AMERICAN PETROLEUM INSTITUTE

API Compendium of GHG Emission Estimation Methodologies for the Oil and Gas Industry Version 3

API Side Event

CCAR Annual Meeting

1 April 2009

San Diego, California

Overview

1. Background
2. Compendium Organization
3. Overview of Methodologies
4. Path Forward

Compendium Background

- Emissions Methodology WG established in 1999 to work with the Climate Steering Committee
  - Multi-sector petroleum industry participation to ensure coordinated industry effort
- 2001 Pilot Version
- Updated February 2004
- Version 3 released in 2009

Objectives

- Promote consistent, standardized methodologies for oil and gas operations
- Assemble a expansive collection of relevant emission factors and methodologies
  - Utilize current public documents
- Provide descriptions of oil and gas industry operations and associated GHG sources that should be considered
- Develop emission inventory examples to demonstrate applicability of methodologies

Compendium At-A-Glance

- Comprehensive compilation of existing factors
  - Combustion and indirect emissions suitable for all industries
  - Non-combustion emissions linked to specialized oil and gas processes
- Decision trees to guide the user in selecting an estimation technique
  - Considerations of materiality, data availability, and accuracy
- Case studies from across the petroleum industry used to demonstrate the computational approach

Specific Attributes

- Classify devices/emissions sources into one of four categories, to streamline computations
- Preserve identity of original emission factors, in the units cited in literature
- Provide common reporting units, and example conversions for English and Metric systems
- Outline calculation methods that require different input complexity, and result in different accuracy

Version 3 - Key Revisions

- Updated decision trees
- Updated emission factors to reflect changes in referenced documents;
- Expanded discussion around emission estimation approaches for sources
  - Dehydration operations, acid gas removal, tank flashing, pneumatic devices, hydrogen plants, catalytic cracking units, asphalt blowing, wastewater treatment
- Added discussion on crude oil characteristics and limited GHG emissions from refined products
- Updated case studies to include additional emission sources and operations
- Revised discussion on inventory uncertainty
- Updated referenced uncertainty values to 95% confidence intervals

Compendium Organization

Industry Description

- Exploration and production
- Oil sands and heavy oil upgrading
- Coal bed methane production
- Gas processing
- Carbon capture and geological storage
- Natural gas storage and LNG operations
- Liquid transportation and distribution
- Natural gas transmission and distribution
- Refining
- Petrochemical manufacturing
- Minerals and mining operations
- Retail and marketing
- Energy generation

Compendium Organization

1. Introduction
2. Industry Description
3. Technical Considerations
4. Combustion Emission Estimation Methods
5. Vented Emission Estimation Methods
6. Fugitive Emission Estimation Methods
7. Indirect Emission Estimation Methods
8. Emission Inventory Examples

Compendium Organization, continued

APPENDICES:

A. Additional Combustion Calculation Information
B. Additional Venting Calculation Information
C. Additional Fugitive Calculation Information
D. Additional Indirect Calculation Information
E. Additional Information
F. Refinery Methane Fugitive Emission Study
Glossary

Compendium Sections 4-7 Emission Estimation Methods

- Organized by categories of emissions
  - Combustion, Vented, Fugitive
  - Indirect
- Compendium provides:
  - Discussion of emission source types
  - Multiple approaches to estimate emissions
  - Decision trees to guide approach selection
  - Example calculations

Compendium Section 8: Emission Inventory Examples

- Provides examples of calculating the GHG inventory for hypothetical facilities from each Oil & Gas Industry sector
- Describes the facility, capacity, and numbers and types of equipment
- Presents a summary of total GHG emissions and emissions by category
  - Aggregates uncertainty for each example facility
- Presents examples of each calculation

Reference Information

- Tables of fuel properties common in the oil and gas industry
- Conversion factors
  - Wt. % & Mole %, gas standard conditions, wet & dry gas, HHV & LHV
- Examples of calculations and units conversions
- References to sources of emission data and standards
- Emission factor derivation

Overview of Methodologies

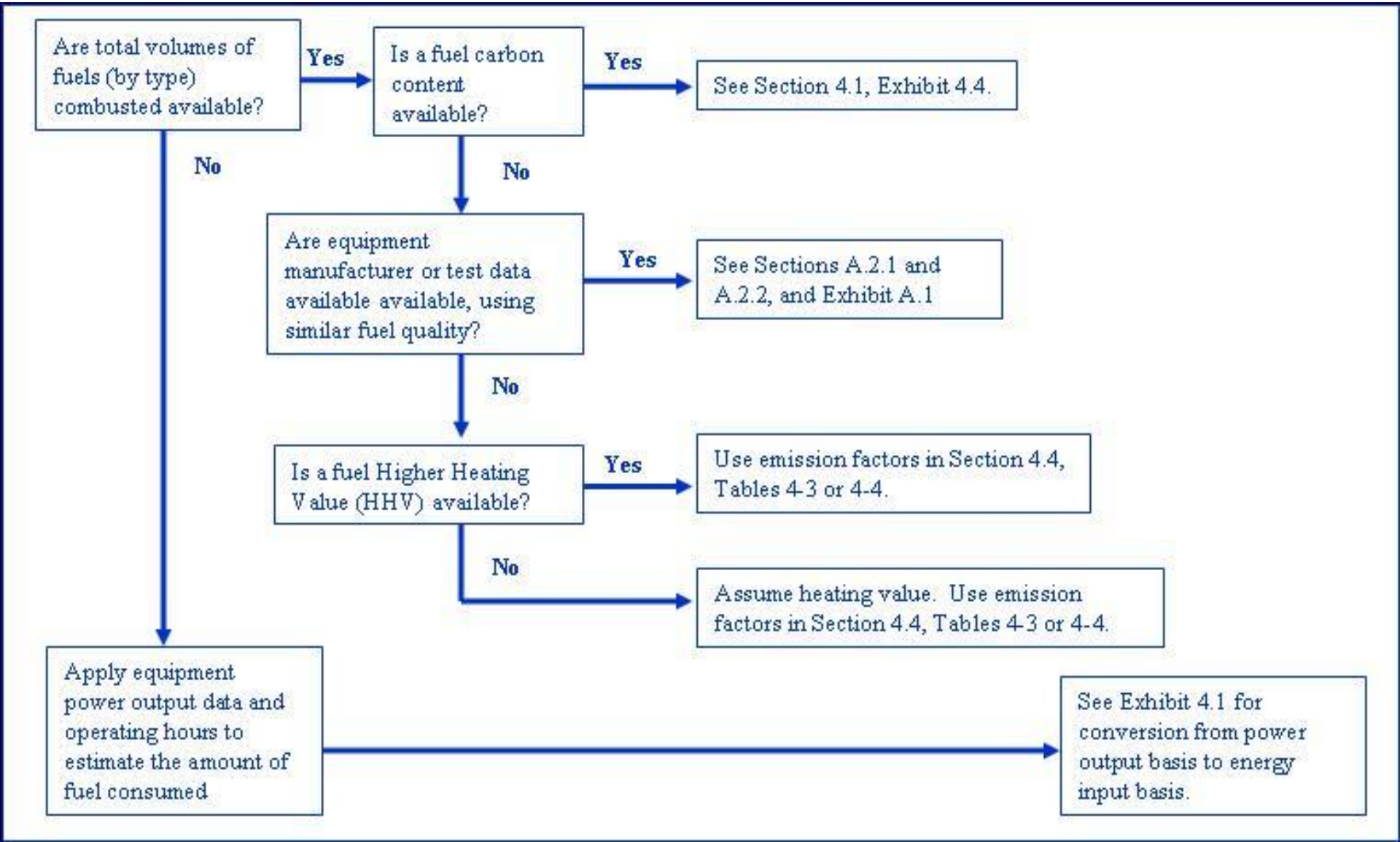
Emission Estimation Approaches

- Published emission factors
- Equipment manufacturer emission factors
- Engineering calculations
- Process simulation or other computer modeling
- Monitoring over a range of conditions and deriving emission factors
- Periodic or continuous monitoring of emissions or parameters for calculating emissions

Combustion Estimation Methods

Approaches	CO2 Emission Considerations	CH4 and N2O Emission Considerations
Published emission factors	Based on “average” fuel carbon content Commodity fuels generally have consistent compositions	Based on “average” equipment characteristics Uncertainty consistent with low emission contribution
Equipment manufacturer factors	CO2 emissions are related more to fuel type than equipment characteristics	Emissions are highly related to equipment characteristics
Engineering calculations	Highly reliable for many emission sources May require detailed input data	Limited application for oil and gas industry operations (e.g., flares)
Periodic or continuous monitoring	Generally not practical for oil and gas operations given the substantial number of sources	Not practical given the number of emission sources and low contribution to emissions

Combustion Decision Tree for CO2



Stationary Combustion

- Data requirements – fuel volume AND
  - carbon content OR
  - HHV
- Assume 100% conversion of C to CO_2

$$C_xH_yO_z + \left(x + \frac{y}{4} - \frac{z}{2}\right)O_2 \rightarrow (x)\,CO_2 + \left(\frac{y}{2}\right)H_2O$$

- CH_4 and N_2O emissions must be calculated separately

Flare Emission Estimation

- Test data or vendor specific information
  - Flare combustion efficiency
- Emissions calculated based on known or estimated the flare gas flow rate and composition
- For upstream operations, CAPP provides an approach for quantifying volumes of gas flared at typical upstream oil and gas facilities

Flared Gas Emission Estimation

- CO2 - 98% combustion efficiency supported by industry practice and recent studies
- CH4 - General industry practice and published emission factors
  - 0.5% residual CH4 for well designed flare (e.g. in a refinery)
  - 2% residual CH4 for production
- N2O – IPCC emission factors (also has default factors for CO2 and CH4)

Other Combustion Sources

- Incinerators, oxidizers and vapor combustion units
  - Methodology similar to flares
- Mobile/transportation combustion sources
  - Methodologies consistent with voluntary registries
  - Fuel based factors and mileage conversions

Conclusions – Combustion Sources

- Combustion is significant source of CO2 emissions
  - Composition and consumption rates provide highly reliable computation
- For most combustion devices, CH4 and N2O emissions are several orders of magnitude less than CO2
- General methodology is applicable to combustion devices used in other industries

Vented Emission Sources

- Releases through stacks, vents, ducts, etc.
- Process vents - emissions resulting from chemical transformation
- Generally specific to type of operation
- Organized by:
  - Industry segment
  - Common equipment

Vented Emission Source Types

- Gas Treatment
  - Glycol dehydrators
  - Acid gas removal/ sulfur recovery
- Refinery Processes
  - Catalytic cracking
  - Hydrogen plant
  - Asphalt blowing
- Uncontrolled crude storage tanks
- Loading, ballasting, transit
- Pneumatic devices
- Production operations
- Non-routine activities

Vented Emission Methodologies

Approaches	CH4 Non-combustion Emissions	CO2 Non-Combustion Emissions
Published emission factors	➢Based on “average” equipment and emission source characteristics	➢Limited EFs specific to non-combustion CO2 ➢May be scaled from CH4
Equipment manufacturer factors	➢Highly reliable for specific emission sources ➢Requires tracking the number of equipment by type	➢May be scaled from CH4 emission factors
Engineering calculations	➢Highly reliable for specific emission sources ➢May require detailed input data	
Periodic or continuous monitoring	➢Highly reliable for specific emission sources ➢Generally not practical given the substantial number of sources	Not practical given the number of sources and low contribution to overall emissions

Vented Emission Methodologies - Tanks

Emission Quantification Method	CH4 Flashing Losses (tonnes/yr)
Vasquez-Beggs Equation	8.04
Standing Correlation	6.44
EUB Rule-of-Thumb	24.56
Chart Approach	40.6
Simple Emission Factor Approach	107.4
E&P TANKS, Version 3.0	12.75
Measured	9.54

Conclusions – Vented Sources

- Several of the vented sources can have significant GHG emissions
  - Tank flashing losses
  - Catalytic crackers/cokers
  - Hydrogen plants
- Many of the other vented sources are relatively insignificant GHG sources
- Use the Compendium to help evaluate the significance of an emission source
- Pick a calculation method appropriate to the emission source's potential significance

Fugitive Emission Sources

- Equipment Leaks
  - Valves, flanges, pump seals, compressor seals, relief valves, sampling connections, process-drains, open-ended lines, etc.
- Other Fugitive Sources (non-point)
  - Typically small GHG emission sources
  - Wastewater treating, Biotreaters
- Fluorinated Fugitive Emissions

Fugitive Emission Sources

Approaches	CH4 Emissions	CO2 Emissions	PFC, HFC, SF6
Published emission factors	➢Based on "average" equipment and emission source characteristics	➢Limited EFs specific to CO2 ➢May be scaled from CH4	➢Consistent with low contribution to overall emissions
Engineering Calculations	➢Highly reliable for specific emission sources ➢May require detailed input data		➢Material balance provides good reliability ➢Requires data tracking
Periodic or continuous monitoring	➢Highly reliable for specific sources ➢Generally not practical given the number of sources	Not practical given the low contribution to overall emissions	

Conclusions – Fugitive Sources

- Significance of fugitive emissions depends on the GHG content of the stream and equipment/component counts
- Use the Compendium to help evaluate the significance of an emission source
- Pick a calculation method appropriate to the emission source's potential significance and the level of accuracy needed
  - Compendium suggests starting with a conservative screening approach first

Indirect Emission Sources

- Purchased electricity
  - Regional or country emission factors
  - Emission factors derived to explicitly exclude heat generation
- Purchased steam/heat
- District cooling

Cogeneration Allocation Approaches - Example

- A cogeneration facility operates 3 natural gas turbines, 3 heat recovery steam generators with supplemental duct firing capability, and a steam turbine
  - Consumes 8,131,500 MMBtu natural gas
  - Produces 3,614,000 MMBtu steam & 1,100,600 MW-hr electricity
  - Consumes 38,500 megawatt-hr of electricity to operate
- Refinery purchases 2,710,000 MMBtu of steam and 206,000 MW-hr electricity
- Net electricity (856,100 MW-hrs) sold to the grid

Cogeneration Comparison

	Allocation Approach	EU/ETS Efficiency Allocation	WRI/ WBCSD Efficiency Allocation	Energy Content	Work Potential
Cogeneration Facility	Fuel consumption	435,983			
	Electricity sold	228,579	253,670	180,581	269,672
	Net facility emissions	45,966	30,992	53,485	34,441
Refinery	Purchased electricity	55,002	58,413	41,582	64,890
	Purchased steam	106,436	92,908	160,335	66,980

Specific Cogeneration Considerations

- Cogeneration within an entity
  - Account for direct emissions
- Cogeneration of product streams and heat
  - Basic allocation approaches apply

Summary

- Robust methods for calculating, reporting, and tracking emissions are essential for cost-effectively managing GHG emissions
- Consistent methodologies lend credibility to the estimates and enable aggregation and comparison
- Petroleum Industry has taken significant steps towards attaining consistency