SANGEA 4.0 – Facilitating Standardization of Greenhouse Gas Emissions Quantification for the Petroleum Industry

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ABSTRACT

Since the early 2000's, the American Petroleum Institute (API) has supported SANGEA[TM] as the standardized tool for petroleum energy companies to quantify greenhouse gas (GHG) emissions. Many large oil and gas companies have applied the spreadsheet-based tool for corporate GHG reporting requirements. In 2009, API published the updated Compendium 2009 with current industry best practices for estimating GHG emissions and the U.S. Environmental Protection Agency (USEPA) promulgated the Mandatory Reporting Rule (MRR) for GHG emissions for all industrial sources. In support of petroleum industry reporting efforts, API sponsored the development of the new SANGEA (Version 4) with new calculation methodologies and requirements. SANGEA-4 includes the GHG calculation methodologies from both Compendium 2009 and related USEPA MRR subparts.

SANGEA-4 is a desktop database program with a user-friendly interface that can be used to manage various types of sources throughout a large entity for corporate and/or USEPA MRR reporting requirements. SANGEA-4 provides calculation methodologies in various modules that are grouped based on API Compendium 2009 and corresponding USEPA MRR subparts. To standardize the calculation methods, input data for each source category are programmed with equations and associate emission factors published by both protocols.

This paper provides an overview of SANGEA-4 functions and features that can streamline reporting and recordkeeping processes. Examples, including emissions calculations based on both methods required by USEPA MRR and API Compendium, are presented to demonstrate how a company with both U.S. and international operations can apply the new software for multi-protocol reporting.

INTRODUCTION

SANGEA™ is a software program owned by the American Petroleum Institute (API). The objective of sponsoring SANGEA is to provide a user-friendly reporting tool to the oil and gas (O&G) industry and to encourage consistent reporting of GHG emissions. Each year, API conducts a survey on GHG emissions and criteria pollutants. SANGEA assists the industry in recording and benchmarking consistent and comparable data, and also in analyzing its environmental footprint.

SANGEA was originally developed by the Chevron Corporation as a GHG emissions reporting tool and implemented it across the entire corporation in the early 2000's. In June 2004, Chevron donated the ownership of SANGEA to API to make it available free of charge to the entire oil and gas

industry as a standardized method of GHG emissions estimation. API supported and distributed SANGEA (Version 3) expanding its use to O&G companies worldwide.

In 2009, API published the updated Compendium 2009 (1) with current industry best practices for estimating GHG emissions and the U.S. Environmental Protection Agency (USEPA) promulgated the Mandatory Reporting Rule (MRR) for GHG emissions for all industrial sources (2). With the development of new GHG emission accounting and reporting protocols and regulatory requirements, SANGEA-3 software has become obsolete.

To continue its support of facilitating standardized emissions accounting and reporting methods, API sponsored the development of the new SANGEA (Version 4) with new calculation methodologies and requirements. SANGEA-4 includes the GHG calculation methodologies from both Compendium 2009 and related subparts of the USEPA MRR (Subparts C, P, W, and Y). SANGEA-4 has been completely redesigned and programmed. The new software includes a user-friendly interface, emission factors, and calculation equations coded in VB.net using an Access database for storing emissions inventory records.

This paper provides an overview of SANGEA-4 functions and features that were designed and developed for O&G companies to streamline their GHG emissions reporting and recordkeeping processes. A copy of the software can be requested at http://www.api-sangea.org

OVERVIEW OF SANGEA 4.0 DESIGN

In 2010, API initiated the SANGEA-4 project and provided the following guiding principles for the software design and work scope:

1. Upgrade the current client distributed software model to be compatible using Microsoft Office 2007, Microsoft Office 2010 as well as the latest Microsoft OS releases of XP, Vista and Windows 7. The upgraded version must also retain the ability to create a flat data file so information from the software can be used for API GHG benchmarking studies, climate change industry reporting, as well as for submission into any federal GHG emission reporting programs and mandatory reporting rules.
2. Improve the usability, appearance and flexibility of the user interface.
3. Simplify maintenance and enhancements.
4. Update the online SANGEA™ user's manual to reflect the changes made in SANGEA-4.

Previous versions of SANGEA were developed within the Microsoft Excel environment and utilized VBA code to enforce the business logic. Through the planning and design phases, the project team recognized that the original development approach had a number of limitations and potential problems for long-term software usability and maintenance. Maintenance of such a system is very difficult and lends itself to compatibility issues when deploying the system across different environments utilizing various versions of Microsoft Excel. In addition, as users of SANGEA inevitably upgrade to newer versions of Microsoft Excel, functionality dependent on older versions of the spreadsheet application is often broken and cannot be made compatible. In consideration of these limitations, the final decision was to completely rebuild the SANGEA-4 interface around the Microsoft .NET Framework, using a Microsoft Access database for storage. The updated interface is a user-friendly desktop application that will be distributed to end-users with standard Windows operating systems. The new software provides much greater functional possibilities through the utilization of setup wizards to aid the users in data entry and also ensures that the application will continue to be

usable and expandable for future updates and modifications. Figure 1 shows the new SANGEA-4 user interface that is designed with a typical and intuitive software navigation style. The overall architecture of the new SANGEA-4 is presented in Figure 2.
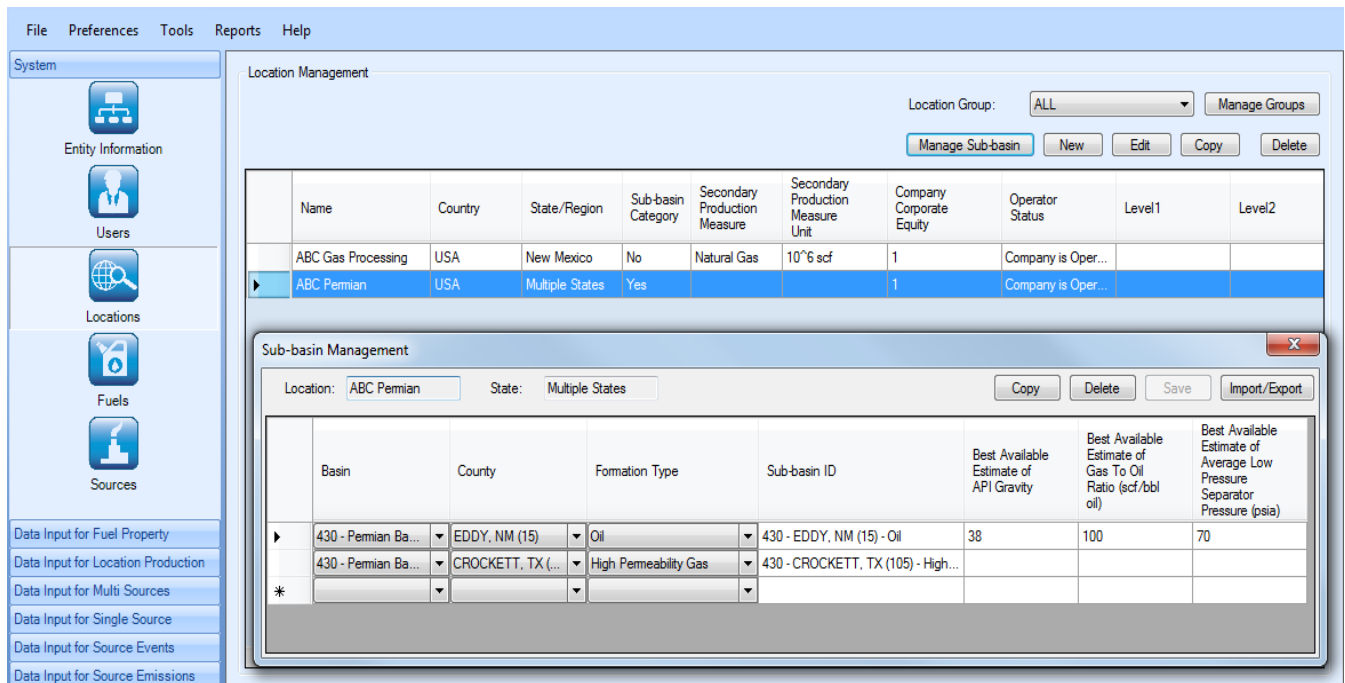

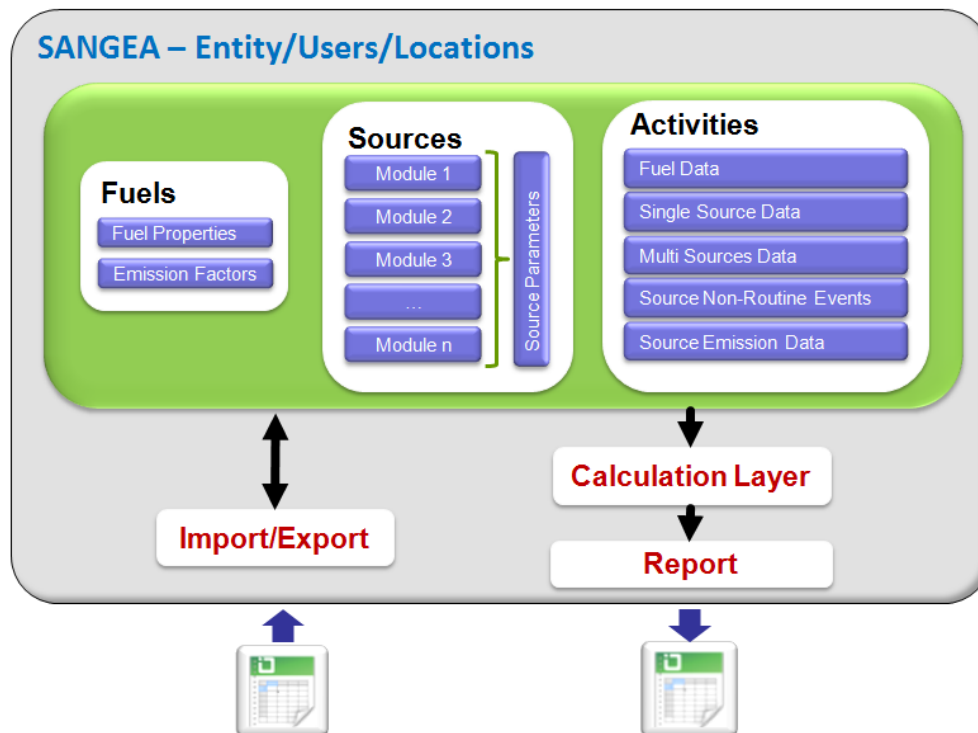Figure 1. A Glance of SANGEA-4 User Interface

Figure 2. Overall System Architecture of SANGEA-4

To maintain the reporting entity hierarchy applied by existing SANGEA users, the new SANGEA-4 keeps the same entity, location, and source set up process with extended steps to incorporate more source specific requirements under multiple protocols. Users must set up sources for a given location. Multiple locations can be created under one SANGEA-4 working file (i.e., a Microsoft Access database file), which allows companies to report emissions by business operation groups, geographical regions, or regulatory reporting entities. Figure 3 provides a typical reporting entity hierarchy structure that can be established in SANGEA-4.
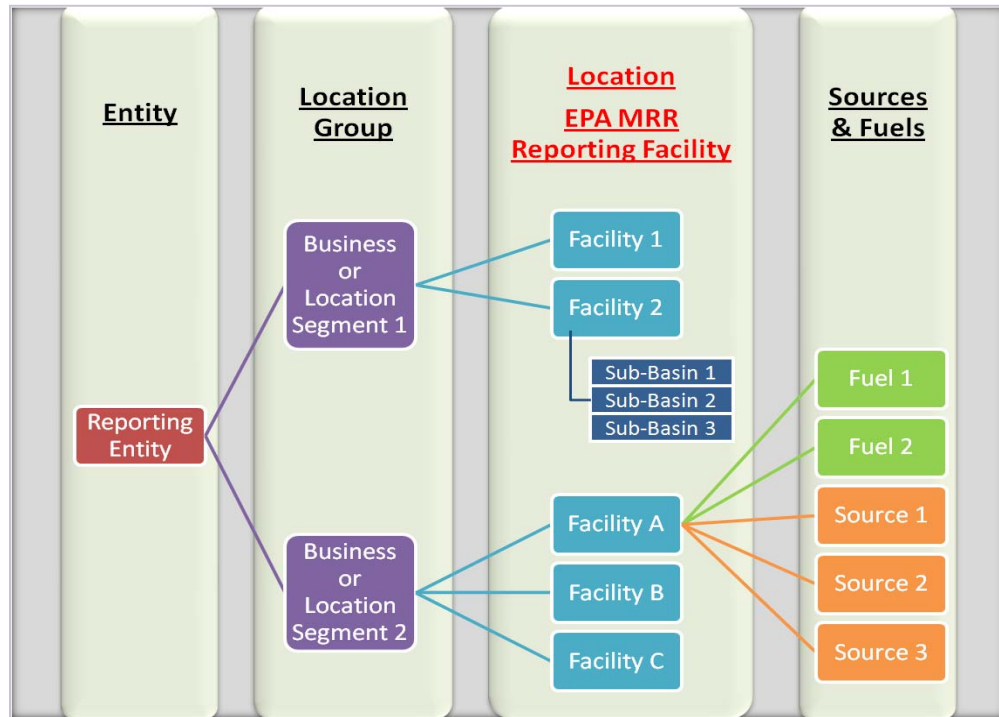

Figure 3. SANGEA-4 Reporting Entity Hierarchy

For each location, the user will set up all reportable sources and fuels applied at that site. The following steps provide a brief description of the basic process for setting up a new reporting entity.

Step 1: **Select overall preferences for a report.**

1.1 *Standard conditions (60 °F vs. 68 °F) used for emissions calculations.* To avoid confusion of the standard condition for different source types, all gaseous material volumes are set under one condition. API Compendium is based on 60 °F while USEPA MRR has mixed standard conditions. SANGEA-4 has converted emissions factors to cover both conditions.

1.2 *Whether to include criteria pollutants.* SANGEA-4 includes calculation methods for evaluating criteria pollutants based on emission factors from USEPA AP-42 (3) or user specified emission factors. If the user elects to calculate criteria pollutant emissions in SANGEA-4, additional questions for each source will appear for proper calculations.

Step 2: **Set up a reporting entity.** For each reporting entity, users will provide basic entity information with the primary product that will be used for normalizing GHG emissions.

Step 3:   **Set up reporting locations.** SANGEA reports emissions for a given location, which can be managed under location groups to cover business segments and/or geographical regions. In order to address USEPA Subpart W reporting requirements for onshore production, a sub-basin database is included in SANGEA-4.

Step 4:   **Set up location specific fuel types**. For each reporting location, users must select fuel types for combustion sources and flares. This will allow the user to maintain fuel property data and corresponding emission factors for all combustions sources at the reporting location.

Step 5:   **Select GHG calculation protocols.** Users can select a preferred protocol during the initial setup. However, when setting up a source, the user can select either API Compendium or USEPA MRR for the specific source.

Step 6:   **Configure emission sources under specific modules.** SANGEA-4 incorporates two GHG reporting protocols with a long list of source types for the petroleum industry. Table 1 shows the source "modules" developed in SANGEA-4. Under each module, multiple emission calculation methods have been configured as a wizard to help users set up emission sources without reading the methods in the protocols. The software guides users to specify source parameters that are needed for GHG emissions calculation and/or reporting requirements. These source parameters are stored in the software source database for future emission inventory reports. SANGEA-4 also offers a "User Defined Sources" module under the API Compendium protocol that allows users to include sources that are not already established in the two protocols of the SANGEA reporting system.

Table 1. Summary of Source Modules in SANGEA-4

SANGEA Source Modules	API Compendium 2009	USEPA MRR Subpart			
		C	P	W	Y
Acid Gas Removal (AGR)	√			√	
Combustion Control	√				
Dehydrator	√			√	
Equipment Leaks	√			√	√
Flare	√			√	√
Hydrogen Plant	√		√		
Indirect Emissions	√				
Liquid Loading	√				√
Miscellaneous	√				
Mobile and Transportation	√				
Oil and Gas Venting	√			√	
Refinery Process Units	√				√
Stationary Combustion	√	√		√	
Storage Tank	√			√	√
Sulfur Recovery Units (SRU)	√			√	
User Defined Sources	*				

* User defined sources allow users to create source types not covered under the protocols.

Step 7:	**Enter source activity data.** For each source set up in Step 6, users will enter activity data (e.g., fuel usage, annual operating hours, source specific carbon contents and many more for the reporting period). SANGEA-4 provides several source activity data entry methods to accommodate the many different sources type including:

7.1.	Fuel properties for fuels data available for the specific location. Monthly fuel sampling data can be specified.

7.2.	Single-source data entry for sources such as combustion emissions from one fuel type reported as one source. Monthly activity data (e.g., fuel usage) can be specified.

7.3.	Multi-source data entry for source activity data are designed to allow the user to enter source parameters for a group of sources such as tanks for onshore production. This is mostly for USEPA MRR sources.

7.4.	Event based sources data entry for sources that are not operated routinely and emissions occurred on an event-basis.

7.5.	Direct source emissions data entry allows users to enter emissions that are quantified by methods not included in SANGEA-4, such as emissions calculated based on continuous emissions monitoring system (CEMS) or software programs such as GRI GLYClac^{TM}.

7.6.	Location specific production data entry to support both USEPA MRR facility reporting requirements and API benchmarking with normalized emissions (e.g., tons GHG per barrel of production). Users can store production data for the reporting year.

Step 8:	**Select reports and execute the calculations.** SANGEA-4 uses Microsoft Reporting Services to generate various types of reports. Currently, the system includes more than 20 different reports. Users can select one report that can be displayed within the system. Results can also be exported to files in Excel.

In addition to the functions described in the source setup process, there are many user-friendly editing functions included in the system to assist users to create, delete and edit sources quickly. The following functions are presented as examples of these user-friendly features:

- Gas composition property and API gravity calculations.
- Source import and export tools in Excel spreadsheets for several common source types (e.g., combustion sources, O&G well venting sources, tanks, etc.). This will allow users to edit a large number of the same type of sources in Excel spreadsheets then import into SANGEA-4.
- Source parameters and calculation results exported to spreadsheets for further data processing that can be applied to reporting requirements.
- Copy an existing report file function copies all source parameters from the existing file but removes all activity data that should be updated for the new reporting year.

SANGEA-4 VALIDATION AND APPLICATION FOR GHG EMISSIONS

SANGEA-4 was released for beta testing in July 2012. All source modules, with the exception of the modules for the USEPA GHG MRR Subpart W covered sources, are finalized in this release. The software has been validated based on emissions inventories provided by the project team as well as examples provided in API Compendium 2009. For the Subpart W sources, the project team also performed validation calculations by comparing with the calculation spreadsheet tool developed by the USEPA to ensure the calculation are consistent with the rule requirements. All discrepancies were

revalidated with the MRR to ensure SANGEA had correctly captured the rule requirements. Some errors in the Subpart W calculation tool were reported to USEPA's electronic Greenhouse Gas Reporting Tool (e-GGRT) website.

Many companies have used previous versions of SANGEA and/or API Compendium (2004 or 2009) for corporate GHG emission reporting worldwide. Under the USEPA MRR reporting protocol, GHG emissions from U.S. based operations will be different from previous reports. Companies can set up sources with both protocols in SANGEA-4 and report emissions for each selected protocol. For the purpose of this paper, a small onshore gas processing plant with hypothetical source parameters will calculate its emissions using the two different protocols. Table 2 shows the source parameters used for this example facility.

Table 2. Source Parameters of the Example Gas Processing Facility

Source type	Source Input Information
Compressor 1 Combustion	A 4SLB unit with annual fuel usage of 50 mmscf/yr. Fuel type is natural gas.
Compressor 2 Combustion	A 4SRB unit with annual fuel usage of 68 mmscf/yr. Fuel type is natural gas.
Flare	Emissions from flaring events with total flare gas of 1.5 mmscf/yr with local specified fuel composition
Dehydrator Reboiler	A small boiler with annual fuel usage of 6 mmscf/yr. Fuel type is natural gas.
Dehydrator	An uncontrolled glycol dehydrator with a design capacity of 6 mmscfd unit.
Equipment Leaks	API protocol – A gas processing plant with 250 mmscf/yr gas processed
	EPA protocol – Two monitoring events with leak counts for various type of components; 800 hours average leak time for 1st monitoring event; 4200 hours average leak time for 2nd monitoring event
Compressor 1 Venting	API protocol – Included in facility level fugitive leaks
	EPA protocol – A centrifugal Compressor with measured release rate at 1 scf/hr for all operating mode; 8000 hours in operation and 200 hours in other modes. The release rate is used for testing only and not meant for a typical rate.
Compressor 2 Venting	API protocol – Included in facility level fugitive leaks
	EPA Protocol – A reciprocating Compressor with measured release rate at 1 scf/hr for all operating mode; 8000 hours in operation and 200 hours in other modes

The source input information in Table 2 does not include all details. The input information only provides a general description of the source, which will help in demonstrating the different approaches. The same source parameters used for the SANGEA USEPA MRR protocol are also entered in the USEPA Subpart W calculation tool to verify the calculation results. Table 3 provides a summary of the calculated results. The results between SANGEA and the USEPA Subpart W calculation tool are within insignificant differences that are due to the decimal points applied by the two tools. The differences between the API Compendium protocol and USEPA MRR protocol are summarized in the key findings:

1. Combustion sources – In USEPA MRR, all combustion units are calculated based on the same CH4 and N2O emission factors, which is very similar to the factors used in the API Compendium for boilers. However, API Compendium also provides additional CH4 and N2O factors for other combustion devices such as compressors. A higher CH4 emission factor is applied when reporting using the API protocol.

2. Flare – Since flare use local specified fuel composition, the results from the two protocols are very similar.
3. Dehydrator – Both protocols allow users to directly input results calculated using approved software, such as GRI GLYCalc. The protocols will produce identical results when the same GRI GLYCalc inputs are entered. However, if users choose to calculate dehydrator emissions using emission factors provided in the API protocol (i.e., a method not approved by EPA MRR), the emissions may be significantly different than the GRI GLYCalc results (i.e., a method approved by USEPA MRR). Table 3 shows the emissions calculated from the same unit using the two calculation methods.
4. Equipment leaks – The API Compendium provides fugitive leak factors at facility level, equipment level, and component by component. The equipment leaks result for API protocol provided in Table 3 is based on the facility level emission factors, which is a popular approach used by companies in previous GHG reports. Based on rule requirements, the USEPA protocol applies component-by component leaks with hypothetical leak times. The results between the two protocols differ drastically.
5. Compressor Venting: The API Compendium does not include compressor specific venting emission. Results from the USEPA protocol show the additional emissions from these source types.

Table 3. Summary of GHG Emissions Calculation Using Different Protocols

Source type	SANGEA Result		EPA Subpart W Calculation Tool
	API (tonnes CO2e)	EPA (tonnes CO2e)	
Compressor 1 Combustion	2887.68	2792.05	
Compressor 2 Combustion	4607.29	3789.22	
Dehydrator	264.00	620.44	620.09
Dehydrator Reboiler	343.06	343.47	
Equipment Leaks	161.94	322.05	323.70
Compressor 1 Venting		4.93	4.90
Compressor 2 Venting		5.86	5.83
Flare	95.41	96.12	95.42

CONCLUSION

SANGEA-4 is built in the latest software development technology, which allows for easy maintenance and future improvements. The reporting system can easily be expanded to provide industry normalized emissions as well as benchmarking analysis.

The purpose of SANGEA-4 is to facilitate standardization of GHG accounting and reporting for O&G companies across the globe. The U.S. EPA has developed detailed GHG emission accounting and reporting requirements and the API Compendium 2009 offers industry best practices to report GHG emissions. By combining the two protocols, SANGEA-4 allows companies to establish a reliable standardized GHG emission reporting system within one software product.

There are significant changes and additions of source types and emission factors in SANGEA-4 from the previous versions of SANGEA. For new users, SANGEA-4 provides a user friendly interface to help establish a new GHG emission inventory system for the reporting entity. Companies, who applied early versions of SANGEA for their previous GHG emission reports, would need to update their

GHG emissions inventory with the new methodologies. These companies will note significant differences for some of the sources. Users can use SANGEA-4 to quickly prepare and evaluate emissions for various source types and determine the differences. Users can also add new source types using SANGEA-4 to prepare a comprehensive GHG emissions inventory. Using SANGEA-4, these reporting entities can manage and generate annual emissions inventories in consistent and approved methodologies, which provide better quality control for entity-wide reporting.

ACKNOWLEDGEMENT

REFERENCES

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2. **USEPA.** *40 CFR 98, Subparts C, P, W, Y.* Washington, DC : GPO.
3. **USEPA.** *AP-42 - Emission Factors.* RTP, NC : OAQPS, USEPA.

KEY WORDS

API Compendium 2009, Emission Inventories, Greenhouse Gas, Mandatory Reporting Rule, MRR, Oil and Gas Industry, SANGEA, SANGEA-4, 40 CFR 98, Subpart C, Subpart W, Subpart Y