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COMPENDIUM OF GREENHOUSE GAS EMISSIONS METHODOLOGIES FOR THE OIL AND NATURAL GAS INDUSTRY

AUGUST 2009



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TABLE OF CONTENTS



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Complete Table of Contents

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PREFACE

The API *Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Natural Gas Industry* (referred to as the "API *Compendium*") was initially distributed in June 2001 as a "Pilot Test" version. Since the initial release, API has reached out to governmental, non-governmental, and industry associations to ensure broad peer review. In addition, API initiated a study to evaluate and compare other greenhouse gas estimation protocols and methodologies. These activities were conducted to better harmonize greenhouse gas emission estimation techniques and enable improved global comparability of emission estimates.

This document represents the third release of the API *Compendium*. The emission factors and methodologies presented here represent the latest information available at the time this document was published. Note, however, that estimating greenhouse gas emissions is an evolving process. As such, the API *Compendium* is intended to also evolve. There is a process for ongoing review and updates, and revisions will be made at regular intervals to incorporate new information. **In the interim, users are encouraged to check the documents referenced within the API *Compendium* for updates.**

API welcomes a continuing exchange of information and broad discussion of greenhouse gas emission estimation methodologies from users of the API *Compendium* and other interested parties. Please direct comments to Karin Ritter, Regulatory and Scientific Affairs Department, at API.

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Table of Contents

PREFACE ..... **II**

1.0 INTRODUCTION **1-1**

1.1 Background 1-2

1.2 Document Overview 1-3

1.3 Organization 1-4

1.4 References 1-7

2.0 INDUSTRY DESCRIPTION **2-1**

2.1 Overview 2-1

2.2 Industry Segment Descriptions 2-4

2.2.1 Conventional Exploration and Production 2-4

2.2.2 Oil Sands and Heavy Oil Upgrading 2-7

2.2.3 Coal Bed Methane Production 2-10

2.2.4 Gas Processing 2-11

2.2.5 Carbon Capture and Geological Storage 2-13

2.2.6 Natural Gas Storage and LNG Operations 2-15

2.2.7 Transportation and Distribution 2-18

2.2.8 Refining 2-21

2.2.9 Petrochemical Manufacturing 2-23

2.2.10 Minerals and Mining Operations 2-25

2.2.11 Retail and Marketing 2-26

2.2.12 Energy Generation 2-27

2.3 References 2-28

3.0 TECHNICAL CONSIDERATIONS **3-1**

3.1 Overview 3-1

3.2 Emission Sources 3-2

3.2.1 Combustion 3-2

3.2.2 Process Emissions and Vented Sources 3-2

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued

3.2.3 Fugitive Sources 3-3
3.2.4 Indirect Sources 3-3
3.3 Greenhouse Gases 3-4
3.3.1 Global Warming Potentials 3-5
3.3.2 Emissions Summaries 3-7
3.4 Data Requirements 3-9
3.5 Data Assumptions 3-11
3.6 Conversions, Numeric Format, and Fuel Properties 3-14
3.6.1 General Units Conversions 3-14
3.6.2 Numeric Format 3-17
3.6.3 Fuel Properties 3-17
3.6.4 Fuel Mixture Conversions 3-22
3.7 Emission Estimation Quality 3-29
3.7.1 General Statistical Approach to Calculating Uncertainty 3-30
3.7.2 Confidence Intervals from GRI/EPA Study 3-34
3.7.3 Quality Ratings 3-36
3.8 References 3-37

4.0 COMBUSTION EMISSIONS ESTIMATION METHODS 4-1

4.1 Estimating Fuel Consumption Data from Energy Output or Volumetric Flow 4-5
4.1.1 Estimating Fuel Consumption from Equipment Data 4-5
4.1.2 Conversion from Volumetric Flow Rate to Energy Input 4-10
4.2 Conversion Between Gross and Net Heating Value 4-10
4.3 Fuel Combustion Emissions Estimated from Fuel Composition and Usage 4-12
4.4 Fuel Combustion Emissions Estimated on a Fuel Basis for Stationary Sources 4-16
4.4.1 Emission Estimation Using Default Average Fuel Composition 4-16
4.4.2 Carbon Oxidation Values 4-16

Documents
Document Sharing Hub
Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued

4.5 Fuel Combustion Emissions Estimated on an Equipment Basis for Stationary Sources 4-24
4.5.1 External Combustion Units 4-25
4.5.2 Internal Combustion Units 4-32
4.6 Flare Emissions 4-37
4.7 Incinerators, Oxidizers, and Vapor Combustion Units 4-52
4.8 Mobile/Transportation Combustion Sources 4-53
4.8.1 Fuel Consumption Basis 4-55
4.8.2 Operational Basis 4-63
4.9 Other Miscellaneous Combustion Source Emissions 4-64
4.10 References 4-64

5.0 PROCESS AND VENTED EMISSIONS ESTIMATION METHODS 5-1
5.1 Gas Treatment Processes 5-2
5.1.1 Glycol Dehydrator Emissions 5-2
5.1.2 Glycol Pumps 5-7
5.1.3 Desiccant Dehydrators 5-10
5.1.4 Other Glycol Dehydrator Alternatives 5-11
5.1.5 Acid Gas Removal/Sulfur Recovery Units 5-12
5.2 Refinery Processes Vents 5-17
5.2.1 Catalytic Cracking Regenerator 5-17
5.2.2 Refinery Hydrogen Plant 5-23
5.2.3 Cokers 5-31
5.2.4 Other Catalyst Regeneration 5-32
5.2.5 Asphalt Blowing 5-34
5.2.6 Other Refinery Process Vents 5-36
5.3 Cold Process Vents 5-37
5.4 Storage Tank Emissions 5-40
5.4.1 Crude Flashing Losses 5-40
5.4.2 Tanks Working/Standing Losses 5-55

Documents
Document Sharing Hub
Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued

5.4.3 Produced Water Tank Emissions 5-56
5.4.4 Natural Gas Blanketed Tank Emissions 5-58
5.5 Loading, Ballasting, and Transit Loss Emissions 5-60
5.5.1 Loading Loss Emissions 5-62
5.5.2 Ballasting Emissions 5-63
5.5.3 Transit Loss Emissions 5-65
5.6 Other Venting Sources 5-66
5.6.1 Gas Driven Pneumatic Devices 5-66
5.6.2 Gas Driven Chemical Injection Pumps 5-71
5.6.3 Mud Degassing 5-74
5.6.4 Heavy Oil and Crude Bitumen Casing Gas Vents 5-76
5.6.5 Low Pressure Gas Well Casing Vents 5-79
5.6.6 Coal Seam Exploratory Drilling and Well Testing 5-80
5.6.7 Coal Mining 5-82
5.6.8 Chemical Production 5-85
5.7 Non-Routine Activities 5-86
5.7.1 Engineering Calculation Approach 5-88
5.7.2 Production Related Non-Routine Emissions 5-90
5.7.3 Gas Processing Related Non-Routine Emissions 5-99
5.7.4 Transmission Related Non-Routine Emissions 5-101
5.7.5 Distribution Related Non-Routine Emissions 5-104
5.7.6 Refining Related Non-Routine Emissions 5-106
5.8 Fire Suppressant Emissions 5-107
5.9 References 5-107

6.0 FUGITIVE EMISSION ESTIMATION METHODS 6-1
6.1 Equipment Leaks 6-2
6.1.1 Facility-Level Average Emission Factors Approach 6-5
6.1.2 Equipment-Level Average Emission Factors Approach 6-13
6.1.3 Component-Level Average Emission Factors Approach 6-27

Documents
Document Sharing Hub
Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued

6.1.4 Emissions from CO_2 Transport 6-38
6.1.5 Time Basis of Fugitive Equipment Leaks 6-38
6.2 Other Fugitive Emissions 6-38
6.2.1 Wastewater Treatment 6-39
6.2.2 Biotreaters 6-45
6.3 Fluorinated Fugitive Emissions 6-46
6.3.1 Emissions from Air Conditioning and Refrigeration Equipment 6-46
6.3.2 Electrical Equipment 6-50
6.3.3 SF_6 Emissions from Pipeline Operations 6-52
6.4 References 6-53

7.0 INDIRECT EMISSIONS ESTIMATION METHODS 7-1
7.1 Emissions Associated with Purchased or Imported Energy 7-1
7.1.1 Electricity from a Known Generator 7-1
7.1.2 Purchased Electricity from an Unknown Generator – State or Regional Basis 7-5
7.1.3 Purchased Electricity from an Unknown Generator – National Basis 7-10
7.1.4 Renewable Energy 7-16
7.1.5 Steam/Heat Utility Emissions 7-17
7.1.6 District Cooling Water Emissions 7-20
7.2 Allocation of Emissions Among Energy Streams 7-21
7.2.1 Cogeneration of Electricity and Steam 7-21
7.2.2 Cogeneration Within An Entity 7-39
7.2.3 Cogeneration of Product Streams and Heat 7-39
7.3 References 7-40

8.0 EMISSION INVENTORY EXAMPLES 8-1
8.1 Exploration and Production 8-2

Documents
Document Sharing Hub
Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued

8.1.1 Onshore Oil Field with High CO_2 Content 8-2
8.1.2 Offshore Oil and Natural Gas Production Platform..... 8-28
8.1.3 Natural Gas Processing Plant 8-56
8.1.4 Production Gathering Compressor Station..... 8-79
8.2 Transportation..... 8-95
8.2.1 Transmission/Distribution..... 8-95
8.2.2 Marketing Terminal 8-105
8.3 Refining..... 8-124
8.3.1 Refinery..... 8-124
8.4 Retail 8-146
8.4.1 Retail..... 8-146

APPENDIX A. ADDITIONAL COMBUSTION CALCULATION INFORMATION..... A-1
A.1 Methodology for Converting Between LHV and HHV Bases.....A-1
A.1.1 Solid Fuels A-1
A.1.2 Liquid Fuels.....A-2
A.1.3 Gases.....A-4
A.2 Additional Stationary Combustion Emission Factors A-4
A.2.1 Combustion Emissions Factor Comparison for Industrial Equipment.....A-4
A.2.2 Combustion Emissions Based on Equipment Manufacturer Data (Canadian).....A-8
A.3 Mobile Source Combustion Emissions - Operational Basis A-11
A.3.1 Automobiles/Passenger Vehicles.....A-11
A.3.2 Marine Vessels.....A-22
A.4 References A-27

APPENDIX B. ADDITIONAL VENTING CALCULATION INFORMATION B-1
B.1 Derivation of Asphalt Blowing Emission Factors.....B-1
B.2 Catalytic Cracking Regenerator "K_1, K_2, K_3" Approach B-3

Documents
Document Sharing Hub
Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued

B.3 Derivation of Simplified Tank Flashing Emission Factor B-6
B.3.1 Crude Oil Flashing Losses B-6
B.3.2 Condensate Flashing Losses B-7
B.4 Additional Loading, Ballasting, and Transit Loss Methodology B-8
B.4.1 Loading Loss Emissions B-8
B.4.2 Ballasting Emissions B-19
B.4.3 Transit Loss Emissions B-21
B.5 Production Sector High-/Low-Bleed Pneumatic Devices Emission Factor Development B-26
B.6 Additional Coal Mining Data B-28
B.7 Additional Vented Volume Calculation Methodologies B-31
B.7.1 Calculating Pressure Vessel Volume B-31
B.7.2 Calculating Well Unloading Emissions B-33
B.7.3 Calculating Pressure Relief Valve Release Volumes B-34
B.8 Derivation of Vented Emission Factors B-35
B.8.1 Derivation of Transmission Pipeline and Compressor Station Blowdown Emission Factor B-35
B.8.2 Derivation of Pipeline Blowdowns Emission Factor B-36
B.9 References B-37

APPENDIX C. ADDITIONAL FUGITIVE CALCULATION INFORMATION C-1

C.1 Additional Equipment Leak Emission Calculation Methodologies C-1
C.1.1 Screening Range Factor Approach C-1
C.1.2 Correlation Approach C-7
C.1.3 Unit-Specific Correlations C-11
C.1.4 Methane-Specific Data for Emission Rate Calculations C-11
C.1.5 Generic Component Counts C-15
C.2 Refinery Fugitive Emissions C-19
C.3 Derivation of Fugitive Emission Factors C-21
C.3.1 Onshore Oil Production Fugitive Emission Factor C-21

Documents
Document Sharing Hub
Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued

C.3.2 Onshore Gas Production Fugitive Emission Factors C-22
C.3.3 Gas Processing Fugitive Emission Factors C-27
C.3.4 Natural Gas Storage Station Fugitive Emission Factor C-29
C.3.5 Gas Transmission Fugitive Emission Factors C-30
C.3.6 Gas Distribution Fugitive Emission Factors C-35
C.3.7 Plastic Pipeline Fugitive Emission Leak Factors C-46
C.3.8 CO_2 Pipeline Fugutive Emissions C-47
C.4 References C-48

APPENDIX D. ADDITIONAL INDIRECT CALCULATION INFORMATION D-1
D.1 Development of International Electricity Grid Emission Factors D-1
D.2 Historical Electric Grid Emission Factors D-12
D.3 References D-16

APPENDIX E. ADDITIONAL INFORMATION E-1
E.1 "Weathered" Crude and Other Petroleum Product Vented CH_4 and CO_2 Emissions E-1
E.2 Default GRI/EPA Methane and Carbon Dioxide Compositions E-6
E.3 Atmospheric Oxidation of Emissions E-7
E.4 Non-GHG Emission Sources E-8
E.5 References E-9

APPENDIX F. REFINERY METHANE FUGITIVE EMISSIONS STUDY F-1
F.1 Overview F-1
F.2 Study Summary F-1
F.3 Conclusions F-3
F.4 References F-3

Documents
Document Sharing Hub
Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents
Tables

Table 1–1. Proposed Source Classification Approach 1-5

Table 2–1. Potential Greenhouse Gas Emission Sources by Sector: Conventional Exploration and Production 2-6

Table 2–2. Potential Greenhouse Gas Emission Sources by Sector: Oil Sands and Heavy Oil Upgrading 2-8

Table 2–3. Potential Greenhouse Gas Emission Sources by Sector: Coal Bed Methane Production 2-10

Table 2–4. Potential Greenhouse Gas Emission Sources by Sector: Processing 2-12

Table 2–5. Potential Greenhouse Gas Emission Sources by Sector: Carbon Capture and Geological Storage 2-14

Table 2–6. Potential Greenhouse Gas Emission Sources by Sector: Natural Gas Storage and LNG Operations 2-16

Table 2–7. Potential Greenhouse Gas Emission Sources by Sector: Liquid Transportation and Distribution 2-19

Table 2–8. Potential Greenhouse Gas Emission Sources by Sector: Natural Gas Transmission and Distribution 2-20

Table 2–9. Potential Greenhouse Gas Emission Sources by Sector: Refining 2-22

Table 2–10. Potential Greenhouse Gas Emission Sources by Sector: Petrochemical Manufacturing 2-23

Table 2–11. Potential Greenhouse Gas Emission Sources by Sector: Minerals and Mining Operations 2-25

Table 2–12. Potential Greenhouse Gas Emission Sources by Sector: Retail and Marketing 2-27

Table 2–13. Potential Greenhouse Gas Emission Sources by Sector: Electricity and Heat/Steam Generation 2-28

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table 3–1. Greenhouse Gas and Global Warming Potentials 3-6

Table 3–2. Emission Estimation Approaches – General Considerations 3-9

Table 3–3. Commonly Used Molar Volume Conversions..... 3-12

Table 3–4. Conversion Factors..... 3-14

Table 3–5. Temperature Conversions..... 3-16

Table 3–6. Unit Prefixes..... 3-17

Table 3–7. Hydrocarbon Molecular Weights and Gross Heating Values 3-19

Table 3–8. Densities, Higher Heating Values, and Carbon Contents for Various Fuels..... 3-20

Table 3–9. Natural Gas Carbon Contents by Heating Value..... 3-22

Table 4–1. Emission Estimation Approaches – GHG and Source Specific Considerations for Combustion Sources..... 4-2

Table 4–2. Energy Conversions by Generator Type..... 4-7

Table 4–3. CO_2 Combustion Emission Factors (Fuel Basis) for Common Industry Fuel Types 4-17

Table 4–4. CO_2 Combustion Emission Factors (Fuel Basis) for Specialized Fuel Types..... 4-20

Table 4–5. CH_4 and N_2O Combustion Emission Factors (Fuel Basis) for Common Industry Fuel Types..... 4-21

Table 4–6. CH_4 and N_2O Combustion Emission Factors (Fuel Basis) for Specialized Fuel Types..... 4-22

Table 4–7. Equipment-Specific Combustion Emission Factors for Boilers and Furnaces (Gas and Liquid Fuels)..... 4-26

Table 4–8. Equipment-Specific Combustion Emission Factors for Boilers and Furnaces (Solid Fuels)..... 4-30

Table 4–9. Engines and Turbines Emission Factors..... 4-33

Table 4–10. “Generic” Upstream Gas Composition 4-39

Table 4–11. GHG Emission Factors for Gas Flares in Developed Countries... 4-42

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table 4–12. GHG Emission Factors for Gas Flares in Developing Countries and Countries with Economies in Transition 4-44

Table 4–13. Default Fuel Economy Factors for Different Types of Mobile Sources 4-57

Table 4–14. Default Fuel Economy Factors for Diesel Freight Mobile Sources 4-57

Table 4–15. Default Fuel Consumption for Marine Vessels 4-58

Table 4–16. Default Fuel Consumption by Engine Type 4-58

Table 4–17. Mobile Source Combustion Emission Factors 4-59

Table 5–1. Emission Estimation Approaches – GHG and Source Specific Considerations for Vented Sources 5-1

Table 5–2. Segment Specific Uncontrolled Gas Dehydration CH_4 Emission Factors 5-4

Table 5–3. GLYCalc™ Generated Dehydration Methane Emission Factors 5-5

Table 5–4. GRI/EPA Kimray Pump CH_4 Emission Factors 5-8

Table 5–5. Uncontrolled AGR CH_4 Emission Factor 5-14

Table 5–6. Composition of U.S. Pipeline-Quality Natural Gas 5-29

Table 5–7. Default Asphalt Blowing Emission Factors 5-34

Table 5–8. Methane Flashing Loss Emission Factors for Crude Oil Storage Tanks 5-52

Table 5–9. Summary of Production Tank Flashing Losses Using Different Correlation Equation Approaches 5-54

Table 5–10. Produced Salt Water Tank Methane Flashing Emission Factors 5-57

Table 5–11. Methane Emission Factors from Produced Water from Shallow Gas Wells 5-57

Table 5–12. Simplified TOC Emission Factors for Loading Losses 5-62

Table 5–13. Average TOC Emission Factors for Crude Oil Ballasting Operations 5-64

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table 5–14. Simplified TOC Emission Factors for Marine Transit Losses 5-65

Table 5–15. Gas-Driven Pneumatic Device CH_4 Emission Factors 5-68

Table 5–16. Gas-Driven Chemical Injection Pump CH_4 Emission Factors 5-73

Table 5–17. Mud Degassing Vented CH_4 Emission Factors 5-75

Table 5–18. Heavy Oil and Crude Bitumen Casing Gas Vented CH_4 Emission Factors – Throughput Basis 5-77

Table 5–19. Heavy Oil and Crude Bitumen Casing Gas Vented CH_4 Emission Factors – Well Basis 5-77

Table 5–20. Average U.S. Coal Mining CH_4 Emission Factors 5-83

Table 5–21. Australian Coal Mining CH_4 Emission Factors 5-84

Table 5–22. Chemical Production Emission Factors 5-86

Table 5–23. Production Segment CH_4 Emission Factors for Maintenance and Turnaround Activities 5-91

Table 5–24. Production Segment CH_4 Emission Factors for Other Non-Routine Releases 5-98

Table 5–25. Gas Processing Segment CH_4 Emission Factor for Non-Routine Activities 5-100

Table 5–26. Transmission Segment CH_4 Emission Factors for Non-Routine Activities 5-102

Table 5–27. Gas Distribution Segment CH_4 Emission Factors for Non-Routine Activities 5-104

Table 6–1. Emission Estimation Approaches – GHG and Source Specific Considerations for Fugitive Sources 6-1

Table 6–2. Facility-Level Average Fugitive Emission Factors 6-8

Table 6–3. Fugitive Emission Factors for Onshore Crude Production Equipment 6-15

Table 6–4. Fugitive Emission Factors for Onshore Natural Gas Production Equipment 6-16

Table 6–5. Fugitive CH_4 Emission Factors for Natural Gas Processing Equipment 6-17

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table 6–6. Fugitive Emission Factors for Natural Gas Transmission and Storage Equipment 6-17

Table 6–7. Fugitive Emission Factors for Gas Distribution Equipment 6-18

Table 6–8. Fugitive Emission Factors for Distribution M&R Stations 6-19

Table 6–9. More Detailed Fugitive Emission Factors for Natural Gas Transmission Equipment 6-22

Table 6–10. More Detailed Fugitive Emission Factors for Natural Gas Distribution Equipment 6-24

Table 6–11. Fugitive Emission Factor from Underground Plastic Pipelines by Construction Year 6-26

Table 6–12. EPA Average Oil and Natural Gas Production Emission Factors 6-29

Table 6–13. API Average Offshore Fugitive Emission Factors 6-29

Table 6–14. API Oil and Natural Gas Production Average Emission Factors 6-30

Table 6–15. Natural Gas Plant, Gathering Compressor Station, and Well Site Average Emission Factors 6-31

Table 6–16. API natural Gas Plant Average Emission Factors 6-31

Table 6–17. Natural Gas Transmission Compressor Station Component Emission Factors 6-32

Table 6–18. Natural Gas Transmission and Storage Average Emission Factors 6-33

Table 6–19. Natural Gas Distribution Meter/Regulator Stations Average Emission Factors 6-34

Table 6–20. Natural Gas Distribution Commercial and Residential Sites Average Emission Factors 6-34

Table 6–21. Additional Natural Gas Facility Average Emission Factors 6-35

Table 6–22. Additional Oil Facility Average Emission Factors 6-36

Table 6–23. Default MCF Values for Aerobic Industrial Wastewater Treatment 6-41

Table 6–24. Default MCF Values for Anaerobic Industrial Wastewater Treatment 6-42

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table 6–25. Default Operating Emission Factors for Refrigeration / Air Conditioning Equipment 6-48

Table 6–26. Global Warming Potentials for Refrigeration Blends 6-48

Table 6–27. Usage Based Fugitive Emission Factors for Electrical Equipment 6-50

Table 6–28. Distance-Based Fugitive Emission Factors for Electrical Transmission and Distribution 6-51

Table 7–1. Electricity Usage Emission Factors by Method of Generation 7-3

Table 7–2. Average U.S. Electricity Usage Emission Factors by eGrid Subregion - 2005 7-6

Table 7–3. Average Australian Electricity Usage Emission Factors 7-8

Table 7–4. Average Canadian Electricity Usage Emission Factors by Province (2006 data) 7-9

Table 7–5. OECD Member Country International Electric Grid Emission Factors (Generation Basis) 7-11

Table 7–6. Non-OECD Member Country International Electric Grid Emission Factors (Generation Basis) 7-13

Table 7–7. Typical Chiller Coefficients of Performance 7-20

Table 8–1. Gas Composition for Onshore Oil Field (High CO_2 Content) 8-2

Table 8–2. Onshore Oil Field (High CO_2 Content) Emissions Sources 8-3

Table 8–3. Onshore Oil Field (High CO_2 Content) Fugitive Emission Sources 8-5

Table 8-4. On-Shore Oil Field (High CO_2 Content) Fugitive Emission Factors 8-22

Table 8–5. On-Shore Oil Field (High CO_2 Content) Fugitive Emissions 8-23

Table 8–6. On-Shore Oil Field (High CO_2 Content) Emissions 8-26

Table 8–7. Gas Composition for Offshore Production Platform 8-28

Table 8–8. Offshore Oil and Natural Gas Production Platform Emissions Sources 8-29

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table 8–9. Offshore Oil and Natural Gas Production Platform Fugitive Emission Sources 8-32

Table 8–10. Offshore Oil and Natural Gas Production Platform Fugitive Liquid Weight Percents 8-32

Table 8–11. Offshore Oil and Natural Gas Production Platform Fugitive Emissions Factors 8-51

Table 8-12. Offshore Oil and Natural Gas Production Platform Fugitive Emissions 8-53

Table 8-13. Offshore Oil and Natural Gas Production Platform Emissions 8-54

Table 8-14. Gas Composition for Natural Gas Processing Plant 8-56

Table 8-15. Natural Gas Processing Emission Sources 8-57

Table 8-16. Natural Gas Processing Fugitive Emission Sources 8-60

Table 8-17. Natural Gas Processing Fugitive Emission Factors 8-73

Table 8-18. Natural Gas Processing Fugitive Emissions 8-74

Table 8-19. Natural Gas Processing Emissions 8-76

Table 8-20. Gas Composition for Production Gathering Compressor Station 8-79

Table 8-21. Production Gathering Compressor Station Combustion and Vented Sources 8-80

Table 8-22. Production Gathering Compressor Station Fugitive Emission Sources 8-81

Table 8-23. Production Gathering Compressor Station Fugitive Emission Factors 8-89

Table 8-24. Production Gathering Compressor Station Fugitive Emissions 8-90

Table 8-25. Production Gathering Compressor Station Emissions 8-94

Table 8-26. Transmission/Distribution Emission Sources 8-96

Table 8-27. Transmission/Distribution Emissions 8-104

Table 8-28. Marketing Terminal Emission Sources 8-106

Table 8-29. Marketing Terminal Fugitive Emission Sources 8-107

Table 8-30. Marketing Terminal Emissions 8-123

Table 8-31. Refinery Fuel Streams 8-124

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table 8-32. Refinery Emissions Sources 8-126

Table 8-33. Refinery Cogeneration Emission Summary – WRI/WBCSD Efficiency Allocation Approach 8-144

Table 8-34. Refinery Emissions 8-145

Table 8-35. Retail Emissions Sources 8-147

Table 8-36. Retail Emissions 8-151

Table A–1. External Combustion Industrial Source Emission Factor Comparison A-6

Table A–2. Internal Combustion Industrial Source Emission Factor Comparison A-7

Table A–3. Waukesha Reciprocating Engines Combustion Emission Factors A-9

Table A–4. CAT Reciprocating Engines Combustion Emission Factors A-10

Table A–5. Default Distance Based CO_2 Mobile Source Emission Factors for the United Kingdom A-12

Table A-6. CH_4 and N_2O Emission Factors for Highway Vehicles by Model Year A-12

Table A–7. Default Distance Based CH_4 and N_2O Mobile Source Emission Factors for U.S. Vehicles A-15

Table A–8. Default Distance Based CH_4 and N_2O Mobile Source Emission Factors for European Vehicles A-16

Table A–9. Default Distance Based CH_4 and N_2O Mobile Source Emission Factors for Alternative Fuel Vehicles A-21

Table A–10. Default Operational Based Emission Factors for Marine Vessels A-24

Table B–1. Default Asphalt Blowing Exhaust Composition B-1

Table B–2. Coke Burn Rate Material Balance Conversion Factors B-4

Table B–3. Crude Oil Tank Flashing Loss Emission Factor Development B-6

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table B–4. Condensate Tank Flashing Loss Emission Factor Development B-7

Table B–5. Average Arrival TOC Emission Factor, C_A, for the Crude Oil Marine Vessel Loading Emission Factor Equation B-10

Table B–6. Properties of Select Petroleum Liquids B-11

Table B–7. Saturation, S, Factors for Estimating Loading Losses B-14

Table B–8. TOC Emission Factors for Gasoline Loading at Marine Terminals B-16

Table B–9. TOC Emission Factors for Marine Loading of Additional Petroleum Products B-17

Table B–10. TOC Emission Factors for Rail/Truck Loading Losses B-17

Table B–11. Simplified TOC Emission Factors for Gasoline Ballasting Losses B-21

Table B–12. Simplified TOC Emission Factors for Rail/Truck Gasoline Transit Losses B-23

Table B–13. Simplified TOC Emission Factors for Marine Transit Losses B-24

Table B–14. Production Sector Pneumatic Device High/Low-Bleed Emission Factor Development B-26

Table B–15. U.S. Total Coal Production, 2005 - 2007 ..... B-28

Table B–16. U.S. CH_4 Emissions from Coal Mining Activities, 2005 - 2007 ..... B-29

Table B–17. CH_4 Emission Factors for Coal Mining B-29

Table B–18. Coal Mining Emission Factors by Coal Supply Region B-30

Table B–19. Volume Per Meter of Pipeline Length B-32

Table B–20. Transmission Compressor Station Blowdown Emission Factor Development B-35

Table B–21. Transmission Pipeline Blowdown Vented Emission Factor Development B-36

Table B–22. Distribution Pipeline Blowdown Vented Emission Factor Development B-37

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table C–1. EPA Oil and Natural Gas Production Screening Factors C-3

Table C–2. API Oil and Natural Gas Production and Processing Screening Factors C-4

Table C–3. Petroleum Industry Leak Rate/Screening Value (SV) Correlations C-8

Table C–4. Default-Zero Values for the Petroleum Industry C-8

Table C–5. Pegged Emission Rates for the Petroleum Industry C-9

Table C–6. "Generic" Speciation Factors for Component Specific THC Emissions Factors for Oil and Natural Gas Operations C-12

Table C–7. "Generic" Production (Canadian) Composition by Service C-13

Table C–8. "Generic" Fugitive Counts for Onshore Oil Production Facilities (per Equipment/Process Type) C-16

Table C–9. "Generic" Fugitive Counts for Gas Production, Gas Processing, and Offshore Facilities (per Equipment/Process Type) C-17

Table C–10. Summary of the Number of Vessels, Compressors, and Pumps Associated with Various Gas Processes C-18

Table C–11. EPA Average Refinery Emission Factors C-20

Table C–12. Refinery Screening Factors C-21

Table C–13. Derivation of Facility-Level Average Fugitive Emission Factor for Onshore Oil Production C-22

Table C–14. Derivation of Facility-Level Average Fugitive Emission Factor for Onshore Gas Production C-23

Table C–15. Derivation of Equipment-Level Fugitive Emission Factors for Gas Production C-24

Table C–16. Derivation of Fugitive CH_4 Emission Factors for Gas Gathering Pipelines, by Pipe Material C-25

Table C–17. Derivation of Combined Fugitive CH_4 Emission Factor for Natural Gas Gathering Pipelines C-26

Table C–18. Derivation of Fugitive CO_2 Emission Factors for Natural Gas Gathering Pipelines, by Pipe Material C-26

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table C–19. Derivation of Combined Fugitive CO_2 Emission Factors for Gas Gathering Pipelines C-27

Table C–20. Derivation of Facility and Equipment-Level Fugitive Emission Factors for Gas Processing C-28

Table C–21. Derivation of Facility-Level Average Natural Gas Storage Station Fugitive Emission Factor C-29

Table C–22. Derivation of Facility-Level Average Fugitive CH_4 Emission Factor for Gas Transmission Pipelines C-30

Table C–23. Derivation of Detailed Equipment-Level Fugitive CH_4 Emission Factors for Gas Transmission Pipelines, by Pipe Material ... C-31

Table C–24. Derivation of Equipment-Level Gas Transmission Pipeline Fugitive CH_4 Emission Factor C-32

Table C–25. Derivation of Fugitive CO_2 Emission Factors for Gas Transmission Pipelines, by Pipe Material C-32

Table C–26. Derivation of Equipment-Level Average Fugitive CO_2 Emission Factors for Gas Transmission Pipelines C-33

Table C–27. Derivation of Facility-Level Average Gas Transmission Pipeline Fugitive CO_2 Leak Emission Factor C-34

Table C–28. Derivation of M&R Stations Fugitive CH_4 Emission Factor C-35

Table C–29. Derivation of Facility-Level Average Fugitive CH_4 Emission Factor for Gas Distribution Pipelines C-36

Table C–30. Derivation of Equipment-Level Fugitive CH_4 Emission Factors for Gas Distribution Mains, by Pipe Material C-37

Table C–31. Derivation of Equipment-Level Average Fugitive CH_4 Emission Factor for Gas Distribution Mains C-38

Table C–32. Derivation of Fugitive CO_2 Emission Factors for Gas Distribution Mains, by Pipe Material C-38

Table C–33. Derivation of Equipment-Level Average Fugitive CO_2 Emission Factor for Gas Distribution Mains C-39

Table C–34. Derivation of Detailed Fugitive CH_4 Emission Factors for Gas Distribution Services, by Pipe Material C-40

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table C–35. Derivation of Equipment-Level Average Fugitive CH_4 Emission Factor for Gas Distribution Services C-40

Table C–36. Derivation of Fugitive CO_2 Emission Factors for Gas Distribution Services, by Pipe Material C-41

Table C–37. Derivation of Equipment-Level Average Fugitive CO_2 Emission Factor for Gas Distribution Services C-42

Table C–38. Derivation of Facility-Level Average Fugitive CO_2 Emission Factors for Gas Distribution Pipelines C-43

Table C–39. Derivation of Equipment-Level Fugitive CH_4 Emission Factor for Customer Meters C-44

Table C–40. Derivation of Equipment-Level Fugitive CH_4 Emission Factor for Distribution/Meter Reg. Stations C-45

Table C–41. Derivation of Fugitive Emission Leak Factor from Plastic Pipelines by Construction Year C-46

Table D–1. Summary of Year 2006 Electricity Generation Information for OECD Countries D-2

Table D–2. Summary of Year 2005 Electricity Generation Information for Non-OECD Countries D-7

Table D–3. OECD Member Country International Electric Grid Emission Factors, Average of 2000 – 2002 Data (Generation Basis) D-13

Table D–4. Non-OECD Member Country International Electric Grid Emission Factors, Average of 2000 – 2001 Data (Generation Basis) .. D-14

Table D–5. Average Canadian Electricity Usage Emission Factors by Province (1999-2001 data) D-16

Table E–1. Liquid “Weathered” Crude Speciation Data E-1

Table E–2. Average Liquid Compositions by Fuel Type E-2

Table E–3. Vapor Phase Speciation Data E-4

Table E–4. Default GRI/EPA Methane and Carbon Dioxide Compositions E-6

Table F–1. Refinery Background Data F-1

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents, continued
Tables

Table F–2. Refinery A Greenhouse Gas Emissions Inventory F-2
Table F–3. Refinery A Fugitive CH_4 Emissions Summary F-2
Table F–4. Refinery B Greenhouse Gas Emissions Inventory F-2
Table F–5. Refinery A Fugitive CH_4 Emissions Summary F-3

Documents
Document Sharing Hub
Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents
Figures

Figure 2–1. Oil and Natural Gas Industry Schematic of GHG Emissions 2-2

Figure 4–1. Calculating CO_2 Emissions from Stationary Combustion Sources (Not Including Flares) 4-3

Figure 4–2. Calculation Approaches for Gas Flare Emissions 4-38

Figure 4–3. Calculation Approaches for Mobile Source CO_2 Emissions 4-55

Figure 5–1. CH_4 Emissions from Glycol Dehydrators 5-3

Figure 5–2. CH_4 Emissions from Acid Gas Removal (AGR) Units 5-13

Figure 5–3. CO_2 Emissions from Fluid Catalytic Cracking Units (FCCU) 5-19

Figure 5–4. CO_2 Emissions from a Refinery Hydrogen Plant 5-25

Figure 5–5. Decision Tree for Crude Oil Flashing Losses 5-42

Figure 5–6. Flashing Losses Chart 5-50

Figure 5–7. Decision Tree for Non-Routine Activities 5-87

Figure 6–1. Emission Estimation Approaches for Fugitive Equipment Leaks 6-3

Figure 6–2. Boundaries Between Crude and Natural Gas Production Equipment 6-7

Figure 6–3. Wastewater Treatment 6-40

Figure 6–4. Refrigerant Emissions 6-47

Figure 7–1. Decision Tree for Purchased Electricity Emissions 7-2

Figure 7–2. eGRID Subregion Map 7-7

Figure 8–1. Onshore Oil Field (High CO_2 Content) Summary of Emissions 8-25

Figure 8–2. Offshore Oil and Natural Gas Production Platform 8-53

Figure 8–3. Natural Gas Processing Summary of Emissions 8-75

Figure 8–4. Production Gathering Compressor Station Summary of Emissions 8-93

Documents
Document Sharing Hub

Full document details: Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry 2009

Table of Contents
Figures

Figure 8–5. Transmission/Distribution Summary of Emissions 8-103
Figure 8–6. Marketing Terminal Summary of Emissions..... 8-122
Figure 8–7. Refinery Summary of Emissions 8-144
Figure 8–8. Retail Summary of Emissions 8-150

Figure B–1. Decision Tree for Crude Loading Losses B-8
Figure B–2. Decision Tree for Gasoline and Other Liquid Loading Losses.....B-9
Figure B–3. Decision Tree for Petroleum Liquid Ballasting Emissions.....B-19

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Document Sharing Hub
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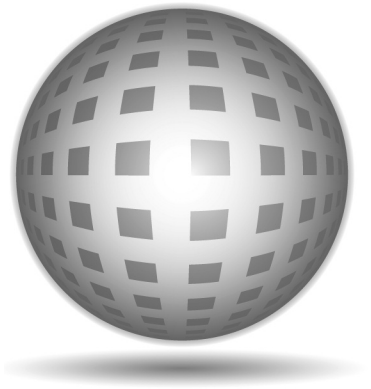
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COMPENDIUM OF GREENHOUSE GAS EMISSIONS METHODOLOGIES FOR THE OIL AND NATURAL GAS INDUSTRY

AUGUST 2009

SECTION 1
INTRODUCTION



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Section 1 - Introduction

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Documents
Document Sharing Hub

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Table of Contents

1.0 Introduction 1-1

1.1 Background 1-2

1.2 Document Overview 1-3

1.3 Organization 1-4

1.4 References 1-7

List of Tables

Table 1-1. Proposed Source Classification Approach 1-5

Documents
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Documents
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1.0
INTRODUCTION

The American Petroleum Institute (API) and many of its member companies are implementing action plans for addressing greenhouse gas (GHG) concerns and policy issues. Concurrently, local, regional, national and international bodies are developing or revising their guidance on estimating, reporting, and verifying GHG emissions. This document is a compendium of currently recognized methods and provides details for all oil and natural gas industry segments to enhance consistency in emissions estimation.

This API *Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Natural Gas Industry* (referred to as the API *Compendium*) aims to accomplish the following goals:

- Assemble an expansive collection of relevant emission factors and methodologies for estimating GHG emissions, based on currently available public documents;
- Outline detailed procedures for conversions between different measurement unit systems, with particular emphasis on implementation of oil and natural gas industry standards;
- Provide descriptions of the multitude of oil and natural gas industry operations—in its various segments—and the associated GHG emissions sources that should be considered; and
- Develop emission inventory examples—based on selected facilities from various oil and natural gas industry operations—to demonstrate the broad applicability of the methodologies.

The overall objective of this document is to promote the use of consistent, standardized methodologies for estimating GHG emissions from oil and natural gas industry operations[1]. As a result, this API *Compendium* recognizes calculation techniques and emission factors for estimating GHG emissions for oil and natural gas industry operations. These techniques cover the calculation or estimation of emissions from the full range of industry operations – from exploration and production through refining, to the marketing and distribution of products.

The API *Compendium* presents and illustrates the use of emission estimation methods for carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons

[1] Although the API *Compendium* was derived for oil and natural gas industry operations, the methodologies presented in the API *Compendium* can be used by other industries, particularly those that utilize fossil fuels.

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(PFCs), and sulfur hexafluoride (SF_6) for all common emission sources, including combustion, vented, and fugitive. Decision trees are provided to guide the user in selecting a calculation or estimation technique that is based on considerations of materiality, data availability, and accuracy. **METHODOLOGIES REQUIRED BY REGULATIONS TAKE PRECEDENCE OVER THE OPTIONS PROVIDED IN THE DECISION TREES.**

1.1 Background

The API *Compendium* was first released in April 2001 (API, 2001). Its initial release as a "road test" or Pilot Version document was geared toward testing its application to project, facility, or corporate level GHG emission inventories. Since that time, comments on the API *Compendium* have been received through a number of mechanisms, including industry conferences, workshops, and focused outreach to other protocol development organizations, particularly those used by the oil and natural gas industry in other regions of the world. Through collaboration with other industry-related protocol development organizations, this version of the API *Compendium* represents industry best practices for estimating GHG emissions.

Also following the release of the API *Compendium* Pilot Version, a parallel effort was initiated to promote consistent, credible, and reliable GHG accounting and reporting practices for the oil and natural gas industry. A team of oil and natural gas industry representatives led by the International Petroleum Industry Environmental Conservation Association (IPIECA), the Association of Oil and Gas Producers (OGP) and API, issued the *Petroleum Industry Guidelines for Reporting Greenhouse Gas Emissions* (referred to as the *Guidelines*) in December 2003 (IPIECA, et al., 2003). The *Guidelines* build upon other existing protocols for estimating GHG emissions by providing information to address the unique operational arrangements of the oil and natural gas industry.

In 2007, API launched an initiative to develop guidelines for quantifying uncertainty associated with GHG emission inventories. API, Conservation of Clean Air and Water in Europe (CONCAWE), and IPIECA convened an international workshop on the topic on January 16, 2007, in Brussels, Belgium, as the first step in the process of addressing inventory uncertainty and accuracy issues (API and IPIECA, 2007). The document *Addressing Uncertainty in Oil & Natural Gas Industry Greenhouse Gas Inventories: Technical Considerations and Calculation Methods* (referred to here as the *Uncertainty Document*) was developed as a result, with the purpose of

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augmenting existing industry guidance and providing technically valid approaches applicable for use by the global oil and natural gas industry to improve GHG emissions estimation robustness and data quality (API, CONCAWE, IPIECA, 2009).

The API *Compendium*, *Guidelines*, and *Uncertainty Document* are complementary; where the API *Compendium* focuses on GHG emission estimation methodologies for industry sources (how to calculate emissions), the *Guidelines* primarily address GHG accounting and reporting questions faced by the industry (how to report emissions), and the *Uncertainty Document* addresses the confidence intervals for the inventory results. Combined, the API *Compendium*, *Guidelines*, and *Uncertainty Document* provide comprehensive guidance for the estimation, accounting, and reporting of oil and natural gas industry GHG emissions.

In addition, API provides (free of charge) the SANGEA™ Emissions Estimating System, an automated, electronic data management information system based on the emission estimation methodologies described in the API *Compendium*. SANGEA™ was designed to assist oil and natural gas companies with estimating, managing, and reporting GHG emissions, and can also be used to track energy consumption and criteria pollutant emissions. SANGEA™ is available at http://ghg.api.org.

1.2 Document Overview

The API *Compendium* is neither a standard nor a recommended practice for the development of emissions inventories. Rather, as the name implies, it represents a compilation of commonly used GHG emission estimation methodologies.

Methodologies outlined in this API *Compendium* can be used to guide the estimation of GHG emissions for individual projects, entire facilities, or company-wide inventories. The purpose of the GHG analysis, as well as the availability of data, will generally determine the level of detail and the estimation approach to be selected. The methodologies presented here address the estimation of all six GHG species or families of gases (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) from oil and natural gas industry operations. This should not imply that emissions of all these GHG compounds are necessarily significant for all emission sources or industry operations, as their presence varies highly and depends on source design and operational practice. The emission estimation approaches presented are believed to be practical for all segments of the oil and natural

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gas industry. The operations and facilities addressed range from the well-head to retail outlets, including exploration and production (E&P), refining, marine vessels, pipelines, bulk distribution, other transportation, and retail marketing. The methods presented in this API *Compendium* pertain only to emissions from operations and not those that might be attributable to product use. Industry data provided throughout this document list the carbon content fraction for typical fuels in commerce, but no attempt is made to account for hypothetical efficiencies associated with product use.

Transparency is a key issue in developing GHG inventory estimates. It is strongly recommended that any estimation approach used should be well annotated, with all input information recorded and careful documentation of the underlying conditions and assumptions. The SANGEA™ calculation tool provided by API may assist in facilitating such documentation. This level of detail is necessary to track and compare GHG emission information over time and to allow for future revisions as new information becomes available. Moreover, the dynamic nature of oil and natural gas industry operations, along with changes in estimation procedures, necessitate good narrative descriptions of included operations and equipment, in addition to careful calculations and knowledge of operating procedures.

It is also important to note that emission results can differ, in some cases significantly, depending on the specific approach(es) used to estimate emissions. The API *Compendium*, *Guidelines*, and *Uncertainty Document* provide guidance for selecting appropriate estimation techniques based on the intended use of the inventory data and the availability of required input data. Beyond regulatory requirements, the use of the information presented in this document is left to the discretion of the user.

1.3 Organization

Section 2 of this API *Compendium* provides a description of the various industry segments and their interrelation. It sets out a common classification for all devices in the various segments and includes listings of operations and sources that need to be assessed for their GHG emissions, with a focus on CO_2, CH_4, and N_2O emissions because these are the most relevant to oil and natural gas industry operations. The equipment classification system described in Section 2 is summarized in Table 1-1 and includes the major emission categories, with a representative list of devices that might fall into each of these categories.

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Indirect emissions are emissions that are a consequence of activities of the reporting company but which result from sources owned or controlled by another party. All other sources identified in Table 1-1 are considered direct emissions, which result from sources owned or controlled by the reporting company. For transparency, if reported, indirect emissions should be reported separately from direct emissions. More information on the differences and reporting of direct and indirect emissions can be found in the *Petroleum Industry Guidelines for Reporting Greenhouse Gas Emissions* (IPIECA, 2003).

Table 1-1. Proposed Source Classification Approach[a]

Category	Principal Sources Include:
Direct Emissions	
Combustion Sources	
Stationary Devices	Boilers, heaters, furnaces, reciprocating internal combustion engines and turbines, flares, incinerators, and thermal/catalytic oxidizers
Mobile Sources	Barges, ships, railcars, and trucks for material transport; planes/helicopters and other company vehicles for personnel transport; forklifts, all terrain vehicles, construction equipment, and other off-road mobile equipment
Process Emissions and Vented Sources[b,c]	
Process Emissions	Hydrogen plants, amine units, glycol dehydrators, fluid catalytic cracking unit and reformer regeneration, and flexi-coker coke burn
Other Venting	Crude oil, condensate, and oil and natural gas product storage tanks, gas-blanketed water and chemical tanks, underground drain tanks, gas-driven pneumatic devices, gas samplers, chemical injection pumps, exploratory drilling, loading/ballasting/transit, and loading racks
Maintenance/Turnaround	Decoking of furnace tubes, well unloading, vessel and gas compressor depressurizing, compressor starts, gas sampling, and pipeline blowdowns
Non-Routine Activities	Pressure relief valves, PCVs, fuel supply unloading valves, and emergency shut-down devices
Fugitive Sources[d]	
Fugitive Emissions	Valves, flanges, connectors, pumps, compressor seal leaks, and catadyne heaters
Other Non-Point Sources	Wastewater treatment and surface impoundments
Indirect Emissions	
Electricity	Off-site generation of electricity for on-site power
Steam/Heat	Off-site generation of hot water and steam for on-site heat
District Cooling	Off-site gaseous pressurization (compression) for on-site cooling

[a] Note that this API *Compendium* uses terms (e.g., "routine," "maintenance," "point source") that may have both a commonplace, non-legal meaning, and a specific, legal meaning. The API *Compendium* uses the commonplace, non-legal meanings for these terms and does not use them in their legal sense.
[b] Vented emissions are intentional or designed into the process or technology to occur during normal operations.
[c] The above categories of emissions are broad listings intended to give an indication of the emission sources in the oil and natural gas industry. Note that some regulatory and/or voluntary reporting programs classify the categories differently, including what sources are included under the vented, process, and fugitive categories.
[d] Fugitive emissions can be individually found and "fixed" to make the emissions "near zero."

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Section 3 presents detailed technical considerations and suggestions for developing a consistent emissions estimate. To allow for global use of the estimation approaches, this section of the API *Compendium* contains conversion factors, standard gas conditions, and fuel properties for fuels typically found in the oil and natural gas industry. It also introduces key statistical calculation methods for assessing uncertainty ranges for GHG emissions from applicable sources. A discussion on emission factor quality and inventory accuracy is also provided in Section 3.

Sections 4, 5, and 6 provide the compiled calculation methodologies for direct emission sources: combustion devices, process and operational venting, and fugitive emission sources, respectively. Each section presents the details of various estimation approaches for each source, device, or operation and also includes example calculations. The methods are organized around the general classification of emission sources and equipment by category, as specified in Section 2. The estimation approaches are therefore presented by either equipment or fuel type, and by operational practices. These sections strive to balance the need to make the computational tasks as simple as possible while retaining sufficient accuracy in the final inventory. To accomplish this, the methodology provides options for relying on generic estimation methods—if applicable—such that specific knowledge of every equipment detail may not be essential. For example, many of the combustion device estimation approaches will be the same regardless of the industry segment in which they occur. However, most of the process vents are specific to an industry segment and reflect a specific operational practice for that part of the oil and natural gas industry. Examples are provided throughout the API *Compendium* to demonstrate calculation methodologies. Examples may be used multiple times throughout the document, and are intended to be as realistic as possible.

Section 7 presents methods that are applicable for estimating indirect GHG emissions from sources that provide power, heat and steam, and cooling. In the case of indirect emissions from power generating activities, the methods rely on average EFs based on national compilation, such as eGrid[2] in the US and the International Energy Agency (IEA) for sources out of the US. The section also describes different methods, recommended by diverse programs, for the allocation of GHG emissions between the power and heat/steam generation aspects of Combined Heat and Power (CHP) installations.

[2] EPA maintains a database with information from power plants and electricity generators. The database is available at the following website: http://www.epa.gov/cleanenergy/egrid/index.htm (accessed June 19, 2009).

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Section 8 presents emission inventory examples for each industry segment. These examples are used to demonstrate methodology and emissions tabulations to help the reader determine the key emission sources for that type of facility. The examples constructed have an abundance of different types of equipment and devices for illustrative purposes, but are not intended to be representative of any specific facility or industry sector. The results presented also feature the calculated uncertainty ranges in order to demonstrate the implementation of the statistical calculation methods to a facility inventory.

A detailed glossary for the terminology used throughout this compendium is provided following the main report sections. Appendices A, B, C, and D provide additional calculation methodologies and further details for emission sources covered in Sections 4, 5, 6, and 7, respectively. Appendix E provides fuel speciation details to support combustion and non-combustion emission estimation. Appendix F contains an analysis of fugitive CH_4 emissions from refinery operations.

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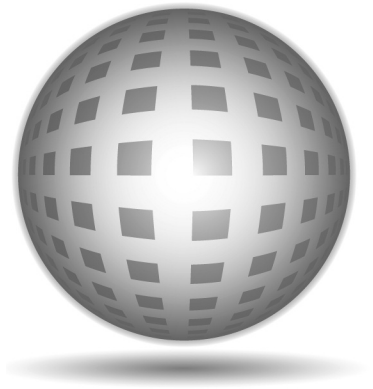
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SECTION 2
INDUSTRY DESCRIPTION



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Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Natural Gas Industry

Section 2 – Industry Description

August 2009

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Table of Contents

2.0 INDUSTRY DESCRIPTION 2-1

2.1 Overview 2-1

2.2 Industry Segment Descriptions 2-4

2.2.1 Conventional Exploration and Production 2-4

2.2.2 Oil Sands and Heavy Oil Upgrading 2-7

2.2.3 Coal Bed Methane Production 2-10

2.2.4 Gas Processing 2-11

2.2.5 Carbon Capture and Geological Storage 2-13

2.2.6 Natural Gas Storage and LNG Operations 2-15

2.2.7 Transportation and Distribution 2-18

2.2.8 Refining 2-21

2.2.9 Petrochemical Manufacturing 2-23

2.2.10 Minerals and Mining Operations 2-25

2.2.11 Retail and Marketing 2-26

2.2.12 Energy Generation 2-27

2.3 References 2-28

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List of Tables

Table 2–1. Potential Greenhouse Gas Emission Sources by Sector: Conventional Exploration and Production 2-5
Table 2–2. Potential Greenhouse Gas Emission Sources by Sector: Oil Sands and Heavy Oil Upgrading 2-8
Table 2–3. Potential Greenhouse Gas Emission Sources by Sector: Coal Bed Methane Production 2-10
Table 2–4. Potential Greenhouse Gas Emission Sources by Sector: Processing 2-12
Table 2–5. Potential Greenhouse Gas Emission Sources by Sector: Carbon Capture and Geological Storage 2-14
Table 2–6. Potential Greenhouse Gas Emission Sources by Sector: Natural Gas Storage and LNG Operations 2-16
Table 2–7. Potential Greenhouse Gas Emission Sources by Sector: Liquid Transportation and Distribution 2-19
Table 2–8. Potential Greenhouse Gas Emission Sources by Sector: Natural Gas Transmission and Distribution 2-20
Table 2–9. Potential Greenhouse Gas Emission Sources by Sector: Refining 2-22
Table 2–10. Potential Greenhouse Gas Emission Sources by Sector: Petrochemical Manufacturing 2-23
Table 2–11. Potential Greenhouse Gas Emission Sources by Sector: Minerals and Mining Operations 2-25
Table 2–12. Potential Greenhouse Gas Emission Sources by Sector: 2-27
Table 2–13. Potential Greenhouse Gas Emission Sources by Sector: Electricity and Heat/Steam Generation 2-28

List of Figures

Figure 2-1. Oil and Natural Gas Industry Schematic of GHG Emissions 2-2

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2.0
INDUSTRY DESCRIPTION

This section presents a description of the oil and natural gas industry and its segments to give some perspective on the potential sources of GHG emissions. Figure 2-1 presents a graphical overview of the primary industry segments with a rudimentary indication of GHG emission sources. The following subsections describe industry segments and specialty operations, and the related GHG emission sources in more detail.

2.1 Overview

For the purposes of this document, the oil and natural gas industry includes all direct activities related to producing, refining, transporting, and marketing crude oil and associated natural gas, and refined products. Figure 2-1 shows a graphical overview of the industry. The key industry segments include:

- Exploration, production, and gas processing;
- Transportation and distribution;
- Refining; and
- Retail and marketing.

These segments are the direct activities within the oil and natural gas industry that have the potential to emit GHG. Integrated petroleum companies may also have operations associated with energy generation (electricity, heat/steam generation, or cooling), mining and minerals, petrochemical manufacturing, and/or carbon capture and geological storage.

Note: The relative scale of the primary GHGs of interest (CO_2, CH_4, and N_2O) are indicated in Figure 2-1. **Carbon dioxide** and **CH_4** (in bold font) represent the most significant emission sources; CO_2, N_2O and CH_4 (in regular font) represent less significant emission sources. If none are shown, emissions are believed to be negligible. The comparison is based on CO_2 equivalents.

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