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Worldwide development potential for sour gas

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Abstract

In this study, we summarize data on the location and scale of proven and probable sour gas resources and compare with size and location of oil fields. This provides an indication of the location and scale of opportunities to gain further experience in the application of CCS. This by using captured carbon dioxide (CO₂) from sour gas resources, which are presently undeveloped or underdeveloped, for carbon dioxide enhanced oil recovery (CO₂-EOR). Currently there are globally many undeveloped or underdeveloped sour gas accumulations containing a significant fraction of CO₂. The high CO₂ content between 15% and 80%, as well as in some cases the addition of hydrogen sulfide (H₂S), severely limits the economic and environmental viability of sour gas resources. Globally a total resource of around 4 trillion m³ of net hydrocarbon gas and 15000 MT of associated CO₂ has been identified. This was done by summing individual undeveloped and underdeveloped fields with ultimate recoverable proven and probable resources larger than 14 billion m³ each of net hydrocarbon gas and CO₂ content between 15% and 80%.

Development of these fields could be enabled by the availability of a cost effective gas separation method such as the Controlled Freeze ZoneTM (CFZ) technology, and of viable CO₂ enhanced oil recovery opportunities (CO₂-EOR) to reduce the cost of CO₂ capture, transportation and storage.

Sour gas resources have been mapped globally using the IHS fields and reservoirs database from 2009. The largest concentrations of sour gas are located in SE Asia & NW Australia, Central USA, Middle East and North Africa. In the USA, Middle East and North Africa, which are oil rich, there is significant potential for CO₂-EOR opportunities. The relative absence of significant oil accumulations in SE Asia & NW Australia will in many cases require the storage of CO₂ in saline aquifers, as is planned for the Gorgon field in Australia.

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The challenges of developing natural gas fields with a high CO₂ content can be best illustrated by ExxonMobil's development of the LaBarge field. This field, located in SW Wyoming, USA, was discovered in 1963, but production was delayed until 1986 because of the challenging gas composition of 65% carbon dioxide, 21% methane, 7% nitrogen, 5% hydrogen sulfide, and 0.6% helium. It is the lowest hydrocarbon content natural gas commercially produced in the world. Currently the majority of the recovered CO₂ is transported and sold to EOR operators.

Additionally, construction of a commercial demonstration facility for ExxonMobil's Controlled Freeze ZoneTM (CFZ) gas treatment technology has been completed at Shute Creek, Wyoming. The CFZTM technology allows the single step separation of CO₂ and other contaminants from a natural gas stream without the use of solvents or absorbents.

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World wide sour gas resources; CO₂ resources; Enhanced oil recovery; Controlled Freeze Zone

1. Introduction

Carbon dioxide (CO₂) emissions can be reduced by, improving energy efficiency, using lower emitting fuels like natural gas and nuclear instead of higher emitting fuels such as coal. Additional emission reductions can be obtained by using renewable energy sources, and by pursuing carbon capture and storage (CCS). As the name implies, CCS includes applying technologies that capture the CO₂ whether generated by combustion of carbon-based fuels or by the separation of CO₂ from natural gas with a high CO₂ concentration (sour gas). Subsequent transport and permanent storage of the CO₂ in the subsurface are the other elements of CCS.

Sour gas resources are natural gas resources that contain a significant fraction of CO₂ and/or H₂S. Produced sour gas is processed, or "sweetened", by separating out the CO₂ and/or H₂S to give a natural gas product with specifications appropriate for transport to a variety of end uses. The Intergovernmental Panel on Climate Change gave a crude estimate of the global rate of CO₂ separated from natural gas processing in the year 2000 of 50 Mt CO₂/yr [13].

Global proven and probable sour gas resources have an estimated potential of 4 trillion m³ of net hydrocarbon gas [7]. These gas accumulations are mostly undeveloped or underdeveloped, as their high CO₂ content (15 to 80%) severely limits their economic and environmental viability. Emerging lower cost separation processes such as the Controlled Freeze ZoneTM (CFZ) technology could make the development of these resources viable. Additionally the cost of carbon dioxide (CO₂) capture, transportation and storage can be reduced by using the CO₂ for enhanced oil recovery (CO₂-EOR).

Development of sour gas resources is evidenced by several ongoing projects that have made the raw hydrocarbon gasses containing CO₂ and sometimes hydrogen sulfide (H₂S) marketable. EOR has been one of the driving forces behind some of these developments and has provided the oil industry with significant experience in successfully transporting and injecting CO₂.

In this study, we summarize data on the location and scale of proven and probable sour gas resources and compare with summarized data on the location of oil fields. This provides an indication of the location and scale of opportunities to gain further experience in the application of CCS. This by using captured CO₂ from sour gas resources that are presently undeveloped or underdeveloped for CO₂-EOR.

2. Challenging natural gas resources

The known total worldwide resources of developed and undeveloped natural hydrocarbon gas are estimated by IHS [7] to be in the order of 270 trillion m³ and roughly ½ of that volume involves resources with CO₂ content greater than 2%. The additional presence of H₂S makes these gasses even less desirable because of additional economical, environmental and safety issues.

One synergy that has the potential to facilitate the development of these challenging resources is the use of CO₂, recovered from produced natural gas, for enhanced oil recovery (EOR). The oil and gas industry has been

successfully using CO₂ for EOR for nearly 4 decades. The CO₂-EOR technology can fulfil a dual purpose: storage of CO₂ and increased recovery of oil (or natural gas with enhanced gas recovery). CO₂-EOR can increase oil recovery by an average of 8% - 11% of the original oil in place [3], which could partly offset the costs of capture, transportation and storage of the CO₂. Development of a CO₂-EOR industry in other parts of the world could proceed along the same lines as in the USA.

In the Permian Basin, CO₂-EOR started in the early seventies in the SACROC field (West Texas), utilizing almost pure natural CO₂ resources which require very limited gas processing. Over the intervening years a pipeline system was developed to move CO₂ from the McElmo Dome, Bravo Dome and Sheep Mountain fields (located in Colorado and New Mexico) to the oil accumulations in the Permian Basin, which are amenable to CO₂-EOR. The total length of the major CO₂ pipelines in the USA has grown to more than 5000 km [11]. Instrumental to the development of the CO₂-EOR industry was the existence of oil fields amenable to CO₂-EOR flooding and the presence of large natural CO₂ resources relatively nearby. This industry expanded into other areas with CO₂ sources from LaBarge in Wyoming (65% CO₂), Jackson Dome in Mississippi and from anthropogenic sources like the Great Plains Synfuels plant in North Dakota supplying CO₂ for the Weyburn field in Canada [11].

Enhanced oil recovery has had a significant impact on the USA oil and gas industry. According to an Advanced Resources International study [11] there are currently in the USA 105 CO₂-EOR projects underway providing over 250,000 barrels per day of incremental oil production. Since 1986, about 1.5 billion barrels of incremental oil has been produced using CO₂-EOR, with another 1 billion barrels currently booked as incremental reserves.

Development of CO₂-EOR is technically dependant on a reliable and affordable CO₂ supply, co-located with adequate oil quantity, quality and reservoir characteristics. According to Nelms [3], miscible flooding with CO₂ requires that the oil fields have adequate remaining reserves in place, a good water flood response, and the API oil gravity should be above 27° and the oil viscosity less than 10 cp. In addition, reservoir properties like porosity and permeability should be relatively good. In other parts of the world the CO₂-EOR industry is in its initial stages of development and expanding. Particularly in the Middle East, efforts are underway to use captured CO₂ for EOR. The presence of substantial sour gas resources in the region could provide a source of CO₂ and (H₂S) needed for enhanced oil recovery.

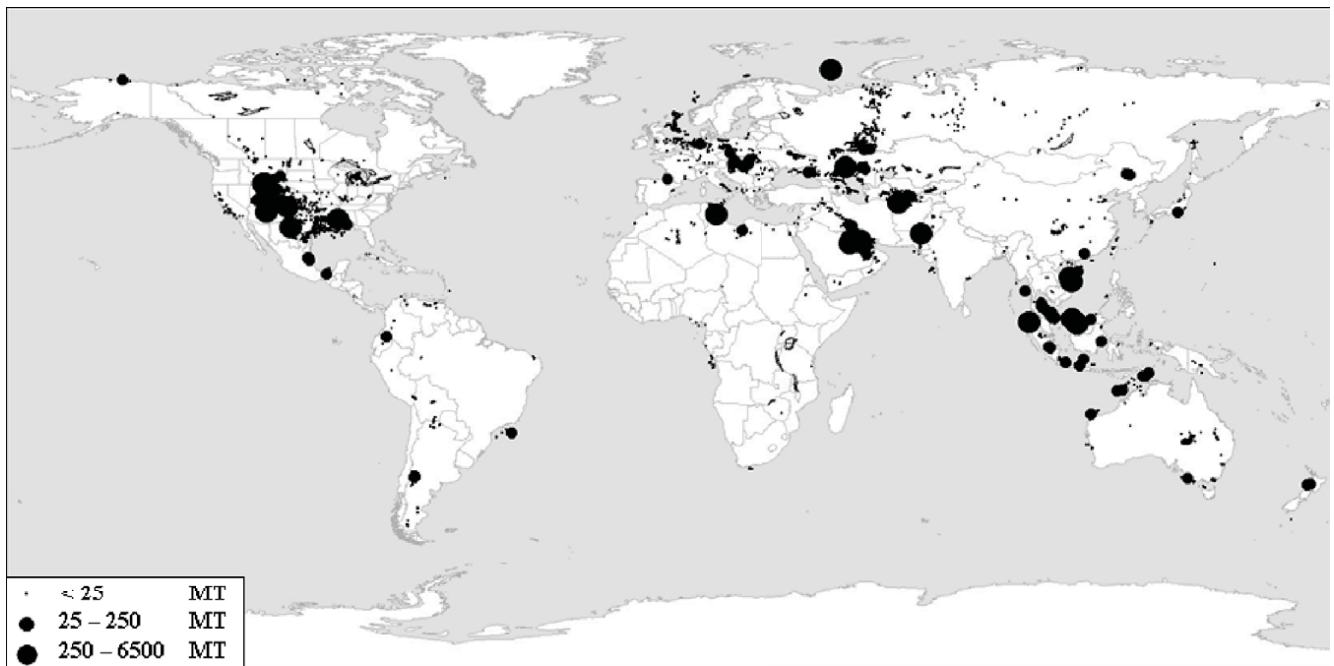


Figure 1 Global distribution of CO₂ Volumes in million metric tons

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3. Global distribution of hydrocarbon gasses with a high CO₂ content

Potential sour gas resources around the world are illustrated in Figure 1, which shows the global distribution of CO₂ in natural gas fields with a net proven and probable volume of CO₂ in million metric ton (1MT $\approx$ 0.5 billion m³ CO₂). The field sizes have been categorized into 3 classes; 1) Less than 25 MT, 2) 25 to 250 MT and 3) larger than 250 MT of net CO₂. The largest known field is Natuna in Indonesia with 6500 MT CO₂ [7]. The total estimated quantity of natural CO₂ in the subsurface is 35 billion (35000 MT) tons, from which 15 billion (15000 MT) tons is in large fields with CO₂ content between 15% and 80% and a net hydrocarbon content of more than 14 billion m³. From the map it can be concluded that the resources with the highest CO₂ content are in SE Asia and NW Australia, Central USA, Middle East and North Africa. The fields are relatively close to many known oil resources in the Central USA, Middle East and North Africa as shown in Figure 4.

The distribution, of natural gas resources with CO₂ content between 2% and 100% is illustrated in Figure 2. The map shows two categories of CO₂ concentrations, one from 2% to 15% and the other from 15% to 100%. Most high concentration CO₂ gasses occur in SE Asia / NW Australia, Central USA, North Africa, Middle East and Central Europe. In Central Europe, however, the volumes of high CO₂ gasses (Figure 1) are relatively small.

These challenged resources are not viable for production unless the impurities (CO₂ and/or H₂S) can be separated economically. The recovered CO₂ can be used for EOR or alternatively it can be injected in saline reservoirs if CO₂-EOR opportunities are not viable. Storage in saline aquifers would be considered in the absence of oil fields amenable to CO₂ flooding or if a suitable pipeline infrastructure is lacking. As a consequence, assessment of the potential for CCS of gas processing CO₂ under the Clean Development Mechanism, which is focussed on the potential in SE Asian countries, may well lose the added benefit of CO₂-EOR [14]. However, this is generally not the case in the USA, Middle East and North Africa where there is significant potential for CO₂-EOR. In these areas the recovered CO₂ and (H₂S) can be used for EOR purposes, which could partially mitigate their separation cost.

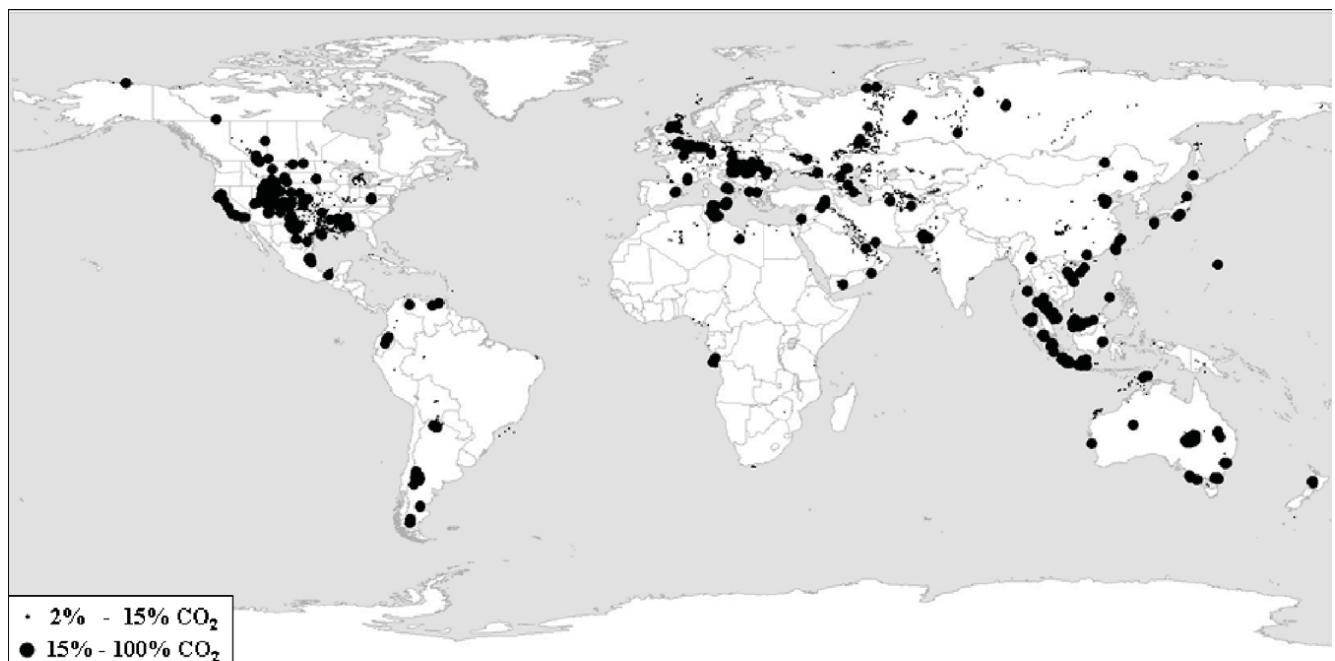


Figure 2 Global distribution of CO₂ content in percent

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Figure 3 Global hydrocarbon volumes; CO₂ 15% - 80%, un- or underdeveloped

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In West Australia the absence of suitable oil fields makes the storage of the recovered CO₂ in saline reservoirs necessary. Thus plans for the development of the Gorgon field call for the captured CO₂ to be stored under Barrow Island. This situation also occurred with other fields like Sleipner in the North Sea (ExxonMobil interest 34%), Snovit in the Barents Sea and In-Salah in Algeria. Each of these oil and gas industry projects captures CO₂ from produced natural gas. An important aspect of each of these projects is that the CO₂ needs to be removed from the produced gas to meet product quality specifications. The marketability of the hydrocarbon product gas includes the CO₂ removal requirement and makes the separation or capture component economically justified by itself. CO₂ captured from combustion sources will not have this advantage and will be burdened with the cost of capture. This anthropogenic CO₂ is certainly usable for CO₂-EOR (after compression to reservoir pressures), but it will not have the same economic advantage as CO₂ separated from natural gas, and thus will have a higher economic threshold.

Significant gas fields with a net hydrocarbon gas volume of more than 14 billion m³ are shown in Figure 3. The total summed-up proven and probable global resources are around 4 trillion m³ of net hydrocarbon gas [7]. These accumulations are mostly undeveloped or underdeveloped as the high CO₂ content (15 to 80%) severely limits their economic and environmental viability. These resources are primarily located in SE Asia / NW Australia, the Central USA., North Africa and Middle East. Emerging, more economical, gas separation technologies might foster their development in the future and facilitate further implementation of CO₂-EOR applications.

Potential CO₂-EOR opportunities are shown on Figure 4, which illustrates the location of oil fields potentially amenable to enhanced oil recovery. The availability of suitable oil fields in the Central USA has encouraged the limited development of some challenged gas resources. Similar opportunities may exist in the Middle East and North Africa. In SE Asia/ NW Australia there are larger hurdles to overcome as there is limited oil potential amenable to CO₂ miscible flooding.

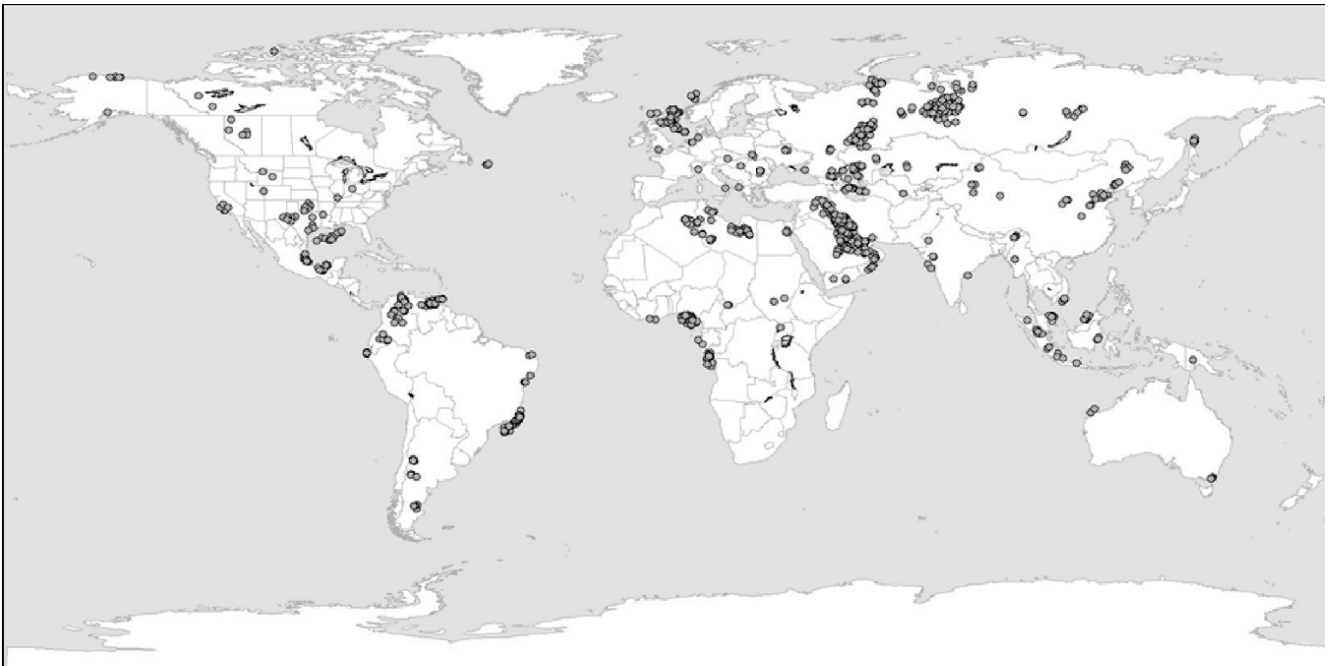


Figure 4 Global oil fields map ; > 250 MBO or 500 MBO (onshore USA and Canada)

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4. ExxonMobil's experience with handling sour gasses

The challenges of developing natural gas fields with a high CO₂ content can be best illustrated by ExxonMobil's development of the LaBarge field. This field, located in SW Wyoming, USA, was discovered in 1963, but production was delayed until 1986, because of the challenging gas composition of 65% carbon dioxide, 21% methane, 7% nitrogen, 5% hydrogen sulfide, and 0.6% helium. It is the lowest hydrocarbon content natural gas commercially produced in the world. The remote location relative to potential EOR opportunities and the absence of infrastructure for the transportation of CO₂ limited the early development of the CO₂ resources in LaBarge. Since, however, the increased recognition of the benefits of CO₂-EOR to improve the recovery from the aging oil resources has allowed the expansion of the CO₂ transportation infrastructure. Currently the majority of the recovered CO₂ is transported and sold to EOR operators.

ExxonMobil has continually enhanced its capabilities to capture and manage CO₂ at LaBarge. It uses Selexol, a physical solvent, to remove CO₂ and H₂S from the natural gas. H₂S was initially converted to elemental sulfur, but subsequently is being disposed of, along with a small portion of the CO₂, by acid gas injection (AGI) into a selected section of the same reservoir from which it is produced. Other technologies and approaches that have reduced CO₂ emissions include the ExxonMobil patented low BTU fuel co-generation system that substantially reduces CO₂ emissions when compared to emissions from purchased power [10].

Additionally, new technologies are being developed that may provide additional reductions in emissions, either at this site or at others with similarly challenged production streams. Construction of a commercial demonstration facility for ExxonMobil's Controlled Freeze Zone™ (CFZ) gas treatment technology has been completed at Shute Creek and operations are about to begin. The CFZ™ technology allows the single step separation of CO₂ and other contaminants from a natural gas stream without the use of solvents or absorbents. Its successful commercial demonstration would enable the development of increasingly sour gas resources around the world by substantially reducing gas treatment and geo-sequestration costs from these sources [9] [12].

5. Conclusions

The amount of undeveloped sour natural gas resources throughout the world is quite substantial. Globally a total of around 4 trillion m³ of hydrocarbon gas has been identified by summing individual undeveloped and underdeveloped fields with ultimate recoverable proven and probable resources larger than 14 billion m³ each and CO₂ content between 15% and 80%. The CO₂ associated with this sour gas totals to 15000 MT CO₂. Development of these fields might become economically and environmentally feasible as gas treatment costs are reduced with the introduction of novel technologies, such as the Controlled Freeze ZoneTM technology referred to in this paper. Additionally, the use of CO₂ for enhanced oil recovery may further enhance the economic viability of these developments.

The oil and gas industry has been successfully using CO₂ for EOR for nearly four decades. The technologies and operational practices for treating, transporting, and injecting CO₂ for EOR are well developed and are very similar to those technologies anticipated to be necessary for CCS. Many of these technologies are considered readily transferable and applicable to the CCS model suggested for mitigating GHG emissions.

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