parliament 2011d. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 4 (GD4): Financial Security and Financial Mechanism. In: European Commission (ed.). *Official Journal of the European Union*: European Commission.

CCS Risk Analysis Mechanisms

storage site operator to further significant financial risk. In the event of leakage, submit allowances for CO_2 leaked. However, the ability of operator to hedge the exposure to allowance price volatility is significantly limited. A reasonable suggested compromise would be for the operator and the competent authority to agree to a shared risk profile, perhaps through an insurance mechanism which would allow risk exposure to be capped for operator. Examples of this can be seen in current proposals in the UK for capping risk of nuclear risk management where the CA is proposing the fixing of a fee in advance that includes a risk premium, but ultimately caps the exposure for operators. As currently drafted, GD4 could require the operator to make an accounting provision equivalent to value of stored CO_2. This would be a significant uncertain liability for the operator and would discourage investment. Furthermore, the financial strength of operator should be taken into account when agreeing an acceptable method such that greater financial strength should provide greater latitude to the operator.

2.4 Proposed Risk Analysis Mechanism

The risk ranking section within the risk analysis method used in GD1 will not be able to act as the optimum solution in real life CCS projects since its outcome only states whether a risk is significant or insignificant. On the other hand, not only the risk ranking techniques used in this research enable CCS stakeholders to assess the significance of risks, they also enable them to determine the extent to which the risks are significant or insignificant in comparison to each other. Therefore, the techniques use in this paper enable storage site operators to assess the probability of occurrence of risks having studied the significance of them in comparison to each other and decide accordingly. In other words, CCS GD1 is only able to determine storage site operators' decisions based on absolute values, i.e. significant or insignificant. On the other hand however, the proposed techniques assist storage site operators in decision making when it comes to dealing with uncertainty and choosing the optimum decision. Moreover, the methods work in conjunction with each other in order to calculate the significance and likelihood of occurrence of the risks of leakage or hazards that may prevent complete and permanent containment of CO_2 in storage reservoirs in comparison with each other. After this, it is the storage site operators' responsibility to make decisions based on the specific location of the storage site, local population density, the nature of the biosphere, atmospheric dispersal and whether the site is onshore or offshore (European Parliament, 2011c).[13] The composition of the CO_2 stream should also be taken into consideration (see Chapter 3 of EU Commission's Guidance Document 2 (GD2) for more discussion).[14]

The GD1 recommends making use of focus groups and brainstorming sessions amongst a group of participants in order to assess the probability, likelihood and potential impact of the risks. It further states that, in order to avoid bias, the participants should be chosen from experts that have detailed knowledge of the particular CCS project in question as well as participants who are not viewed as experts in the CCS technology. This is sensible.

Hence, similar to the GD1 risk assessment method, this research also made use of expert opinion in order to perform the risk analysis techniques. However, this research project has only relied upon opinions of national and international experts in the field of geological storage of CO_2. Equally, it has mathematically devised a risk rating system that also takes into account uncertainty by performing sensitivity analysis.

Two quantitative methods were used in this research, Analytical Hierarchy Process (AHP) and Fuzzy AHP (FAHP) in order to analyse the importance and criticality of the risks associated with the storage of CO_2 in underground storage reservoirs. The said techniques produced a series of rankings for the risks of CO_2 through the cap rock of the storage reservoir.

The AHP method was used since it is a useful and effective way to prioritise between a set of alternatives taking into account certain criteria in addition to its sophisticated but yet relatively easy nature.

Moreover, the Fuzzy AHP method was used in order to overcome the fact that human judgements are commonly imprecise, subjective and ambiguous, by calculating the importance and criticality of the risks associated with CO_2 storage through fuzzifying the pair-wise comparison matrices that were used as part of the AHP method. The results of which can be seen in Table 1.

Table 1: Calculated resutls using the AHP and FAHP methods

Alternatives	**AHP**	**FAHP**
Percolation of CO_2 through the caprock	0.125	0.036
Migration of CO_2 along a fracture or permeable zone	0.108	0
Leakage of CO_2 through or along the injection well	0.378	0.502
Leakage of CO_2 through other wells	0.389	0.461

[13] European Parliament 2011c. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 3 (GD3): Criteria for Transfer of Responsibility to the Competent Authority. In: Commission, E. (ed.). *Official Journal of the European Union*: European Commission.

[14] European Parliament 2011b. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 2 (GD2): Characterisation of the Storage Complex, CO_2 Stream Composition, Monitoring and Corrective Measures. In: Commission, E. (ed.). European Commission.

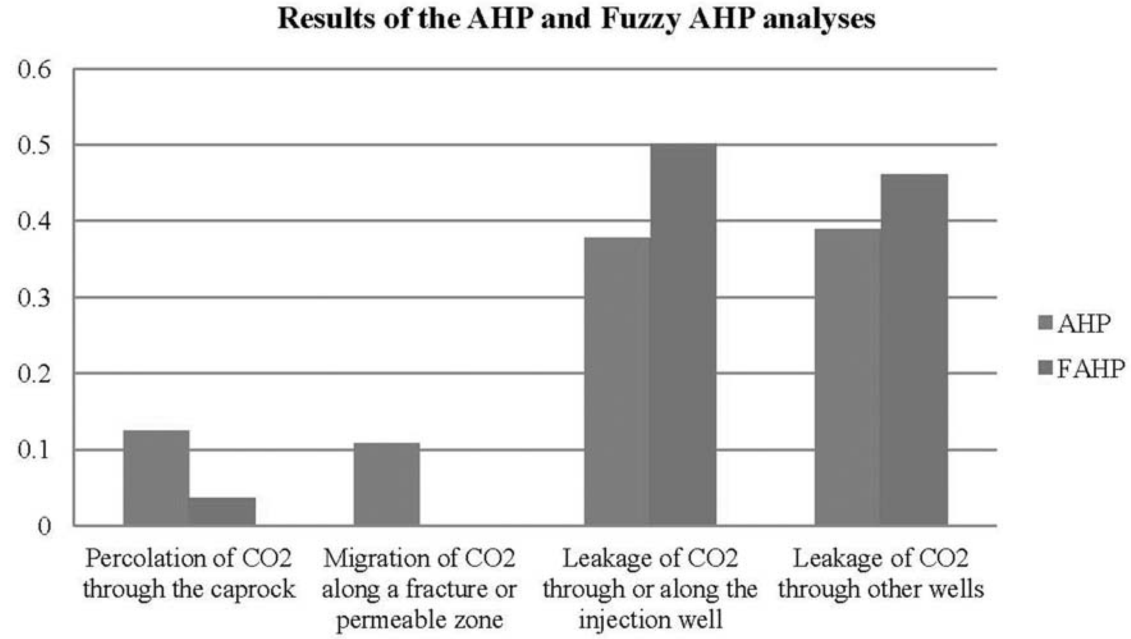

Figure 2: Comparison of results of the AHP and FAHP methods

As seen in table, the AHP and FAHP methods produced very similar results. Furthermore, using the AHP method resulted in the following ranking. The “leakage of CO_2 through other wells” was ranked first, “leakage of CO_2 through or along the injection well” was ranked second, “percolation of CO_2 through the caprock” was ranked third and finally the “migration of CO_2 along a fracture or permeable zone” was ranked as the least important risk associated with CO_2 storage. On the other hand, results of the FAHP method suggests “Leakage of CO_2 through or along the injection well” is ranked above the “Leakage of CO_2 through other wells” in terms of importance, criticality and likelihood of occurrence.

As shown in Figure 2, this suggests that these two risks are as important as each other and have to be taken into account equally when storage site operators and insurance companies are analysing the risks of CO_2 leakage from storage sites.

In order to test the robustness of the AHP and AHP Fuzzy methods used in this research and to see whether or not the obtained ranking of the risks would change when different methods are used two other systems engineering optimisation techniques were used, TOPSIS and PROMETHEE. The legal community would benefit from knowing that TOPSIS is a multi-criteria decision making method developed by Hwang and Yoon in 1981 which is used on a large scale .[15] The method was further developed by Yoon in 1987[16] and Hwang, Lai and Liu in 1993[17].

Gumus describes TOPSIS as an approach for dealing with complex systems related to making a preferred choice amongst several alternatives and which provides a comparison of the considered options (Gumus, 2009). TOPSIS is based on a simple and intuitive concept; it enables consistent and systematic criteria, which is based on choosing the best alternative having the shortest distance from the positive ideal solution and the furthest distance from the negative ideal solution.[18]

Furthermore, in the case of the CO_2 storage technology, the negative ideal solution would be the leakage of CO_2 from underground storage reservoirs and the positive ideal solution would be containment of CO_2 underground.

Additionally, the legal community would also benefit from knowing that PROMETHEE method is based on mathematics and sociology.

The PROMETHEE method has been used extensively in a wide range of topics ranging from Environmental Management, Hydrology and Water Management, Business and Financial Management, Chemistry, Logistics and Transportation, Energy Management to Medicine, Agriculture and Education.

[15] Hwang, C. L. & Yoon, K. 1981. *Multiple Attribute Decision Making – Methods and Applications,* Berlin-Heidelberg, Springer-Verlag.

[16] Yoon, K. 1987. A reconciliation among discrete compromise situations. *Journal of Operational Research Society,* 38, 277-286.

[17] Hwang, C. L., Lai, Y. J. & Liu, T. Y. 1993. A new approach for multiple objective decision making. *Computers and Operational Research,* 20, 889-899.

[18] Joshi, R., Banwet, D. K. & Shankar, R. 2011. A Delphi-AHP-TOPSIS based benchmarking framework for performance improvement of a cold chain. *Expert Systems with Applications,* 38, 10170-10182.

CCS Risk Analysis Mechanisms

Table 2: Numerical value that each MCDM method calculated for the risks associated with CO_2 storage.

Alternatives	**AHP**	**TOPSIS**	**PROMEHTEE**	**FAHP**
Percolation of CO_2 through the caprock	0.125	0.203	–0.249	0.036
Migration of CO_2 along a fracture or permeable zone	0.108	0.116	–0.302	0
Leakage of CO_2 through or along the injection well	0.378	0.67	0.261	0.502
Leakage of CO_2 through other wells	0.389	0.676	0.289	0.461

Table 3: Ranking of risks of CO_2 storage using different MCDM methods

Alternatives	**AHP**	**TOPSIS**	**PROMEHTEE**	**FAHP**
Percolation of CO_2 through the caprock	3	3	3	3
Migration of CO_2 along a fracture or permeable zone	4	4	4	4
Leakage of CO_2 through or along the injection well	2	2	2	1
Leakage of CO_2 through other wells	1	1	1	2

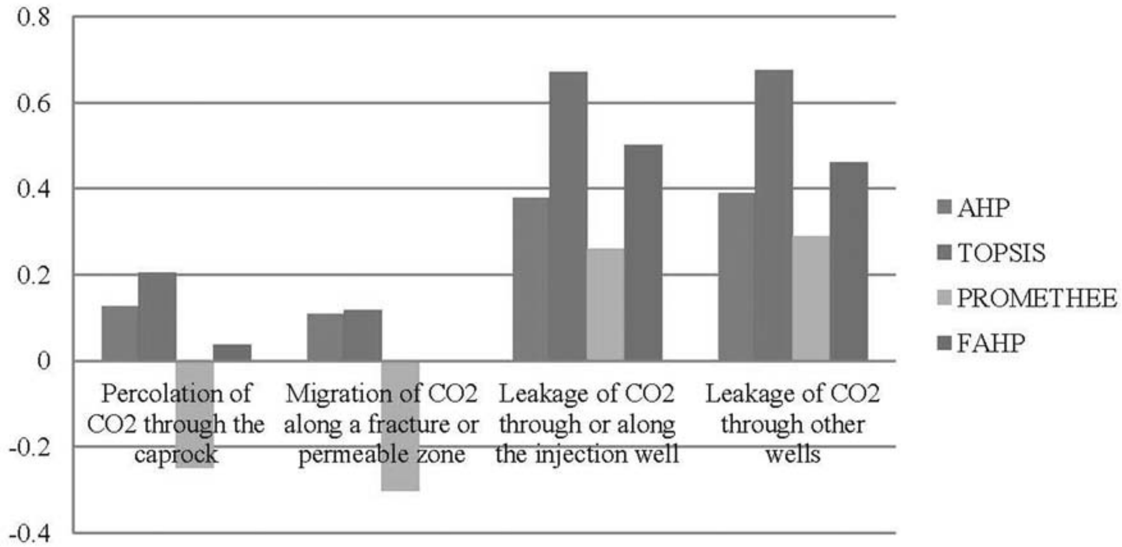

Figure 3: Comparison of results of AHP, TOPSIS, PROMETHEE and FAHP methods

This technique, which is a type multi-criteria decision making technique, helps decision makers find an alternative solution that best suits their respective projects as oppose to providing them with one solution. One of the main advantages of this technique is that it can be used when the important elements of the decision are difficult to quantify or compare.

According to Tables 2 and 3, the AHP, TOPSIS and PROMETHEE methods all produced the same ranking for the risk events. The "leakage of CO_2 through other wells" was ranked first, "leakage of CO_2 through or along the injection well" was ranked second, "percolation of CO_2 through the caprock" was ranked third and finally the "migration of CO_2 along a fracture or permeable zone" was ranked as the least important risk associated with CO_2 storage. Therefore, it was concluded that the AHP method is a useful and robust method in analysing the risks associated with the underground storage of CO_2.

Having looked at the quantitative outputs shown in Table 3, it was realized that the performance values are such that establishing a solid rank between some alternatives is challenging as simple changes in the input information can potentially change the rankings. For example, the performance values of "Leakage of CO_2 through or along the injection well" and "Leakage of CO_2 through other wells" were very close to each other which can be shown by undertaking sensitivity analysis. Therefore, the said matter was another reason for using the Fuzzy AHP method in this research in order to inspect whether or not the results of the AHP method would vary with little variation in the input parameters.

Furthermore, using the Fuzzy version of the AHP method, it was inspected that the order of importance and significance of the said two risk elements changed. Figure 2 further illustrates this matter by showing that the said two alternatives are not that different in performance. This is why the FAHP results are slightly different to the AHP results.

Therefore, it is concluded that "Leakage of CO_2 through the injection well" and "Leakage of CO_2

through other wells" are more important than other risks. However, it is difficult to say with certainty as to which one of the said two risks are more important in comparison to one another. Therefore, it was further concluded that the said two risks is potentially as important as each other and have to be taken into account equally when analysing the risk of leakage associated with CO_2 storage.

III. Conclusion

In conclusion, such risk analysis methods enable the storage site operators to focus on the weak points within the storage site, rank them in accordance to their importance and criticality towards the leakage of CO_2, evaluate how these weak points can be properly tested and addressed if need be. Furthermore, this will enable the insurance industry and regulators to understand the risks associated with this industry as a whole more effectively and insure and regulate the storage sites more to the benefit of the CCS industry in order to incentivise the growth and implementation of this technology.

IV. Bibliography

Det Norske Veritas (DNV) 2010. Co2qualstore Report – Guideline for Selection, Characterization and Qualification of Sites and Projects for Geological Storage of CO2.

European Commission 2009. Directive 2009/31/EC of the European parliament and of the council of 23 April 2009 on the geological storage of carbon dioxide and amending council directive 85/337/EEC, European parliament and council directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and regulation (EC) no 1013/2006. In: Commission, E. (ed.). *Official Journal of the European Union*.

European Parliament 2011a. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 1 (GD1): CO2 Storage Life Cycle Risk Management Framework. In: Commission, E. (ed.). *Official Journal of the European Union*: European Commission.

European Parliament 2011b. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 2 (GD2): Characterisation of the Storage Complex, CO2 Stream Composition, Monitoring and Corrective Measures. In: Commission, E. (ed.). European Commission,.

European Parliament 2011c. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 3 (GD3): Criteria for Transfer of Responsibility to the Competent Authority. In: Commission, E. (ed.). *Official Journal of the European Union*: European Commission.

European Parliament 2011d. Implementation of Directive 2009/31/EC on the Geological Storage of Carbon Dioxide Guidance Document 4 (GD4): Financial Security and Financial Mechanism. In: European Commission (ed.). *Official Journal of the European Union,*: European Commission,.

Gumus, A. T. 2009. Evaluation of hazardous waste transportation firms by using a two step fuzzy-AHP and TOPSIS methodology. *Expert Systems with Applications,* 36, 4067-4074.

Hwang, C. L., Lai, Y. J. & Liu, T. Y. 1993. A new approach for multiple objective decision making. *Computers and Operational Research,* 20, 889-899.

Hwang, C. L. & Yoon, K. 1981. *Multiple Attribute Decision Making – Methods and Applications,* Berlin-Heidelberg, Springer-Verlag.

Joshi, R., Banwet, D. K. & Shankar, R. 2011. A Delphi-AHP-TOPSIS based benchmarking framework for performance improvement of a cold chain. *Expert Systems with Applications,* 38, 10170-10182.

Yoon, K. 1987. A reconciliation among discrete compromise situations. *Journal of Operational Research Society,* 38, 277-286.