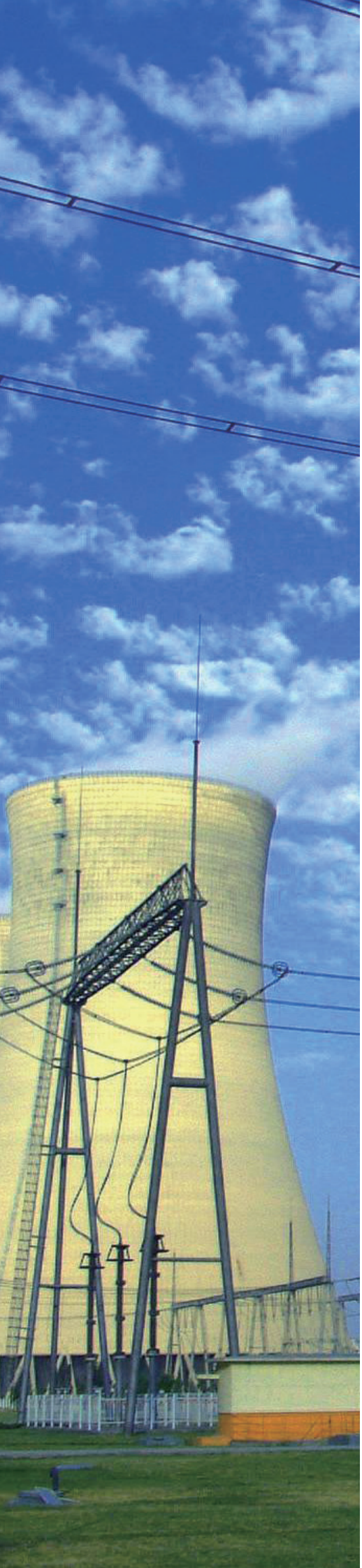

2014/D06

根据 DNV-RP-J203 对于广东省碳封存项目推荐方法

讨论待修改稿

Draft for Discussion and Further Revision

中英（广东）CCUS 中心
UK-China (Guangdong) CCUS Centre

CCUS

中英（广东）CCUS 中心
UK-China (Guangdong) CCUS Centre

2009 年，中国国务院提出 2020 年温室气体排放行动目标，并在 2010 年把广东省列为低碳试点省份。英国能源与气候变化部与广东省发展及改革委员会在广东省省长朱小丹的见证下于 2013 年 9 月在伦敦签订了推动低碳合作的联合声明，以深化双方合作，其中强调了开展碳捕集与封存（CCS）合作的重要性。2013 年 12 月 18 日中英（广东）碳捕集，利用与封存产业促进与学术交流中心，即中英（广东）CCUS 中心正式成立。中心致力于推动大型 CCUS 项目的示范，应对人类面临的温室气体排放的挑战，为中国面对的雾霾、水污染的问题提供国际合作平台，催化清洁化石能源技术产业化，以及培养相关专业人才。

In 2009, China's State Council proposed its 2020 goal for greenhouse gas emissions, and then in 2010 made Guangdong a low carbon pilot province. Guangdong has made remarkable achievements in greenhouse gas emission control to which the UK-China low carbon cooperation has contributed significantly. In September 2013 the UK Department of Energy and Climate Change (DECC) signed a joint statement in London with the Guangdong Development and Reform Commission, witnessed by governor Zhu Xiaodan of Guangdong Province, to strengthen low carbon cooperation. The joint statement highlights the importance of collaborating in Carbon Capture and Storage (CCS).

Supported by the Guangdong and UK governments, the UK-China (Guangdong) Carbon Capture, Utilisation and Storage Industry Promotion and Academic Collaboration Centre (the "Centre") was officially founded on December 18th, 2013. The Centre is committed to promoting the demonstration of large-scale CCUS projects to tackle greenhouse gas emissions. At the same time, the Centre will also provide an international collaboration platform for solutions to other local pollution problems (such as haze, water pollution) caused by coal utilization, and to accelerate the industrialization for clean fossil energy technologies and to train qualified professionals.

支持单位：
SUPPORTING INSTITUTES

广东省发展和改革委员会 · 英国驻广州总领事馆 · Scottish Enterprise · Department of Energy & Climate Change · The Scottish Government

中心发起机构：
FOUNDING MEMBERS

CEEDC 中国能建广东院 Energy China GEDI · UKCCS Research Centre · SCCS · 華潤電力 CR Power · CNOOC · 中国科学院南海海洋研究所 · linkschina 领先财讯 · Howden · ALSTOM · Shell Canada · DNV·GL · CIMC

致谢与声明

本报告由中科院南海研究所周蒂教授和李鹏春博士，DNV-GL 首席顾问 Mike Carpenter 先生，中英（广东）CCUS 中心秘书长、爱丁堡大学梁希副教授，爱丁堡大学博士生导师李佳，爱丁堡大学博士生舒宇彤女士共同编写。特别感谢周蒂教授和李鹏春博士对于广东省封存潜力评估所作出的努力。真诚的感谢 Mike Carpenter 先生对于 DNV 推荐方法 RP-J203 以及 DSS-402 内容的指导、中心与 DNV-GL 合作方式的提案、以及对于报告的修改意见。感谢挪威驻华大使馆的 Jock Brown 先生和 Harold Nordgaard 先生对于合作的支持。感谢英国驻广州总领馆 Neal Carling 先生和宰培女士对广东省碳减排工作的重视。感谢广东省发改委和爱丁堡大学对项目的支持。

舒宇彤[1]，周蒂[1,2]，李鹏春[1,2]，M.E. Carpenter[3]，梁希[1,4]，李佳[1,4]，

（1 爱丁堡大学，2 中科院南海研究，3DNV-GL，4 中英（广东）CCUS 中心）

Acknowledgements & Disclaimer

This report is jointly produced by Pro Di Zhou and Dr Pengchun Li from South China Sea Institute of Oceanology, Chinese Academy of Sciences, Mr Mike Carpenter, Principal Consultant of DNV-GL, Dr Xi Liang, Secretary General of UK-China (Guangdong) CCUS Centre and Senior Lecturer at the University of Edinburgh, Dr Jia Li, Lecturer at the University of Edinburgh, Ms Yutong Shu, PhD student at the University of Edinburgh. Special thanks to Pro Di Zhou and Dr Pengchun Li for their effort on storage potential assessment of Guangdong Province. Sincere gratitude goes to Mr Mike Carpenter for his instructions on RP-J203 and DSS-402, his collaboration proposal and his revision on this report. Thanks to Mr Jock Brown and Mr Nordgaard from Royal Norway Embassy for their support on collaboration. Thanks to Mr Neal Carling and Ms Adee Zai from British Consulate General in Guangzhou for their special attention on decarbonization. Finally, thanks to Guangdong Development and Reform Commission and the University of Edinburgh for their support.

Yutong Shu[1], Di Zhou[1,2], Pengchun Li[1,2], M.E. Carpenter[2], Xi Liang[1,3], Jia Li[1,4],
(1University of Edinburgh, 2South China Sea Institute of Oceanology, Chinese Academy of Sciences, 3DNV-GL, 4UK-China (Guangdong) CCUS Centre)

目 录

目录

目 录

Contents

Content

Contents

基于 DNV 推荐方法 J203 的广东二氧化碳封存推荐流程设计

Recommended practice for CO2 storage in Guangdong based on DNV-RP-J203

DNV 推荐方法 J203 是一套可以被广泛应用的指导方法，其中运用项目分段管理，资本价值管理的方法在二氧化碳封存项目前期阶段的应用。其应用方法在不同的项目开发者中有不同的应用方法，但是基本的风险管理方法，基本流程设计，降低不确定性的机制，配合预先决定的判断标准所用的阶段－端口基本方法是相同的。这个推荐指导方法在与大型的油气公司和能源企业合作项目中得到了进一步的发展。加拿大、美国、英国和澳大利亚的一些相关机构也参与进来进行监督，给予宝贵的建议。

DNV-RP-J203 的内容与其他二氧化碳封存的指导标准类似（例如加拿大的 CSA-Z741），指导标准在广东省的应用主要是为项目开发商提供一个能使各个参与方都适用的框架。阶段－端口流程设计和标准能够使重要的利益相关方在项目进行的每一步都有一个比较清楚的掌握，这样能够最大限度的规避金融上的风险。DNV 服务指导说明书 402（DSS-402）中介绍了一个服务案例，DNV 会在项目进行中的每一个关键步骤步进行检验核查保证其安全性。

在 DNV RP-J203 中，一个运用阶段－端口流程设计的二氧化碳封存项目被划分为 7 个阶段，其流程在图一中所示。阶段的范围和划分在运用在二氧化碳驱油项目中会有所不同， 但是因为驱油与封存项目通常是通过相同的上游行业来负责的，其主要的特点是通用的。但是封存和驱油的选择问题在筛选阶段应该根据发展规划进行调整。

DNV-RP-J203 is a generic guideline document that is designed to facilitate the alignment of CO2 storage projects with the stage-gate capital-value process that is used in the upstream sector. While differences do exist between major operators, the basic principles of financial risk management, iterative cycles of uncertainty reduction and stage-gates with pre-determined criteria are common. This guideline was developed through Joint Industry Projects with leading IOCs, NOCs and power utilities from around the world. Regulators from Canada, USA, UK and Australia were involved as observers, interviewees and through the process of peer review.

The content of DNV-RP-J203 is broadly similar to that of other guidelines and standards for CO2 storage (such as Canadian Standard CSA-Z741), but the major contribution that this document can make in Guangdong is by providing a peer-reviewed framework around the project development that makes sense to industrial partners. The stage-gates and criteria that are described in the document will allow key stakeholders to verify the progress and maturity of the CO2 storage project at each step and ensure that undue financial risk may be avoided. A model for this exists in the form of DNV Service Specification 402 (DSS-402), which describes the verification steps that can be applied at each key step.

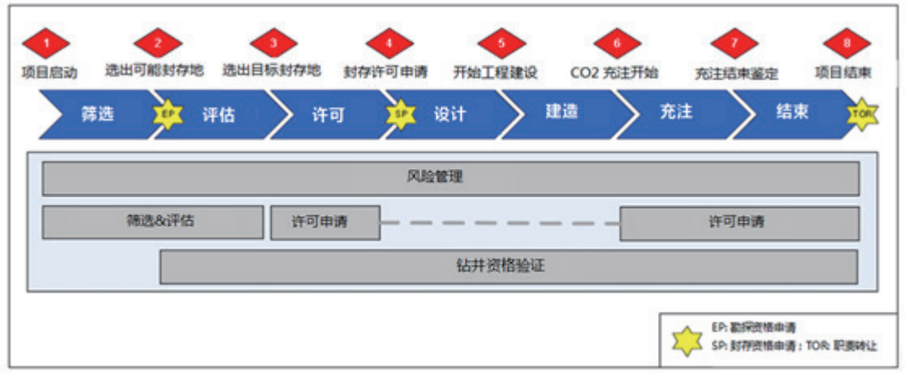

图 1：二氧化碳封存项目流程图（DNV RP-J203）

对于咸水层封存的封存地址的筛选和评估结果为阶段 4 的投资决定提供了技术支持。许可申请代表了规定和法律方面工作需要。当一个合适的封存地址被选择出来，得到封存许可以后，工程建设就可以正式启动了－或者是已有管道和海上平台的翻新整修和再利用。

本推荐方法给出的封存地址筛选、评估和许可申请的方法建议可以应用于广东省二氧化碳离岸封存项目中，其基本流程设计参照 DNV RP-J203。封存地筛选和选择过程中的所用的筛选标准是结合了国际能源署（2009）（温室气体研究与发展计划：碳捕集与封存标准），Bachu （2003）和 Chadwick （2008）的标准制定的。封存地封存能力的计算建议采用美国地质调查局（2009）（概率分析法评估封存地封存能力）。二氧化碳驱油地选择的技术标准建议采用 Pershad 等人（2012）和 Shen（2007）等人的二氧化碳性质标准。在评估阶段建议采用 CASSEM（咸水层封存地址选择以及监测）。排序阶段建议采用 Bachu（2003）提出的的封存地筛选排序框架，其中封存地各个特性和特质都会被赋予不同的权重和不确定等级，据此各可能封存地的总分可以计算出来进行分数排序。

来自中科院南海所的专家（周蒂教授和其团队）和爱丁堡大学的专家（Stuart Haszeldine 教授）已经完成了一部分的对于广东省近海地区碳封存潜力和二氧化碳驱油潜力的分析研究工作。Bill Senior 博士对于工作组给予了宝贵的建议并且审核了工作报告。

The generic stage-gate model that is used in DNV RP-J203 breaks down the life-cycle of a CO2 storage project into 7 phases, as shown in Figure 1. The scope of these phases will be different for CO2-EOR due to the operating experience of a greater a prior knowledge of an operating field, but since the basic stage-gated process originates from the upstream sector many features will remain the same. Indeed the Screening phase may be adapted to assist with Concept Selection during field development planning, for example aquifer storage vs. CO2-EOR.

For aquifer storage the site screening and appraisal phases represent the technical work required to be able to make a Final Investment Decision at Stage Gate 4. The Permitting phase represents the legal and regulatory work required.. It may take an estimated 3-10 years to conduct the pre-operation works together with commercial factors evaluations. Once the a suitable site is selected and permit is granted, infrastructure construction could can begin – or modification in the case of re-using existing pipelines or offshore platforms. In the hydrocarbon reservoirs, the some infrastructures in-place could be re-used.

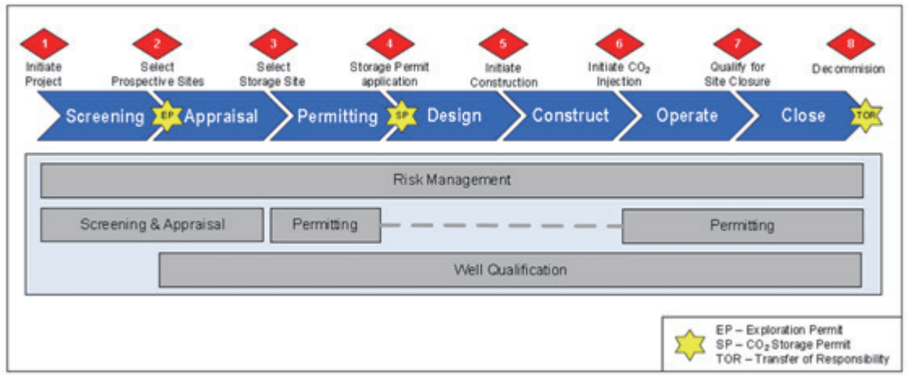

Figure 1: the life cycle diagram of a CO2 storage project (from DNV -RP-J203)

This recommended practice gives a suggestion on the workflow of site screening, and appraisal and permitting phases that may be applied to offshore CO2 storage activities in Guangdong. The basic workflow is based on the recommended procedure from DNV-RP-J203, with some modifications to make it more suitable for Guangdong off-shore CO2 storage. The screening and selection criteria is are athe combination of IEA (2009) (Green house R& D programme: CCS characterisation criteria), Bachu (2003) and Chadwick et al. (2008). The storage capacity calculation is from the calculation formulas given by USGS (2009) (Development of a Probabilistic Assessment Methodology for Evaluation of Carbon Dioxide Storage). The criteria for CO2-EOR is after Pershad et al. (2012), coupled with the CO2 property requirements according to Shen et al. (2007). The geotechnical requirements used in appraisal phase is from the the project of CASSEM (CO2 Aquifer Storage Site Evaluation and Monitoring). The sites ranking method is suggested to use Screening and Ranking Framework by Bachu (2003). In this method the properties of attributes are assigned with weight and uncertainty, so that a total score of can be calculated to enable ranking quantitatively.

Researchers from South China Sea Institute of Oceanology, Chinese Academy of Sciences (SCSIO) (Pro Zhou Di and her colleagues) and the University of Edinburgh (Pro Stuart Haszeldine) have done some work on CO2 storage and CO2-EOR potential for Guangdong near sea. Dr Bill Senior helped to give valuable recommendations and reviewed the reports.

1. 封存地筛选和评估
Site Screening and appraisal

1. 1 封存地筛选

根据中国广东省 CCS 预留预可研最终报告 2- 中国广东省二氧化碳封存潜力评估，基本的储存地筛选工作已经完成。广东省陆上封存的可能性非常小，但是离岸封存的可能性还是很大的，其中最有可能性的是珠江口盆地。经过比较分析，珠江口盆地的陆丰 2-1 咸水层和惠州 21-1 油田被认为是最有可能的二氧化碳封存地。惠丰 21-1 油田的开发能力已经接近极限，上覆良好盖层，有现有的海上平台和油井有可能被再利用，距离二氧化碳源海丰电厂 170km，但是油田的封存能力较小需要利用旁边的咸水层；陆丰 2-1 干构造有较大的二氧化碳封存容量（>300Mt），距离海丰电厂距离仅 120km，但是现有的钻井资料有限还需要深入研究。在附录 1 中给出了地址选择阶段推荐使用的技术标准。

出于经济性的考虑，二氧化碳驱油的可能性在这个阶段也要被考虑进去。附录 2 中给出了 EOR 地址的选择标准。二氧化碳珠江口盆地离岸封存已经被认为是广东 CCUS 链中必要的一环。因此研究小组也对于广东省二氧化碳驱油的可能性做了初期的研究。结果显示一个可能运用此技术的油田是最大的 LH11-1 油田。需要对于油田有更深入的了解需要更多的数据资料支撑。

1. 2 不确定性评价

在项目的下一个阶段应该对于符合条件的不确定性进行评级。数据的可靠性需要被评估。不确定性等级与方法的不确定性和数据的精度有关。

1.1 Storage Site Screening

According to the Pre-Feasibility Study of CCS-Readiness in Guangdong Province, China (GDCCSR) Final Report: Part 2 (Assessment of CO2 Storage Potential for Guangdong Province, China) the basic site screening has been completed. There is little potential for onshore CO2 storage, but for the potential for offshore carbon storage is promising. The most favorable basin is Pearl Mouth River Basin. The objective for site screening is to evaluate the storage potential of sites in Pearl River Mouth Basin. The result of the site screening and selection is, the most favorable storage sites are Lufeng 2-1 saline aquifer and Huizhou 21-1 oil field. Oil production of Huizhou 21-1 is approaching the limit. The reservoir is covered by seal with good quality, and the existing infrastructures might be re-used. The proximity from the site to Haifeng Power Plant is only 170km. The major barrier is the storage capacity of the oil field is quite small. The saline aquifer should be used. Lufeng 2-1 dry structure has large capacity (>300Mt). The distance from Haifeng is only 120km. But only very limited data are available so far. The suggested geotechnical criteria for site screening and selection are compiled in Annex 1.

For economic reasons, the potential for CO2-EOR should also be taken into account in the phase. The criteria for EOR is given in Annex 2. Offshore CO2 storage in the Pearl River Mouth Basin has been identified as a necessary component of the CCUS chain in Guangdong Province.

1. 封存容量的不确定性：推荐使用美国地质调查局（2009）的容量计算公式在附录 3 中给出。

2. 储层可充注性的不确定性：不确定性取决于储层的渗透性。

3. 封存密闭性的不确定性：通常上部盖层的数据相比储层数据更难取得。但是盖层岩石的性质对于衡量封存安全性非常重要。圈闭类型、深度、盖层厚度、覆盖范围、一致性、断层位移等性质都需要被评估从而得到一个对于圈闭安全性的全面的衡量。研究盖层安全性的方法主要有三种：

a. 天然类比法：天然类比是一种很有效的研究 CO2 大量、永久（地质时间）封存的方法。但是有时不是很容易找到目标储存地的有效天然类比。

b. 实验室研究可以得到有效的数据，但是实验结果在实际的工程中应用的可靠性值得怀疑，因为实验结果的时间标尺有限。

c. 数学建模法可以应用于大范围、长时间的地质封存的模拟。但是所选用模型对于目标封存地的可应用性应该先进行检验。

1. 3 风险评价

最初风险认证的方法应该被应用于每一个步骤的对比，并且进行独立的审计和检验。建议使用电子风险数据库的方法来跟踪风险随时间和项目进展的变化。在数据库中，开发者的行为和责任应该被明确的记录。

在封存地筛选阶段结束的时候，项目实施者应该在进行下一步的计划之前完成封存地不确定性检验结果和风险评估结果的报告。一个可能封存地的名单和相关的风险评估报告应该被给出。RP-J203 给出了一个项目筛选阶段结束的检查清单（见 DNV RP-J203 的 17 页）。给出的筛选报告是 DNV 进行项目可行性资格证明的依据。这项证明是说明了封存地在理论上进行封存的可行性，并且值得进行下一步的研究和资格检验。此外，DNV 会对于筛选步骤的检验给出一个独立的报告。

A preliminary study on CO2-EOR potential in Guangdong has been assessed. A possible opportunity of CO2-EOR in the PRMB might exist in the largest field LH11-1. More data is needed for more detailed study.

1.2 Uncertainty assessment

In the next step of the project, the level of uncertainties that meeting the requirements is suggested to be evaluated. The integrity of data will also be identified. The level of uncertainties relate to the uncertainties and resolution of the data, and the selected method.

1. Uncertainty of capacity: recommended volumetric formulas for discovered traps by USGS (2009) (Annex 3).

2. Uncertainty of reservoir injectivity: the uncertainty depends on the reservoir permeability.

3. Uncertainty of the containment: the data of the caprocks are more difficult to get than the reservoirs. However, the property of caprock is crucial to assess to security of the storage. The trapping type, depth, thickness, rock properties, extent, uniformity, faults displacement, etc. will be assessed to make an overall evaluation of the security of containment. Three possible ways are suggested to be used to assess the safety of caprock:

a.Natural analogues: natural analogue is a very useful way to study the behavior of CO2 in long-term fate (geological timescale) and large spatial scale. But it might not be easy to find a natural analogues to the picked sites.

b.The laboratory measurement could be used to get data, but the time-scale is limited.

c.Numerical models could cover wide range of spatial and time scales, but the verifications and feasibility of each model should be done before.

1. 4 评估

在这一阶段需要对可能的封存地的封存能力、可充注性和圈闭性和钻井工程都需要做详细的分析和评估。

1. 4. 1 评估依据

评估的依据包括了附录 4 中所列出的要求。除此之外，封存地的封存许可申请，钻井的再利用和其他设施的应用应该在评估依据中列出。项目的施工方应该与项目相关的开发者进行咨询沟通，确保项目开发的各方都能了解评估各项标准。

1. 4. 2 评估计划

1. 评估计划包括了技术评估计划，沟通计划，设施再利用计划和成本核算计划几部分。

2. 技术评估计划中应该包括了可能封存地址的特征描述和模型。这些都为之后的特性描述和钻井工程提供了技术基础。

3. 沟通计划的目的是描述作为项目施工方如何能和相关参与单位有效的沟通。

4. 设施再利用计划：建造新设施的成本是很贵的。运用已有的钻井平台和管道的有可能会大幅度降低成本。推荐方法 J203 中并没有包含这样一个评估计划，但是作者认为如果一个封存地现有的油气田开采设施可以再利用与二氧化碳封存，这可能会成为一个封存地备选的优势。设施再利用计划中建议包括现有设施的评估方法，可再利用设施的翻新和与设施所有方沟通计划，以及现有设备不能再利用情况下的措施。

5. 成本预算计划也没有包括在 J203 中，但是作者认为预算成本可以影响到后面的封存地排序。在这个成本计算计划中建议列出成本计算的方法。欧盟零排放平台 ZEP（2011）利用“自下而上”的

1.3 Risk assessment

The initial risk register should be used for comparison in the following selection step and should be suitable for independent audit and verification. An electronic risk database is recommended to be used to keep track of the changes overtime. The actions and responsibilities should be identified in the database.

At the end of site screening stage, Uncertainty assessment findings and Risk assessment findings shall be finished and reviewed before proceeding to the next stage. A list of prospective storage sites and the related risks are assessed. A checklist is given by RP-J203 to ensure the completeness of the screening stage (See Page 17 in DNV RP-J203). The Screening report is the basis for DNV's Statement of feasibility Certification to confirm the storage sites conceptually feasible and thereby suited for further development and qualification according to DNV RP-J203. Verification of the screening process shall include an independent review by DNV of the Screening Report.

1.4 Appraisal

At this stage, the assessment of the prospective storage sites that provides the required capacity, injectivity and containment in detail and develop a well engineering concept are required.

1.4.1 Appraisal basis

Appraisal basis should include the requirements listed in Annex 4. Besides, how to get the permits of storage, re-use of well logs and other infrastructures, and how to communicate with other commercial activities in the same region should be mentioned. The operator should consult with any involvements that related to this project to ensure that all the requirements are understood and accounted for.

方法给出了成本计算和成本组分敏感度的计算方法。其他成本估算的方法也同样应该被评估，并找出一种最适合广东碳封存成本计算的方法。

1. 5 封存地特性描述和建模

上一步的评估计划在这个阶段将进行实践，可能的封存地将会被进行特性研究。需要取得新的数据和信息来增进对于储存地储层、封闭性、圈闭机制和封存容量等内容会有更详细的了解。所需的新的数据和信息包括充注区域的等厚线图，地震剖面图，毛细管压力数据、断层和褶皱的信息，破裂压力，封存地的动态容量，天然类比情况等（详见附录4）

这个阶段末建议给出一个编辑整合各类模型的报告。这个报告可以为之后的封存风险评估和钻井工程设计提供重要参考。

1. 6 风险评价

建议在更详细的特性描述和建模之后同样要完成一个风险分析的评估报告。评估报告的结果可以作为封存地的筛选评估阶段完成情况和封存地资格验证的依据。

1. 7 评估回顾与封存地排序

对真个封存地评估过程的回顾可以确保评估步骤的完整性。由于新数据的获得和建立模型得到的新信息，地址筛选期间的早期数据应该被即使更新。

对于 多于一个的备选封存地址，DNV 根据 4 个不同的方面对于封存地进行了排序：健康、安全和环境影响，成本，进度安排，封存表现。对于封存地的健康、安全性和环境影响的排序，Bachu（2003）给出了筛选和排序框架建议，这个框架建议运用了给封存地特性对于封存能力打分和数据可靠性评级最后计算总分排序的方法最后可以得到一个潜在封存地的排序。这个方法在神华（2013）CCS 项目中得到了应用。

1.4.2 Appraisal plan

Technical appraisal plan, communication appraisal plan, infrastructure re-usage appraisal and cost estimation appraisal plan will be included.

1. echnical appraisal plan:
Storage site characterization and modelling activities will be performed for each prospective storage site in order to provide the technical basis for the storage site characterization and well engineering activities.

2. Appraisal communication plan
The Appraisal Communication Plan will describe how the operator intends to communicate with the relevant participants.

3. Infrastructure re-usage appraisal plan
It is quite expensive to build new infrastructures off-shore. It would be much cheaper to use the existing platform and pipelines. This plan is not included in guidelines of RP-J203, but author believes the available of infrastructures would be a strong advantage of a site. The appraisal plan shall include the ways to evaluate the existing infrastructures, the retrofit of the existing infrastructures and how to communicate with the owners and how to collaborate with them if the infrastructures can be reused, and the solutions if the infrastructures cannot be used.

4. Cost estimation plan
This plan is not included in RP-J203 as well, but the author believes the cost of the sites should be estimated, and the factors should constitute as a criterion in site ranking. The cost estimation methods will be illustrated in the plan. ZEP (2011) gives “bottom-up” cost estimation approach based on potentially cost components. Some other cost estimation models should also be assessed to find a most suitable way to calculate storage projects in Guangdong.

1. 8 钻井工程

这个阶段的目的是找出对于潜在封存地最合适的新井和已有钻井的工程解决方法。解决方法需要同时兼顾经济性和可实现性。

1. 9 监测和风险管理

在这个阶段建议给出初期的检测和风险管理计划。

1. 初期的监测计划应该对可能的风险做出鉴定和评估。

2. 初期的风险管理计划应该确定检测目标，技术要求，技术和检测的步骤等。

3. 在本阶段完成时应该得到一个可能封存地的排名，钻井工程解决方案，初期的风险管理和检测计划。包括了以下一些阶段性文件和报告。

- 评估依据
- 评估计划
- 特性研究报告
- 模型研究报告
- 风险分析评估报告
- 评估过程总结回顾
- 钻井工程
- 初期风险管理计划
- 初期检测计划
- 评估依据和计划评价

评估报告是 DNV 授予认可声明证书的依据。证书确认了被选封存地和钻井工程概念符合了可以充注要求容量的二氧化碳，并且封存地可以实现永久封存。DNV 会对于评估报告进行独立的检验。

1.5 Site Characterization and modeling

The appraisal plans are preformed in this part to characterize the prospective storage sites. The acquisition and analysis of new data will enhance the understandings of storage sites. The characteristics of reservoirs, confining zones, trapping mechanisms and storage capacity shall be enhanced with more detailed information such as isopach maps of injection zone, seismic of cross-section, capillary pressure data, faulting and folding, fracture pressure, dynamic storage capacity, natural analogues information (see Annex 4).

At the end of this stage, a compilation of modeling report will be given to provide relevant input to the risk assessment and Well Engineering Concept.

1.6 Risk assessment

An appraisal risk assessment report shall be given. The findings shall be used to support decisions about the completeness of the appraisal stage and the qualification of storage sites.

1.7 Appraisal review and sites ranking

An appraisal review shall be given to ensure the completeness of the appraisal process. The iteration of data enhancement shall be done after the modeling.

For more than one prospective storage sites, DNV gives ranking guidelines in 4 consequence categories: Health, safety and environment (HSE), cost, schedule and storage performance. For HSE ranking, it is suggested to use screening and ranking framework (SRF) by Bachu (2003). The framework allows users to weight and assign uncertainty to the properties of the attributes of the basic characteristics to evaluate and rank two or more sites relative to each other. This ranking method was also successfully used in Shenhua (2013) project.

1.8 Well engineering

The purpose of this step is to identify the most appropriate well engineering solution for new and existing wells at each prospective storage site. The most economical and feasible well engineering solutions shall be found in this stage.

1.9 Monitoring and risk management

A preliminary monitoring and preliminary risk management plan shall be given in this stage.

The appraisal report is also the basis for DNV's Statement of endorsement certification to confirm the storage site and well engineering concept have the required characteristics for injecting the specified mass of CO2 over the specified duration of the project and storing it on a long-term basis. Verification of the Appraisal process shall include an independent review by DNV of the Appraisal Report.

1. Preliminary monitoring plan should be designed to manage the risks identified and assessed in the risk assessment stage.

2.Preliminary risk management plan shall describe the targets of the monitoring, the requirements of the technology performance, the technologies and monitoring procedures, etc.

3.At the end of appraisal stage, a ranking of potential storage sites, well engineering suggested solution, preliminary risk management and monitoring plans shall be given. Several reports should be given.

-Appraisal basis
-Appraisal Plan document
-Characterization Report
-Modeling Report
-Appraisal Risk Assessment Report
- Appraisal review document
- Well Engineering Concept document
-Preliminary Risk Management Plan
-Preliminary Monitoring Plan
-Evaluation against the Appraisal Basis and Appraisal Plan

2. 许可申请
Permitting

2. 1 许可背景和要求

申请新的封存许可的第一步是整理许可的背景和相关的要求。当封存许可过期的时候，或者当项目实施方想要转为他用（比如从二氧化碳驱油转为二氧化碳封存）的时候，也必须申请新的封存许可。几种不同的许可申请的步骤相似，对于转为他用的项目，需要着重指出转用的原因和规定的不同。

2. 2 风险处理绩效目标

第二步是项目实施者需要对封存做风险评级并且做出相应的风险处理计划。风险处理绩效目标应该和相应的许可申请背景和要求相对应。然后管理者和工程实施方应该就风险等级划分和风险处理是否有效进行讨论。如果认为风险划分或处理有问题，双方需要对问题进行修正直到意见达成一致。

2. 3 封存许可申请

这一阶段将完成一个封存发展计划。计划的内容将包括以下几个组成部分：

- 封存地特性分析报告
- 充注和施工计划
- 环境声明
- 封存表现预测
- 风险管理计划
- 检测计划
- 各方沟通计划
- 封存项目结束计划
- 成本计算和报告计划

2.1 Permit context and requirements

The first step for applying a new storage site is to document the permit context and relevant requirements. When the storage permit has expired, or the operator wants to transfer the usage of the site (e.g. from CO2-EOR to CO2 storage), a new permit is required. The basic procedure for different types of permits are similar, but for usage transfer needs special highlight on the rationale for the need of usage transfer and the differences of the regulatory frameworks.

2.2 Risk performance targets

In the second step, the operators should assess the level of risks, design the risk treatment plan. The risk performance targets should be relevant to the permit context and requirements. Then the regulators and operators should discuss about the risk level and whether the related treatment is sufficient; if not, the risk levels and treatment shall be modified until agreement is reached.

2.3 Storage permit application

Storage Development Plan shall be completed in this step. The content of the plan include the following components.

-a storage site Characterization Report
-an Injection and Operating Plan
-an Environmental Statement
-a Storage Performance Forecast
-a Risk Management Plan
-a Monitoring Plan
-a Communication Plan
-a storage site Closure Plan
-an Accounting and Reporting Plan

封存发展计划是 DNV 检验和认证的基础。DNV 会颁发一个适合封存认证来确认目标封存地的选择符合 DNV RP-J203 推荐方法，DNV 认为封存地址符合计划。对于评估过程的检验会通过对封存发展计划书的复审来完成。

项目结尾时需申请的停止许可。必须完成一个项目停止资格声明 ,其内容包括：

- 停止依据描述
- 封存停止的环境声明
- 封存地停止后的封存表现预测
- 封存停止后的监测计划
- 更新的封存停止计划

DNV 会根据声明颁布一个项目关闭合格认证 来确认项目停止。DNV 将会根据项目停止资格声明做独立的检验。

2. 4 完整性检验

在这一步，项目工程执行方和管理者需要对许可申请的完整性，目的性以及是否符合规定做核查。核查的依据是封存发展计划。如果申请程序没有完成，应该回到第三步重新分析风险等级和风险处理方案，如此循环直到双方意见达成一致。

2. 5 提交申请

工程执行方和管理者双方均认为申请材料的完整性的情况下，可以提交申请。

This plan is also the basis for DNV's verification and certification. DNV may issue a Certificate of Fitness for Storage to confirm that the Storage Development Plan for a specified storage site is in accordance with DNV RP-J203 and that DNV considers the storage site as fit for service subject to the constraints of the Plan. Verification of the Appraisal process shall include an independent review by DNV of the Storage Development Plan.

A project closure permit shall be applied when the operation is getting close to the end. The application should be in form of Closure Qualification Statement. The following components shall be included in the statement:

-a description of the Closure Basis
-an Environmental Statement for storage site closure
-a Storage Performance Forecast for storage site closure
-a Monitoring Plan for storage site closure
-an Updated Closure Plan

Based on this statement, DNV may issue a Certificate of Conformity (Closure) to confirm the fitness for closure. Verification of the closure process shall include an independent review by DNV of the Closure Qualification Statement.

2.4 Verify the completeness

In this step, operators and regulations should check the completeness of the permit application, fit for purpose and in compliance with regulations. The basis is storage development plan. If the application is not completed, the risk levels and treatments should be re-assessed (go back to step 3) and do iteration until agreement is reached.

2.5 Submit the application

If the application is believed to be completed by operators and regulators, the permit application could be submitted.

3. 钻井资格验证
Well qualification

钻井资格验证过程需要与项目同时进行，从封存地评估开始一直到项目停止结束。其目的是确保当二氧化碳注入后钻井能够正常工作。推荐方法 J203 中给出的验证流程可以应用于废弃井、工作井和设计新钻井中。主要的验证工作包括鉴定潜在风险，设计相关风险处理机制和监测方法。在工程钻井概念报告中，钻井资格验证的初期工作已经完成（其成果会作为封存地选择和排序的部分依据）。当初期的资格验证和修正完成后，正式的资格验证过程开始。分析结果需要与封存要求相对比。如果钻井资格验证的结果与要求相符，可以给出最后的资格验证报告；如果和要求不相符，需要回到钻井资格认证流程第一步开始重新分析。分析结果会体现在钻井资格验证报告里面。

项目执行方会记录每口钻井资格验证的结果在最终钻井分析报告书中。这个报告书将会成为封存发展计划的一个部分作为封存许可申请的依据。

DNV 推荐方法 J203 强调了在二氧化碳封存项目用钻井的资格验证的时候需要特别注意的一些问题：

- 碳钢的腐蚀和水泥的老化
- 合成橡胶（表现随时间变化）
- 低温二氧化碳作为制冷剂影响金属的韧性和合成橡胶的弹性
- 液态或超临界二氧化碳放气
- 钻井内环管理

Well qualification shall be implemented from the site appraisal stage to the project closure. The purpose is to make sure that a given well will function when exposed to the stored CO2. The process provided in RP-J203 could be applied to abandoned wells, active wells or the design of new wells. The major work is to identify the potential risks, design relevant risk treatment scheme and monitor activities. In well engineering concept report (appraisal stage), the initial well qualification report is completed (the result will compose the basis for storage site selection and ranking). When the initial qualification and modification is completed, the qualification activities could be commenced. The result of the assessment shall be compared with the requirements. If the result could meet with requirements, the final qualification report shall be given, otherwise the basis of the well qualification should be re-assessed and the whole well qualification process should start over. The result of the well qualification activities is a Well Qualification Report.

The operator shall document the well qualification findings for each well in a Final Well Qualification Report. This report shall be included in the Injection and Operating Plan (one component of Storage Development Plan) within the storage permit application.

DNV RP-J203 pointed the special considerations shall be included in risk identification in well qualification under exposure to CO2.

-Corrosion of carbon steel pipe and degradation of cement
-Elastomers (performance changes with time)
-CO2 as a refrigerant influences the toughness of metals and flexibility of elastomers
-Blow-down considerations
-Annulus management

4. 已经完成的广东近海二氧化碳封存报告

Completed reports for CO2 storage potential for Guangdong near sea

报告 1：中国广东省 CCS 预留可行性研究（GDCCSR）最终报告第二部分：中国广东省二氧化碳封存潜力分析

Report 1: Feasibility Study of CCS-Readiness in Guangdong Province, China (GDCCSR) Final Report: Part 2 (Assessment of CO2 Storage Potential for Guangdong Province, China)

在这份报告利用已有的数据资料（公开资料）分析了广东省陆上盆地的封存容量（三水盆地）和离岸封存容量（珠江口盆地，北部湾盆地，琼东南盆地，莺歌海盆地）。可以得到以下结论：

– 中国东南部地区（广东，广西，福建，江西，海南）基本不存在陆上封存的可能性。因为陆上盆地面积小，分散，储层质量差，并且人口密度大。

– 广东省离岸封存有巨大的潜力：良好的储层 – 盖层匹配，远离内陆减少土地使用和饮用水污染的危险。离岸封存最大的问题在于高成本。一种可能的解决办法是利用已有的设施。

– 通过比较最适宜封存的是珠江口盆地。有效封存容量可以达到 77Gt 二氧化碳（85% 的概率）。

– 通过分析发现了一些 CCUS 一体化示范工程的早期机会。正在计划惠州沿海的一家的炼油厂中氢气制造每年会排放 3.2 Mt 二氧化碳。汕尾海丰电厂正在策划建设的 3，4 号机组每年排放二氧化碳达到 10Mt。

In this report, the effective storage capacity of CO2 in sedimentary basins onshore Guangdong (the Sanshui Basin) and offshore (the Pearl River Mouth Basin, Beibuwan Basin, Qiongdongnan Basin, and Yinggehai Basin) are assessed based on available geological data (published data). The conclusions are as follows:

- There is essentially no CO2 storage potential inland in South East China (Guangdong, Guangxi, Fujian, Jiangxi, Hainan). Because of the small, scattered basins with poor reservoir quality and big population.

- Guangdong offshore has promising CO2 storage capacity: high quality reservoir-seal couplet, less competition in land use and potable water and low environmental risks. The major barrier for offshore CO2 storage is the high cost. One way to reduce the cost is to use existing infrastructures.

- The most favorable storage area is the northern Pearl River Mouth Basin. The total effective capacity is 77Gt CO2 (at 85% probability) .

- An early opportunity for a full-chain CCUS demonstration project is identified. A planned oil refinery on the coast of the Huizhou city will emit 3.2 Mt/yr high-purity CO2 from H2 production. Under planned 3, 4 units of Haifeng power plant will emit 10 Mt/yr CO2.

报告 2：二氧化碳离岸运输与封存的工程要求：国际经验简介

Report 2: Engineering Requirements for Offshore CO2 Transportation and Storage: A Summary Based on International Experiences

本报告根据英国对 Kingthnorth 和 Longannet 项目的前端工程设计（FEED）报告，总结了二氧化碳运输与封存（尤其是离岸）的工程要求，讨论了相关的健康、安全和环境问题，列举和比较了关于二氧化碳运输与封存的成本估计。主要结论如下：

– 二氧化碳运输与封存的主要工程要求以及基础设施大部分可从于天然气运输与生产中移植过来，所需的改造相对较少

– 只要工程设计得当而且有操作规程的严格控制，二氧化碳运输与封存的健康、安全和环境（HSE）风险一般是可控的

– 目前对于二氧化碳运输与封存成本的估计值变化很大。

– 对于成本估计得到了一些意外的结论还需要进行进一步的研究：对海上封存成本，两个英国 FEED 项目的估计值比 ZEP（2011a）的高得多。将两个英国 FEED 项目的单位资本成本的估计值相比较，再利用现有天然气管道、平台和钻井的 Longannet 项目的成本不一定低于全部采用新建设施的 Kingsnorth 项目。

Released FEED documents of Kingsnorth and Longannet projects are reviewed to study the engineering requirements, the health, safety, and environmental issues, the cost estimates models for CO2 transport and storage offshore. The general conclusions are:

-The engineering requirements as well as infrastructure for CO2 transport and storage are mostly transferable from those for natural gas transport and production.

-The health, safety, and environmental issues in CO2 transport and storage are in general manageable with proper engineering design and strict operational regularity controls.

-The present cost estimates on CO2 transport and storage are highly dynamic and sensitive.

-Some unexpected outcomes remain to be explained for the cost estimates:
The estimates of offshore storage costs by ZEP (2011b) are much (11 to 30 times) smaller than those given by UK FEED studies for the Hewett and Goldeneye CO2 storage. Comparing the unit capital costs for the two UK FEED studies, the costs for the Longanett project, where legacy pipelines, platform and wells are used, are not all less than the costs for the Kingsnorth project using all new infrastructures.

报告 3：二氧化碳驱油及其在广东省近海的潜力

Report 3: CO2-EOR and its Potential Offshore Guangdong Province, China

这份报告回顾了二氧化碳驱油的概念，方式，方法和全球发展现状，也初步探讨了广东省海上珠江口盆地 CO2-EOR 的潜力。以下为主要讨论和结论：

总结结论如下：

In this paper the concept, styles, methods, and global status of CO2-EOR are reviewed, and the CO2-EOR potential of the Pearl River Mouth Basin offshore Guangdong Province is discussed.
The summarized conclusions are:

– 二氧化碳驱油是一项相对成熟的三次驱油技术。现有的技术包括混相驱油，非混相驱油，水气交替注入，重力稳定注气，单井的吞吐驱油。

– 二氧化碳捕集技术可以解决二氧化碳驱油技术中缺少二氧化碳来源的问题。

– 与陆上驱油相比，离岸驱油具有更大的挑战性。这不仅是因为需更多的资金和运营成本，而且还存在技术上的困难及操作的复杂性。

– 珠江口盆地海上二氧化碳封存已经被确认为广东省 CCUS 链中一个必要组成部分，因此需要详细地了解盆地中的 CO2-EOR 的潜力。

– 珠江口盆地中 CO2-EOR 的潜在可能性也许存在于 LH11-1 油田。

– 这份告对珠江口盆地开展 CO2-EOR 的潜力进行了初步的分析，指出了一些有限的可行性，但尚需进行进一步评估。

- CO2-EOR is a relatively matured technique for the tertiary recovery of crude oil. The technologies include miscible CO2-EOR, immiscible CO2-EOR, water alternation gas injection, gravity stable gas injection and Single-well huff-and-puff flooding.

- CO2 capture technology can solve the lacking of CO2 source for CO2-EOR.

- Compared with onshore CO2-EOR, offshore CO2-EOR is more challenging. This is not only in much higher capital and operational costs, but also in technical difficulties and operational complexities.

- Offshore CO2 storage in the Pearl River Mouth Basin has been identified as a necessary component of the CCUS chain in Guangdong Province. Thus the potential of CO2-EOR in the basin needs to be understood in more detail.

- A possible opportunity of CO2-EOR in the PRMB might exist in the largest field LH11-1.

- This study presents a preliminary screening analysis of CO2-EOR potential in offshore PRMB. Some limited possibilities for offshore CO2-EOR are identified which should be evaluated further.

报告 4：广东省近海二氧化碳封存的数学模拟

Report 4:Numerical simulations for the CO2 storage potential of Guangdong near sea

中科院南海研究所的周蒂教授和和她的团队成员完成了广东省近海 HZ21-1 油田和 LF2-1 干构造的充注模拟研究。油田的封存能力非常有限，所以在模型中油田相连接的咸水层也被用来封存 CO2。模型中研究了两种不同的填充情景：每年 1Mt 和每年 2Mt 的充注 10 年和 20 年。模拟结果表明，两个封存地都可以安全充注 20 年不泄露。

但是以上的研究都是比较初期的。充注模型的建立在一口井的数据基础上。在以后的研究中，需要更多的数据支持找出最合适的封存地。

Pro Zhou from South China Sea Institute and her colleagues have completed the reports on CO2 storage potential of Guangdong near sea and injection models of HZ21-1 and LF2-1. The oil fields have very limited storage capacity. Therefore, the saline aquifers in connection with the oil reservoirs are used in the numerical models. Two different injection scenarios are studied: 1Mt/yr and 2Mt/yr for 10 years and 20 years. The conclusion is both of the two aquifers will not leak after the 20 years injection.

However, this is just a preliminary study. Both the injection models were built on one well log data. For further study, more data shall be used to have a more confident assessment to find the most promising site.

5. 推荐方法 J203 的特点和评价

Summarized characteristics and comments on RP-J203

5. 1 针对碳封存的推荐方法

DNV 推荐方法 J203 是 DNV 一系列推荐方法中的一个，其主要目的是提供一套碳封存地选址、资格验证和管理的系统方法。这套推荐方法是 CO2QUALSTORE 和 CO2WELLS 的综合。推荐方法 J203 提供了一套工程项目发展的框架，并在地质学、环境、法律、规定、社会等问题解决方案上给出了全面的指导，此外还在利益相关者的沟通策略上给予了建议。

二氧化碳地质封存资格验证管理方法（DNV-DSS-402）给出了 DNV 颁发碳封存地证书的框架。文件中涵盖了选址原则，资格验证和管理，DNV 所提供的服务概述（包括 DNV 证书的样板文件）。DNV 的服务范围包括了封存地的选址，资格验证和管理。

本文是针对广东省的推荐方法，主要基于 DNV 推荐方法 J203（结合 DSS-402）。推荐方法可以用于项目执行方，管理方，监理方，投资方和其他利益相关方。

5. 2 选择 DNVRP-J203 的原因

从 2004 年开始，DNV GL（GL Noble Dention 公司于 2013 年加入 DNV 公司）作为一个有丰富资格验证，检验，证书认证和技术咨询的公司，已经参与了 98 个与 CCUS 相关的示范项目、研究项目或者工业研究。DNV 所参与的与碳封存密切相关的项目已经在附录 5 列出。选择 DNV 推荐方法 J203 作为基本方法的理由如下：

5.1 RP specially for carbon storage

DNV RP-J203This Recommended Practice (RP) is part of DNV´s series of RPs. The main objective is to provide a systematic approach to the selection, qualification and management of geological CO2 storage sites. The RP incorporates and combines the guidance given in: CO2QUALSTORE and CO2WELLS. DNV RP-J203 provides framework for project development and gives very comprehensive guidelines not only on geology and environment, but also on perspectives of legal, regulatory and social. It also gives detailed suggestions on the communication strategies of the stakeholders should be included in the report.

Qualification Management for Geological Storage of CO2 (DNV-DSS-402) provides a framework for the certification of geological storage sites for CO2. It covers principles for selection, qualification and management of geological storage sites for CO2, service overview (basically what services DNV can provide, and examples of CO2 storage certification documents). It is a description of DNV's services within selection, qualification and management of geological storage sites.

This recommended practice for Guangdong is generally based on the guidelines given by DNV RP-J203 (supported by DSS-402). The recommended practice is for operator, regulator, verifier and investor or other financial stakeholder.

– 灵活的参与方式：作为一个成熟的技术咨询公司，DNV 根据项目背景、项目开发者和要求的不同，提供多种的合作方式。例如，在 QUEST 项目中，DNV 成立工作研讨小组组织多方专家团队帮助壳牌的项目做检验工作。对于经验不是那么丰富的团队，比如 CarbonNet 项目，DNV 会提供更多的服务来帮助项目顺利的通过证书验证和资格审查。在这个项目中，一个独立的项目专家组成立了，其中包括 DNV 内部和外部的专家。对于倾向于应用自己工作流程的项目实施方，DNV 可以帮助管理者对于工程要求作出检验。

– 对于 CCUS 项目提供整合的资格检验和证书认证服务：DNV 所提供的基本服务包括资格管理，颁发证书和项目验证。考虑到 CCS 项目覆盖面积的广泛性和内在的复杂性，DNV 倾向于向客户提供整合的资格检验和证书认证服务，以确保客户的项目能够顺利达到推荐方法 J203 中的要求。这种方式的好处在于客户在每个阶段能够充分的准备证书验证中所需的所有文件资料。否则，如果客户准备的材料不是 DNV 所需要的，就需要花费更多的时间重新做资料准备。检验的范围除了 DNV 自己的推荐方法 J203 中的要求之外，也包括了客户自己的和一些内部的标准和步骤。CCUS 是一个新的领域，DNV 会与客户讨论哪一种标准最为实用，尽量避免不同标准之间的冲突。

– 技术咨询服务：DNV 如果对项目提供证书和检验服务的话就不会帮助客户进行项目的设计（利益冲突），但是 DNV 会帮助进行问题的诊断并且会帮助客户准备证书所需的资料文件。如果 DNV 不是作为证书和检验方的话，DNV 可以帮助客户进行项目设计（技术咨询服务）。

– 覆盖面广且描述详细：在碳封存领导论坛 2013 年年度报告二氧化碳地质封存和监测的最佳方案和标准中对于不同出处的最佳方法进行了比较。DNV 推荐方法 J203 对于地质封存地的筛选，选

5.2 Why choose DNV RP-J203

From the year 2004, DNV GL (GL Noble Dention joined DNV in 2013) as a company with rich experience in qualification, verification, certification and technical advisory service, has engaged in 98 CCUS related demonstration projects, research projects or joint industrial studies. The projects have significant storage component is listed in Annex 5. The reasons for DNV RP-J203 is chosen are:

- Flexible engagement modes: As a sophisticated technical advisory company, DNV has various collaboration models, based on the project context, project developers and the requirements. For example, for QUEST project, DNV held workshops and assembled a team of experts from outside the project and outside DNV to help to verify what Shell had done. But less experienced team, such as CarbonNet project, need more hands-on help to get through the certification and some qualification management services. A team of independent experts from inside and outside DNV are established for this project. For clients want to use their own workflow, DNV help the regulator verify the project against their own set of requirements.

-Combined qualification and certification services in CCUS project: the basic services provided by DNV include qualification management, certification and verification. In view of the wide variability between CCS projects and their inherent complexity, DNV favors combining Certification and Qualification Management services in order to assists the client in managing the storage site qualification process in order to comply with requirements in DNV RP-J203. The advantage of combining two services is to help the client go through the certification process so that they have the documents needed to do the certification at each stage gate. Otherwise there is a risk that the documents prepared by the client are not what DNV needs and there is a delay while they have to revise all the paperwork. The scope of the verification could be parts of DNV RP-J203, other standards or internal procedures provided by the client. CCUS as a new industry, DNV recommends to discuss with the client which standards or internal procedures are most relevant and help to avoid conflicting requirements from different documents.

择和特性描述，钻井工程建造，监测以及风险管理等方面都给出了详细的指导。

– 为项目开发各方提供有效的沟通平台：推荐方法 J203 为利益相关的各方提供了一个交流的平台。在地址筛选阶段，建议设计一个有效的沟通策略来保证利益相关者能够被及时告知项目进展和下一步的参与计划。在评估阶段，建议设计一个独立的评估交流计划，其中包括沟通目的，实施方是否有能力和信心能管理号选址等内容。沟通计划的有效实施可以保证项目实施方能及时掌握管理方的意见。沟通计划作为封存发展计划的一部分，各方利益相关者将会被及时告知项目的可能存在风险，以及风险原因，可能造成结果和采取的相关措施。

– 可追踪、透明的风险管理机制：在推荐方法 J203 中，风险分析必须以一个透明壳追踪的方式进行。项目实施方的建议实施一个全面的风险鉴定流程其中包括所有的相关可能风险以及风险造成的威胁，事件和后果都会被考虑。建议采用电子风险数据库的方法来追踪风险随时间的变化并且管理与其相关的行为活动和责任。

5. 3 为广东省项目做的修正

– 根据报告 1，盆地规模的筛选工作已经被中科院南海所的团队完成。珠江口盆地被选为最适宜二氧化碳封存的地址。在报告 4 中 HZ21–1 和 LF2–1 的封存能力和可充注性有了初步的分析。在以后的研究中，在有更多数据资料的前提下，应该进行更加仔细的封存地特性分析。同时封存地的评估和排序应该按照推荐方法的步骤进行。

– 建议在封存地评估环节，一个初步的设施再利用计划（海上平台，管道等）和一个成本计算方法计划应该被加入评估计划中。现有的设施的可再利用可以成为一个封存地备选的巨大优势。封存成本的核算可能会因为场地的专属性等原因变化很大。

- Technical Advisory services: DNV is not supposed to help the client design the project if it is involving in certification or verification (conflict of interest), but DNV can help diagnose problems and guide the client through preparation of documents. In the case that DNV is not doing certification or verification then they can help clients design projects (Technical Advisory service).

- Wide scope and detailed explained: in the report 2013 Annual Report by the CSLF Task Force on Reviewing Best Practices and Standards for Geologic Storage and Monitoring of CO2 , different recommended practices from various sources are compared. DNV RP-J203 has detailed guidelines for site screening, selection and characteristics, well construction and integrity, monitoring and verification and risk management and assessment.

- Effective communication platform for internal and external developers: RP-J203 provides an effective communication platform for stakeholders. In the screening plan, the communication strategies for involved stakeholders shall be designed to ensure the future involvement and the stakeholders are fully informed of the progress. In appraisal stage, an independent appraisal communication plan shall be prepared, where the communication goals, the operator's ability and ambition to manage the site selection shall be illustrated. Executing the communication plan can help the operator gain understandings of any preferences the regulator may have for which storage site to select. In the communication plan as part of Storage development plan, the stakeholders are informed by the possible risks, including the causes, the consequences and the treatment.

- Traceable and transparent risk management: in RP-J203, risk assessments shall be executed and documented in a transparent and traceable way. The operator is suggested to perform a comprehensive risk identification process that considers all relevant risks, which the threats, events and consequences have been included. An electronic risk database is also recommended in order to keep track of changes over time and manage actions and responsibilities.

5.3 Modifications for Guangdong

- According to report 1, basin scale screening work has completed by the team from SCSIO. Pearl River Mouth basin is selected as the most favorable basin

– 由于 DNV 推荐方法 J203 主要目标是二氧化碳的咸水层封存，如果应用于二氧化碳驱油需要做一些修改。但是由于此推荐方法的普遍适用性，整体的阶段–端口结构和框架同样适用，并且可以在选址阶段用来横向对比两种选择的优缺点。

– 这份报告提供了一些基本意见。进一步的为广东碳封存项目的细节讨论和全面的工作流程设计还需要进行。

for CO2 storage. Report 4 has done the preliminary assessment of potential capacity and injectivity of HZ21-1 and LF2-1. In further study, the more detailed characterization shall be done when more data is available, and the appraisal and ranking shall be done according to recommended practice.

- It is suggested that in the appraisal stage, a preliminary re-usage plan of infrastructure (platform, pipelines, etc.) and preliminary cost estimation should be added in appraisal plan. Because the availability of existing infrastructures can be a strong advantage for the storage sites. The estimation could be highly dynamic and sensitive based on the nature of highly site-specific.

- For the technical content of DNV RP-J203 is focused on aquifer storage of CO2 , and this will require modification for CO2-EOR. The project development framework and stage-gate structure is, however, applicable to both and may provide a structured approach to comparing the pros and cons of each option during the screening or concept selection phase.

- This report just provides basic suggestions. Further detailed and comprehensive workflow guidelines for CO2 storage in Guangdong near sea are required.

文献引用
References

Bachu, S. (2003). Screening and ranking of sedimentary basins for sequestration of CO2 in geological media in response to climate change. Environmental Geology, 44(3), 277-289.

Chadwick, A., Arts, R., Bernstone, C., May, F., Thibeau, S., & Zweigel, P. (2008). Best practice for the storage of CO2 in saline aquifers. Observations and guidelines from the SACS and CO2STORE projects.

DNV GL. (2012). Recommended practice RP-J203: Geological Storage of Carbon Dioxide. Det Norske Veritas As.

IEA Greenhouse Gas R&D Programme (IEA GHG). (2009). CCS Site Characterisation Criteria, Report No. 2009/10. Cheltenham. United Kingdom.

IPCC. (2005). IPCC Special Report Carbon Dioxide Capture and Storage Technical Summary.Intergovernmental Panel on Climate Change.

Li, Q., Liu, G., Liu, X., & Li, X. (2013). Application of a health, safety, and environmental screening and ranking framework to the Shenhua CCS project. International Journal of Greenhouse Gas Control, 17, 504-514.

Pershad, H., Durusut, E., Crerar, A., Black, D., Mackay, E., Olden, P., 2012. Economic impacts of CO2-enhanced oil recovery for Scotland: Final report. Element Energy Limited, Dundas Consultants, and Heriot Watt University, p. 111.

Shen, P.-p., Jiang, H.-y., Chen, Y.-w., Li, Y.-t., Liu, J.-s., 2007. EOR study of CO2 injection. Special Oil and Gas Reservoirs 14, 1-4.

Smith, M., Campbell, D., Mackay, E., & Polson, D. (2011). CO2 Aquifer Storage Site Evaluation and Monitoring. Heriot Watt University, Edinburgh, ISBN, 978-0.

US Geological Survey, (2009). Development of a probabilistic assessment methodology for evaluation of carbon dioxide storage. Reston, Virginia.

Zhou, D., Zhao, Z., Liao, J., Sun, Z., 2011. A preliminary assessment on CO2 storage capacity in the Pearl River Mouth Basin offshore Guangdong, China. International Journal of Greenhouse Gas Control, 308-317.

Appendix 1

Site screening and selection criteria are classified as:

- Eliminatory criteria, on which basis sites are eliminated from further consideration; The eliminatory criteria fall into two categories:

  a)critical – these criteria have to be met without exception; and
  b)essential – these criteria should also be met, but some exceptions may occur/be granted, depending on circumstances. and
- Selection criteria, on which basis sites that passed the eliminatory screening are selected on the basis of having most favorable characteristics. Sites may still be rejected if too many unfavorable conditions exist.

Site screening and selection criteria. Compilation of IEA (2009), Bachu (2003), Chadwick et al. (2008) and CASSEM (2007)

	Criterion type	Criterion	Not Suitable/ Unfavorable	Suitable/Desirable
1	Critical	Depth	Less than 1000m or deeper than 4000m	1000m to 4000m
2		Reservoir-seal pairs and stratigraphic sequences	Poor (few, discontinuous, faulted and or breached	Intermediated and excellent. At least one major extensive competent seal
3		Pressure regime	Over-pressured	Hydrostatic or sub-hydrostatic
4		Legal accessibility	Forbidden	Possible
5		CO2 source within economic distance	More than 300km	Less than 300km
6		Data availability	Not available or old 2D seismic data	Not available or old 2D seismic data
7	Essential	Seismicity (basin tectonic setting)	High and very high (subduction zones; syn-rift and strike-slip basins)	Very low to moderate (foreland, passive margin and cratonic basins)
8		Faulting and fracturing intensity	Extensive	Limited to moderate

	Criterion type	Criterion	Not Suitable/ Unfavorable	Suitable/Desirable
9	Essential	Hydrogeology	Shallow, short flow system, or compaction flow	Intermediate and regional-scale flow; topography and erosional-rebound flow
10		Surface areal extent	Less than 2500 km2	Greater than 2500 km2
11	Selection	Within fold belts	Yes	No
12		Significant diagenesis	Present	Absent
13		Geothermal Regime	Warm basin (Gradient >0.04 °C/m)	Cold or moderate basin (Gradient >0.04 °C/m)
14		Evaporites (salt)	Absent	Domes and beds
15		Hydrocarbon potential	Absent or small	Medium to giant
16		Industry maturity	Immature	Mature
17		Climate	Harsh	Moderate
18		Infrastructure	Absent or rudimentary	developed
19		Reservoir thickness	Very thin (<20m)	Thick (>20m)

	Criterion type	Criterion	Not Suitable/ Unfavorable	Suitable/Desirable
20	Essential Selection	Average porosity	<10%	>10%
21		Maximum permeability	<200mD	>200mD
22		Salinity	<10g/l	>10g/l
23		Reservoir stratigraphy	Complex lateral variations and connectivity	Uniform
24		Caprock thickness	<20m	>20m
25		Igneous rock	Little knowledge about the existence	Appreciation of the existence, geometry and effect on the surrounding rocks
26		Static capacity	<20 million tonnes of CO2	>20 million tonnes of CO2

Appendix 2

Site screening requirements for CO2-EOR. Compilation by Zhou et al. (2014) from the combination of requirements from Pershad et al. (2012) and Shen et al. (2007).

	Positive Indicators	Contra Indicators	Other remarks
Oil Properties			
Composition	High concentration of intermediate	< 22 – Consider immiscible CO2-EOR, fill reservoir voidage if capacity is large > 48 – Extremely light oil such as condensate is not conducive to multi-contact miscibility	
Density ρ	hydrocarbons especially C5 to C12,		
Viscosity μ	relatively few aromatics	> 10 – Consider immiscible CO2-EOR	
Reservoir Properties			
Depth (~ reservoir pressure)	For miscible displacement depth must be great enough to allow injection pressures greater than the MMP	Reservoirs at very great depth >~3500 m are likely to be considered uneconomic because of the higher CO2 compression costs	MMP - minimum miscibility pressure
Temperature	Reservoirs in regions with low geothermal gradients and ground temperatures	> 121 °C limit proposed by US National Petroleum Council	CO2 supercritical phase T > 31.1 °C, P > 7.38 MPa. CO2 density decreases with increasing temperature

	Positive Indicators	Contra Indicators	Other remarks
Ratio of reservoir pressure P and MMP (P/MMP)	Normally > 1, but > 0.95 may still be satisfactory		MMP depends on oil composition and increases with temperature and gravity
Original and current oil in place (OOIP/ COIP)			Reserve estimates and production histories of both oil and water needed to make storage capacity estimates
Oil saturation-porosity product Soϕ	≥ 0.05	< 0.05. Consider filling reservoir voidage if capacity is large	Soϕ is the fraction of oil remaining per unit volume of rock before EOR
Specific CO2 (theoretical) storage capacity C	> 10 kg/m3	< 10 kg/m3	$C = \rho(1-Sor-Swr)\varphi + Swr\varphi Cs$ Sor residual oil saturation; Swr irreducible water saturation. Cs specific water dissolution capacity. ρ and φ density and porosity of reservoir.
Formation injectivity (permeability-thickness product) kh	≥ 10-14 - 10-13 (m3)	≤ 10-14 (m3). If kh is less, consider if injectivity will be sufficient	Injectivity may be lost due to precipitates forming near the wellbore

	Positive Indicators	Contra Indicators	Other remarks
Reservoir heterogeneity	High heterogeneity improves extent of CO2 flood invasion throughout the whole reservoir	Relatively homogeneous and high permeability formations allow lighter CO2 to readily rise to the top of the reservoir bypassing oil	High mobility paths (including faults) may cause early breakthrough. Steeply dipping beds may lead to reduced residence times
Aquifer–reservoir coupling	Weak aquifer support increases storage capacity	Strong aquifer support reduces storage capacity	Difficult to assess – high oil recovery is usually indicative of strong aquifer support – WOR also indicator
Seal and well integrity	Minimal formation damage and good well integrity	Areas prone to fault slippage or well leakage	
CO2 properties			
CO2 purity	Low N2, S, SOx, NOx		The contaminants increase MMP.

Appendix 3

Volumetric formulas for discovered physical traps (from USGS, 2009)

Calculation method	Storage type	Formula
A	Conventional EOR, SEOR	=OOIP×IR×CEOR
B	Net cumulative volume, SNCV	=NCV×CWD×CF1×ρCO2
C	Total known volume, STKV	=TA×TI×NTP×Φ×CSE×CF2×ρCO2
D	Total Trap Volume, STTV	=STKV×CG

OOIP: Volume of original oil in place (in petroleum barrels)
IR: Incremental recovery of OOIP induced by CO2 enhanced oil recovery, in fraction
CEOR: storage efficiency of EOR, in metric tons of CO2 retained in the reservoir per barrel of incremental oil recovered (fraction).
NCV: net cumulative volume of reservoir fluid produced, in barrels at subsurface conditions.
CWD: correction factor for potential refilling of trap by natural water recharge or water flooding during oil recovery (fraction).
CF1: conversion factor, petroleum barrels (42 gallons) to cubic meters (m3): 0.159 bbl/m3
ρCO2: density of CO2 in metric tons per cubic meter (metric tons/m3).
TA: trap area from which hydrocarbons and water have been produced, in acres, defined by production well locations.
OOIP: Volume of original oil in place (in petroleum barrels)
IR: Incremental recovery of OOIP induced by CO2 enhanced oil recovery, in fraction
CEOR: storage efficiency of EOR, in metric tons of CO2 retained in the reservoir per barrel of incremental oil recovered (fraction).
NCV: net cumulative volume of reservoir fluid produced, in barrels at subsurface conditions.
CWD: correction factor for potential refilling of trap by natural water recharge or water flooding during oil recovery (fraction).
CF1: conversion factor, petroleum barrels (42 gallons) to cubic meters (m3): 0.159 bbl/m3
ρCO2: density of CO2 in metric tons per cubic meter (metric tons/m3).
TA: trap area from which hydrocarbons and water have been produced, in acres, defined by production well locations.

Appendix 4

The requirements in the site appraisal phase after Smith et al. (2011)

Types	Information	Additional data	Objective
Geological	1.Log column 2.Detailed reservoir correlation 3.Structural maps 4.Interpreted depositional model; facials distributions 5.Porosity maps 6.Isopach map of injection zone 7.Seismic of cross-sections 8.Analog well data 9.Faulting and folding history of the confining zone 10.Trapping mechanisms	Additional seismic, well tests, fluid level data, fluid samples, etc.	1.Complete the short list of qualified sites 2. Characterize and rank 3. Establish and optimize the models 4.Complete data enhancement
Geochemical	Analyze the fluid-CO2-rock reactions based on fluid composition, geochemistry, pH, conductivity, mineralogy		
Geomechanical	1.Develope injection rates and pressure baselines 2.Identify the security of faults and fractures 3.Predict the possibilities of induced seismic activities		
Hydrological	1.Multiphase flow migration models 2.Multi-well tests		

Appendix 5

DNV GL reference project for CCUS (by Michael Edward Carpenter)
Industrial/demonstration projects

01	**Petroleum Technology Research Centre (Canada) (2004):** **Risk Assessment Methods for Geosequestration of CO2** DNV was contracted by PTRC to present a summary of a wide variety of risk assessment methods. The goal of this effort was to identify ways of assessing the risks from geosequestration of CO2 that be applicable to the IEA Weyburn CO2 Monitoring and Storage Project.
02	**Vattenfall (2008):** **Coarse Risk Assessment (RA) of the potential storage site for Vattenfall´s CCS demonstration project in northern Denmark** Assessed the current state of knowledge about the geological formation and it's suitability for CO2 storage. Identified hazards, safeguards and major uncertainties and gaps in knowledge and ranked these in order of significance. Documented the RA process carried as input to the documents that Vattenfall intends to produce for Danish authorities.
03	**Vattenfall (2009):** **Risk assessment of CO2 storage** Risk assessment of geological storage of CO2 from Vattenfall's power plant in Germany. The assessment included two possible storage sites.
04	**Vattenfall (2010):** **Update of risk assessment of Birkholz storage site** Update on the risk assessment work performed with Vattenfall and partners on CO2 storage project in Birkholz, related to the Jänschwalde power station. The update was based on new knowledge of project and the storage complex, and the risk were reassessed and updated. Results were inserted into the risk element database EasyRisk.

05	**Qatar Shell (2010):** **CO2QUALSTORE workshop for Qatar Shell** DNV supported Qatar Shell in hosting a technical workshop for Qatar Petroleum (QP) on CO2 storage in general and the CO2QUALSTORE guideline in particular. DNV facilitated two half-day workshop sessions with geologists and reservoir engineers from QP that were structured around the Screen and Assess & Select stages of the guideline. This provided an opportunity for all parties to discuss the current status of the CO2 storage in Qatar and potential next steps to move the technology forward.
06	**Australian Coal Association/ZeroGen CCS (2010):** **Independent Project Review** The ZeroGen CCS project in Queensland is funded by the Australian Coal Association Low Emissions Technology Fund (ACALET) and the Queensland Government. ACALET requested that the project received an Independent Project Review (IPR) in order to check project progress and investment. DNV was engaged to facilitate a technical review of the CO2 transport and storage elements of the project using the CO2QUALSTORE guideline as a template for CCS project development. DNV's findings were used to support a re-evaluation of the project schedule.
07	**Shell Canada (2010):** **Independent Project Review of QUEST CCS project** Client wanted to build confidence among regulators and external stakeholders that the selected storage site meets capacity, injectivity and containment requirements, and can be monitored to ensure safe long term storage of CO2. DNV contracted an expert panel consisting of 6 experts with cross-disciplinary expertise, and facilitated knowledge sharing between Shell and the expert panel. DNV also reviewed the risk management framework and risk assessment work to date. A publicly aimed report, including input to regulatory submission was produced. In addition, guidance for further work and suggestions for modifications of risk assessment was provided.

08	**PGE (Polska Grupa Energetyczna):** DNV developed Risk register as part of NER300 application (2011) DNV supported PGE Poland's largest utility company with developing the Risk register for the Carbon Capture and Storage project at the Bełchatów power plant using DNV's Enterprise Risk Management approach. DNV has supported PGE in preparing the Risk register for the full CCS project as part of the NER 300 application process (Application form 13).
09	**Shell Canada (2011):** **Verification of fitness for CO2 storage** Follow on project to DNV's Independent Project Review of QUEST CCS project in 2010 (see above). DNV issued the world's first certificate of fitness for a CO2 storage development plan. DNV was commissioned by Shell to coordinate a comprehensive review to assess the suitability of the Quest project's underground storage formation to safely and permanently store injected CO2. The review also assessed the project's measurement, monitoring and verification program to validate that it would provide the necessary rigor to demonstrate effective containment. DNV assembled a panel of seven CCS experts from academia and research institutions to perform the review over a two-week period. Based on the conclusions of the expert panel DNV certified that Shell's Storage Development Plan is fit for purpose based upon a number of different metrics, such as: sufficient storage capacity, long-term containment, proper risk management plans, and a measurement, monitoring and verification program capable of continuously demonstrating containment.
10	**SINOTECH (2012):** **Risk Management Worskshop on CO2 Storage** DNV held a training workshop on introduction to risk management of CO2 Geological Storage (CGS) sites for SINOTECH and Taipower in Taipei, Taiwan (March 28-30, 2012). The topics covered a selected set of examples that illustrate some of the risk analysis and treatment concepts and methods including Coarse Risk (risk matrices), Monte Carlo simulation (sampling), probability integrals (adaptive numerical integration), barrier analysis (bow-tie models) and Quantitative Risk Analysis (QRA).

11	**CENOVUS Risk Assessment (2012)** **Assessment of wells at the Weyburn oilfield** DNV was commissioned by Cenovus to facilitate a qualitative risk assessment of the well population at the Weyburn oilfield. The purpose of this exercise was threefold: 1: To assess the risk of out of zone migration along wells. 2: To assess the fate of any out of zone migration from a risk perspective. 3: Inform the design of a work program for managing the risk of out of zone migration.
12	**BG Group (2012-2013)** **Monitoring and Accounting for CO2-EOR in Brazil** DNV was engaged by the BG group to develop a monitoring framework suited for demonstrating CO2 emissions reduction associated with pre-salt operations. DNV designed a step wise approach to screen and evaluate monitoring technologies and activities applied within the CO2-EOR and CCS industry in order to assess their potential application for validation of CO2 emission abatement from fields in the pre-salt offshore Brazil.
13	**Review and Verification of the CarbonNet storage site selection process with respect to DNV** **Recommended Practice for CO2 Storage, RP-J203. Australia (2013)** DNV was hired by CarbonNet to review and verify their storage site selection process. After reviewing the project screening report and interviews with project personnel, DNV issued a 'Statement of Feasibility' for the portfolio of sites. DNV reviewed and verified the process used by the CarbonNet project Team in the selection of the storage sites and provided independent expert opinion.

Governmental/regulatory bodies

14	**UK Department of Trade and Industry (2003):** **Risk Analysis of the Geological Sequestration of Carbon Dioxide** The study analysed the environmental and human-impact risks and human-fatality risks associated with the pipeline transport and sequestration of carbon dioxide (CO2) in geological reservoirs. Potential hazards arising from the pipeline transport and associated systems were assessed using a generic modular approach, with release frequencies derived from oil and gas industry failure data. The consequences of the potential releases of CO2 were then modelled using dispersion analysis software, and analyses conducted to determine the extent of resultant risks arising from the generic modular system. The sequestration risks were analysed using a structured 'what if' exercise conducted by and expert panel.

15	**UK Department of Trade and Industry (2003-2004):** **Developing Monitoring, Reporting and Verification Guidelines for CO2 Capture & Storage under EU-ETS** DNV and ERM were engaged to develop guidelines for the monitoring, reporting and verification of CO2 capture & storage under the EUETS. The report drew on input from Power Sector Advisory Group ad hoc working group of the DTI Cleaner Fossil Fuels Programme. The report reviews the key issues presented by CCS when considering its inclusion in emissions trading, and outlines a proposed approach for developing interim guidelines for monitoring, reporting and verification for CCS under the EUETS. The proposed approach involves the application of direct measurements of CO2 flows across a CCS chain (capture-transportation-injection), with the subsequent application of a mass balance reconciliation to estimate any fugitive emissions occurring across the chain to the point of injection.
16	**Norwegian Petroleum Directorate (NPD) (2007):** **Risk Assessment of two Sub-Seabed Geological Storage Sites** DNV facilitated an expert panel workshop in order to evaluate the suitability and identify risks related to two potential CO2 storage sites in the North Sea; the Utsira and the Johansen formations. The expert panel included representatives for NPD, Gassnova, SINTEF, U. of Bergen, U. of Oslo, Norwegian Geotechnical Institute, British Geological Survey, Norwegian Geological Survey, Geological Survey of Denmark and Greenland, Norsk Hydro, Statoil, CGG-Veritas, Schlumberger Carbon Services and DNV. The outcome of the workshop is also intended to be a starting point for Joint Industry Project with the objective to develop a Recommended Practice on selection and qualification of CO2 storage sites.
17	**Norwegian Ministry of Petroleum and Energy (OED) (2006, 2007):** **North Sea Basin Task Force (NSBTF): Gap Analysis - CO2 injection and permanent storage in sub-seabed geological structures** DNV has on behalf of NSBTF undertaken a gap analysis on CO2 injection and permanent storage in sub-seabed geological structures with respect to legal and regulatory issues as well as incentives. "Traffic lights" (red/amber/green) have been assigned to classify short-term and long-term gaps in expected results from initiatives outside of the Task Force with respect to the objectives of the Task Force. Barriers and enablers are classified as international, regional or national.
18	**Gassnova (2008-2009)** **Environmental impact assessment - transport and storage of CO2 from Kårstø** The objective of the study is to define consequences of introducing large scale CCS transport and storage solutions from power plant at Kårstø. Environmental status of the impacted area was described, and also the impact of transport and storage of CO2 on marine recourses, land, emissions to air, impact on the society was evaluated.

19	**Institute of Nuclear Energy Research (INER) Taiwan (2010):** **CO2QUALSTORE / Carbon Capture and Storage (CCS) workshop in Taipei** DNV supported INER (who has been appointed by the Taiwan government to develop CCS in Taiwan) organising a public technical workshop and round table discussion on CO2 capture, transport and storage and on the CO2QUALSTORE guideline in particular. Following the workshop and discussion DNV was asked to provide training in Taiwan on CO2 capture, transport and storage and on CCS value chain analysis (VCA) for INER and Taiwan Institute of Economic Research (TIER).
20	**European Investment Bank (2011, second round in 2013)** **Due Diligence for projects for NER 300 funding scheme** Due Diligence Services on 7 Full-Scale European CCS Demonstration Projects. Assist the EIB in assessing and ranking the CCS project proposals in the EU NER 300 competition for funding. This funding scheme, NER 300, will select projects for financing commercial CCS demonstration projects in Europe. DNV performed services to assist the EIB in undertaking due diligence on proposals, including: conducting financial and technical due diligence; the procurement strategy of the project sponsors with a view to assessing compliance with relevant EU legislation and identifying whether the procurement procedures are appropriate, well planned and in progress such as to allow satisfactory delivery of the project. A second call for proposals was issued in 2013, and DNV was selected to perform due diligence of the only project submitting a proposal for funding in the second round. Value to the client included neutral, independent evaluation of project proposal quality and detailed checking of key aspects of the 7 CCS projects. Full evaluation report for each proposal review addressing the full CCS value chain. Assessment of project's plan for compliance with EU CCS directive.
21	**Technical Review of Gorgon CO2 Injection Project and training (2013)** DNV was hired by the Department of Mines and Petroleum, Western Australia, to execute a due diligence review to assess if the Gorgon Joint Venture has addressed key previous engineering and geotechnical recommendations by the Gorgon CO2 Injection Project operator. Furthermore, DNV facilitated an 'on-the-job' training program for relevant technical staff at DMP covering topics that would strengthen the DMP's ability to assess and monitor the process and risks involved in the further planning and execution of the Gorgon CO2 Injection Project.

Dear Mr Mike Carpenter:
In response to the proposed Norwegian activity for Guangdong CCUS Centre, 2014: techno-economic assessment of HZ CCS project, a compilation table is made hope to outline the responsibilities of different collaborators and the relationship with Demonstration Project Plan. For the carbon transport and storage, the collaboration is subject to further communication with CNOOC.

The table is based on the compile of :
11.Proposed Norwegian activity for Guangdong CCUS Centre, 2014: techno-economic assessment of HZ CCS project (from DNV-GL),
12.UK-China (Guangdong) CCUS Centre and Guangdong CCUS Demonstration Project Plan (Consultation Document) (from GDCCUS center),
13.Feedback from SCSIO.

<table>
<tr><th colspan="3">Task</th><th>Collaborated Participants</th><th>DNV</th></tr>
<tr><td colspan="5">Geological carbon storage</td></tr>
<tr><td colspan="3">Site Screening and Selection (5.6.1, 5.6.5)</td><td>output: report (SCSIO&CNOOC)</td><td>risk and uncertainty assessment</td></tr>
<tr><td rowspan="7">Appraisal</td><td colspan="2">Appraisal basis</td><td rowspan="3">provides documents and advises (SCSIO&CNOOC)</td><td>design appraisal basis and plan for Guangdong project</td></tr>
<tr><td rowspan="2">Appraisal plan</td><td>Appraisal communication plan</td><td>design communication plan for Guangdong project</td></tr>
<tr><td>Technical appraisal plan</td><td rowspan="3">output: plan and report (SCSIO&CNOOC)</td><td rowspan="3">verification</td></tr>
<tr><td colspan="2">Site characterization (5.6.3)</td></tr>
<tr><td colspan="2">Modeling (5.6.7)</td></tr>
<tr><td colspan="2">Infrastructure engineering (5.6.2)</td><td>Infrastructure qualification report (SCSIO&CNOOC)</td><td>develop well engineering concept and OLGA simulation</td></tr>
<tr><td colspan="2">Preliminary monitoring and risk management plan (5.6.6)</td><td>provides documents and advises (SCSIO&CNOOC)</td><td>design preliminary monitoring and risk management plan for Guangdong project</td></tr>
</table>

<table>
<tr><th colspan="2">Task</th><th>Collaborated Participants</th><th>DNV</th></tr>
<tr><td colspan="4">Carbon transport</td></tr>
<tr><td rowspan="4">Appraisal</td><td>Technical design of pipeline offshore solution on a stand alone basis (including re-qualification of existing pipelines) (5.5.2, 5.6.8)</td><td rowspan="4">UoE, SCSIO and CNOOC provides support and advises.</td><td>routing and design</td></tr>
<tr><td>Technical design of ship transport solution on a stand alone basis (5.5.2, 5.6.8)</td><td></td></tr>
<tr><td>Economic assessment of the transport solutions on a stand-alone basis (5.5.3)</td><td>economic assessment</td></tr>
<tr><td>Compare transport implementation options</td><td>work out optimum solution</td></tr>
<tr><td rowspan="3">CCUS clusters</td><td>Develop scenarios for CCS development in the region (5.5.4)</td><td rowspan="3">UoE and CNOOC provides support and advises; GDCCUS Center provides platform to negotiate with CCUS cluster participant</td><td>work out optimum solutions on different scenarios</td></tr>
<tr><td>Compare transport implementation options</td><td>techno-economic assessment</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="2">Interface on going projects</td><td>Build effective collaboration platform for on going projects and different stakeholders</td><td>GDCCUS Center provides support and advises</td><td>workout an interface plan</td></tr>
<tr><td>Training staff involved in the project with the knowledge of CCUS, RP-J203, and risk management.</td><td>GDCCUS Center host</td><td>co-host</td></tr>
<tr><td colspan="4">Note: the serial numbers in the bracket are in accordance with those in demonstration work plan Consultation document). It means the output could be used in the prescribed report.</td></tr>
</table>