

Compressors & Engines

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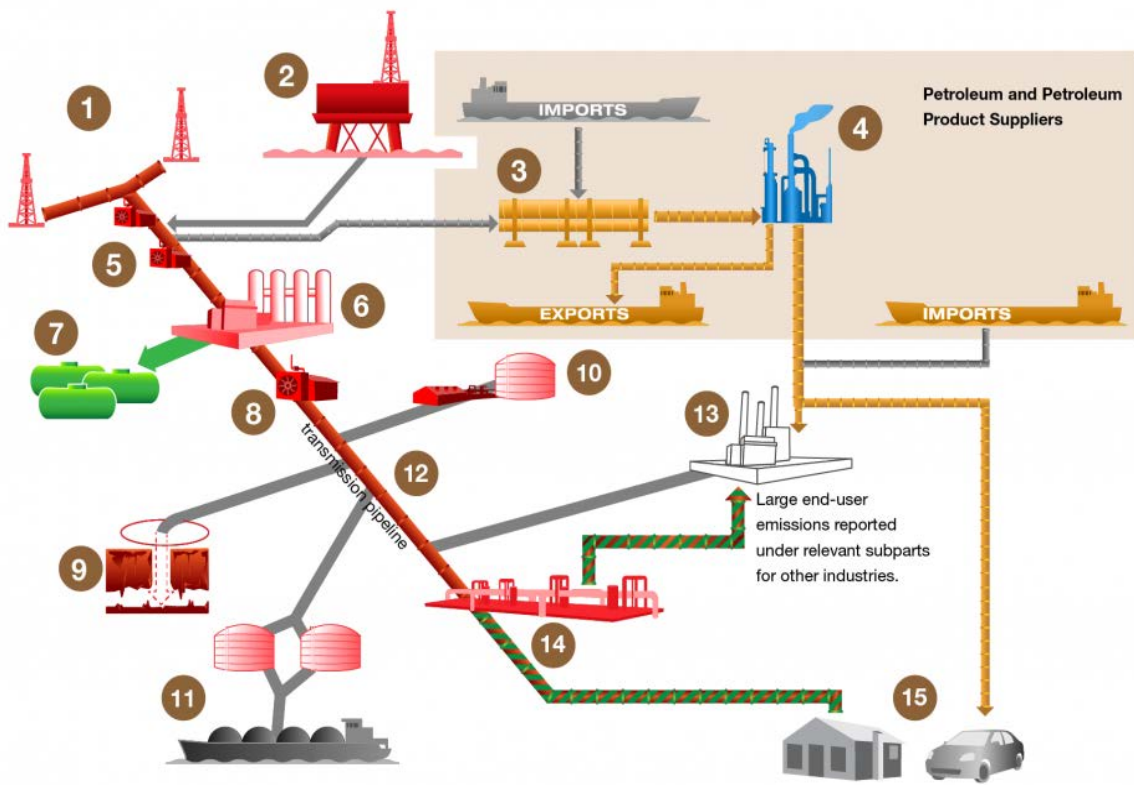
DCP Midstream, Denver, CO

1. Where Compressors/Engines are Used
2. Types of Compressors & Engines
3. Sources of Methane
4. Methane Reduction Opportunities

Compressors & Engines

- Use of Compressors & Engines

Keep Natural Gas Pressures at the Level Required to Move Gas from the Wellhead to the Consumer



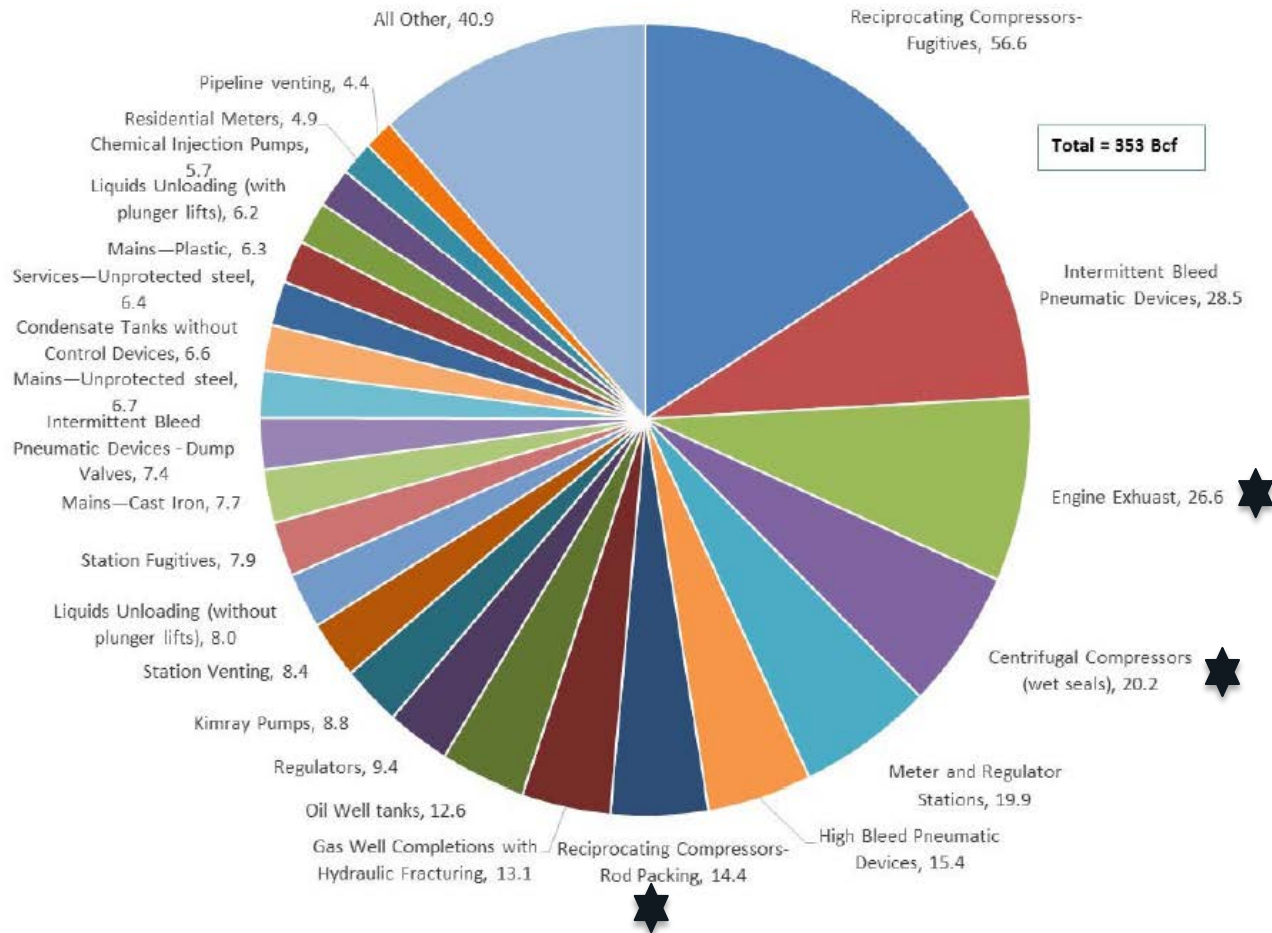
Where Compressors are Used

- 1 O&G production for enhanced oil recovery, maintaining reservoir pressures, gas lift, gas reinjection, and wellhead compression of natural gas
- 5 Gas gathering compressor stations to move raw natural gas from the wellhead to gas processing plants
- 6 Moving gas into and out of natural gas processing plants and within the plant.
- 8 Downstream of the natural gas processing plant in the gas transmission sector to move natural gas long distances in large diameter pipelines.
- 9 Moving natural gas into and out of natural gas storage facilities

* From EPA GHG Reporting program, see Reference #2.

Compressors & Engines

- Sources of Methane Emissions

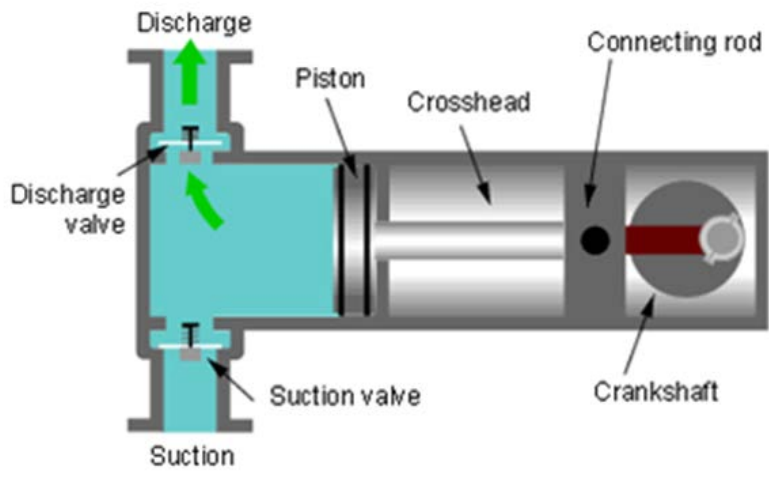


*From Reference 10 - One Future/ICF International (May 2016), "Economic Analysis of Methane Emission Reduction Potential from Natural Gas Systems", Section 2.2, citing 2014 EPA GHG Inventory

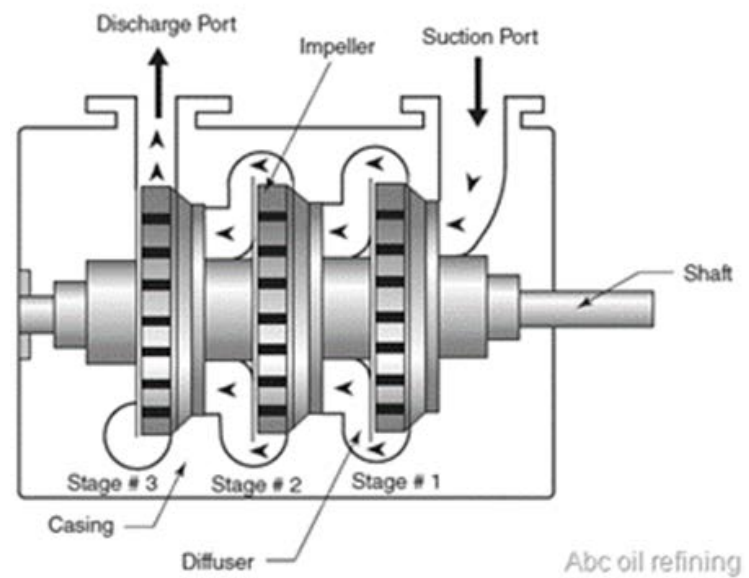
Compressors & Engines

- Types of Compressors

Reciprocating



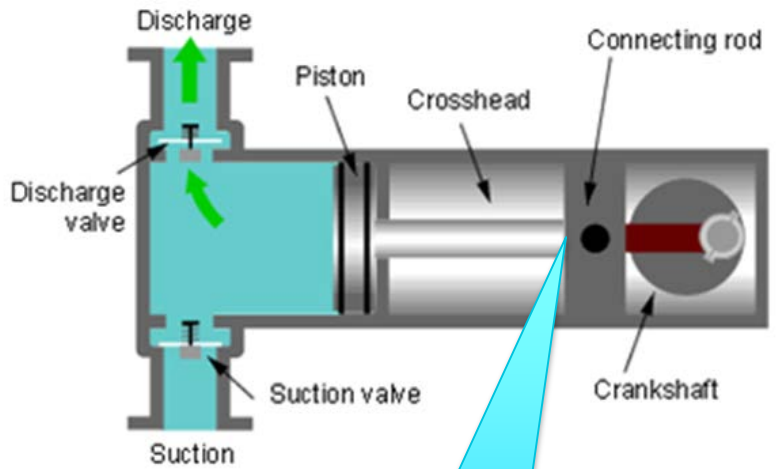
Centrifugal



Compressors & Engines

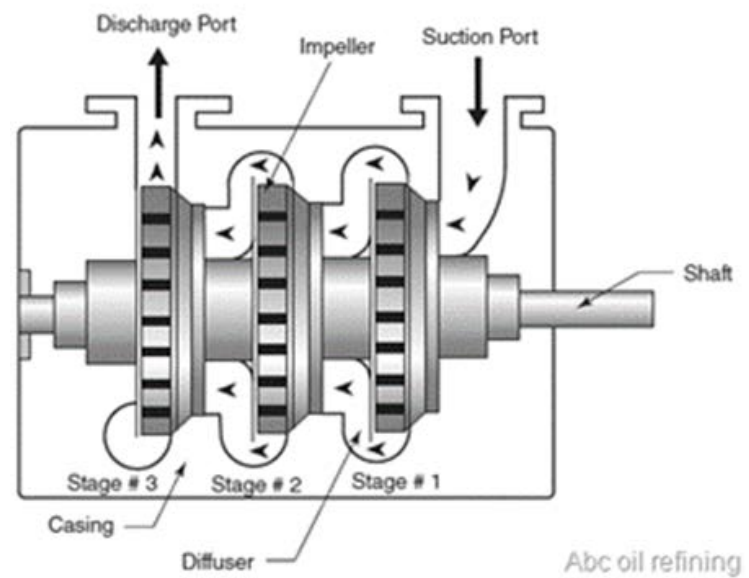
- Types of Compressors

Reciprocating



Rod Packing Seals

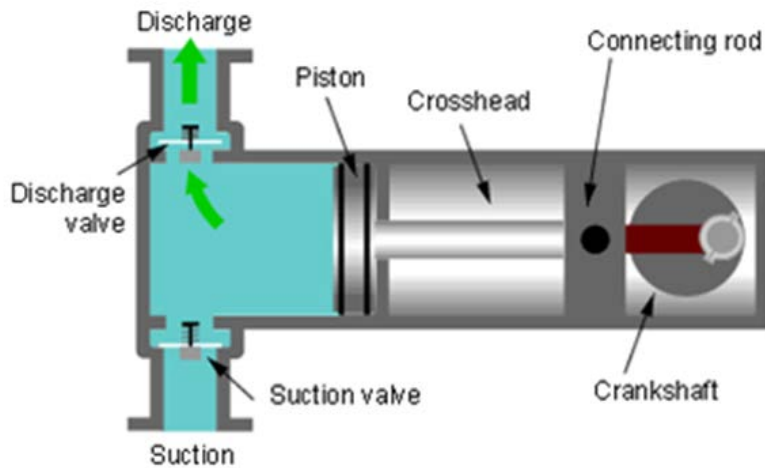
Centrifugal



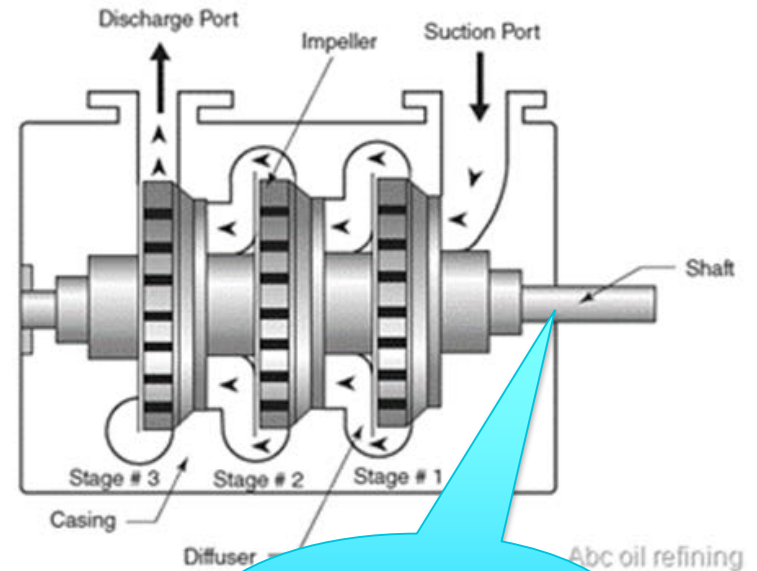
Compressors & Engines

- Types of Compressors

Reciprocating



Centrifugal



Shaft Seals -
Wet or Dry

Compressors are always paired with a driver

Compressors & Engines

- Sources of Methane Emissions - Engines

- Emissions from engines are typically associated with engine exhaust from combustion of fuel (natural gas)
- Combustion emissions include primarily NO_x, CO, VOC and CO₂
- In addition, methane is emitted from the engine exhaust, often referred to as “methane slip”
 - Unburned methane from the fuel that is emitted with the engine exhaust.
 - Result of the fundamental combustion chamber design and type of combustion system for various engine types.
 - Technology to reduce methane slip is unproven and further development is required to make technology commercially available

*See Reference 10 - One Future/ICF International (May 2016), "Economic Analysis of Methane Emission Reduction Potential from Natural Gas Systems", Sections 2.3 & 2.6; and Reference 6 - International Council on Combustion Engines (CIMAC) (April 2014), "CIMAC Position Paper, Methane and Formaldehyde Emissions of Gas Engines"

Compressors & Engines

- Methane Reduction Opportunities
 - Centrifugal Compressor Wet Seals - Replacing Wet Seals with Dry Seals
 - New centrifugal compressors typically have dry seals
 - May not be technically feasible in some cases due to design of existing compressor or operational conditions, such as:
 - Sour gas service, i.e. gas with H₂S, common in SENM
 - Certain pressure & temperature conditions
 - If feasible, potential to reduce methane emissions by 95%
 - High cost to implement reported by a NG STAR partner as \$324,000 in 2006 dollars (\$475,000 in today's dollars w/ 3% inflation)

Compressors & Engines

- Methane Reduction Opportunities

- Centrifugal Compressor Wet Seals - Wet Seal Degassing Capture

- Collect vapor from seal oil degassing and route for other uses or destruction, such as:
 - Compressor suction
 - High pressure turbine fuel gas
 - Low pressure fuel gas for heaters/burners
 - Flare purge gas
 - Flared
- If feasible, potential to reduce methane emissions by 95%
 - Some of the above uses may not be feasible, e.g. for sour gas
- Requires capital costs to install seal oil separator, oil demister/filter, piping, flow controls, and instrumentation
- Cost to implement can be highly variable based on facility requirements. One NG STAR partner reported costs to be \$33,000 in 2014 dollars.

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- Methane Reduction Opportunities
 - Centrifugal Compressor Wet Seals – Existing Regulations
 - OOOO/OOOOa requires 95% reduction from wet seals for new and modified compressors
 - Most new compressors use dry seals
 - Some states have established regulations
 - CO requires 95% control of VOC/hydrocarbon emissions from compressors with wet seals
 - EPA GHG Reporting Program requires annual reporting at plants/basins with over 25,000 mtCO₂e, as well as monitoring of vented wet seal emissions at subject plants.

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- Methane Reduction Opportunities
 - Reciprocating Compressor Rod Packing – Rod Packing Replacement
 - Rod packing emissions increase over time due to wear at the seal surfaces
 - Replacement of rod packing is routine maintenance task
 - Cost to replace compressor rod packings is highly variable
 - Dependent on size of the compressor, composition of the gas being compressed, operating pressures, operating temperatures, other operating conditions (such as demand and speed), technology selected, and materials selected.
 - One NG STAR partner reported costs to be \$1,350 - \$1,700 per compression cylinder. For a typical compressor with 4 cylinders this would equate to a range of \$5,400 - \$6,800 for parts & labor.

Compressors & Engines

- Methane Reduction Opportunities
 - Reciprocating Compressor Rod Packing – Existing Regulations
 - OOOO/OOOOa requires rod packing replacement every 3 years for new and modified compressors
 - Some states have established regulations
 - CO extends the 3-yr replacement requirement to all compressors
 - EPA GHG Reporting Program requires annual reporting at plants/basins with over 25,000 mtCO₂e. Also, rod packing monitoring at plants with over 25,000 mtCO₂e.



Questions & Discussion

Compressors & Engines

Sources of Information

- 1) EPA Air Emissions Factors and Quantification. This is a link to EPA background information on natural gas fired reciprocating internal combustion engines (RICE) and Chapter 3.2 of EPA's *Compilation of Air Pollutant Emissions Factors (AP-42)* for RICE. [AP 42, Fifth Edition, Volume I, Chapter 3: Stationary Internal Combustion Sources.](#)
- 2) [EPA Greenhouse Gas Reporting Program.](#)
 - a. This link contains EPA basic information on sources of GHG emissions in the petroleum and natural gas industries (Subpart W), emissions data reported, and guidance for reporters. This subpart covers compressors, plus engines in the gathering and boosting segment. [GHGRP for Petroleum and Natural Gas Systems \(Subpart W\).](#)
 - b. This link contains EPA information on sources of GHG emissions from stationary fuel combustion sources, including engines (Subpart C). This subpart covers engines at gas processing plants. [GHGRP for General Stationary Fuel Combustion Sources \(Subpart C\).](#)
- 3) Colorado State University, Energy Institute, 2019. From the introduction: "The study had two primary objectives: 1) Collect data on equipment counts and types (activity data) of gathering stations and 2) Perform component level leak measurements suitable for developing new emission factors". ["Characterization of Methane Emissions from Gathering Stations: Final Report"](#)
- 4) Colorado State University, Energy Institute, 2019. This paper presents the technical information related to the CSU Gathering Station study direct measurement of methane emissions in the exhaust of engines. ["Methane Emissions from Gathering and Boosting Compressor Stations in the U.S. Supporting Volume 2: Compressor Engine Exhaust Measurements"](#)
- 5) Climate & Clean Air Coalition, 2017. From the introduction: "This is a technical guidance document for Partners to the CCAC Oil and Gas Methane Partnership (OGMP). This document is one in a series that describes a core source of methane emissions. The document introduces suggested source-specific methodologies for quantifying methane emissions and describes established mitigation options that Partners should reference when determining if the source is "mitigated"". This document is specific to centrifugal compressors with wet seals. ["Technical Guidance Document Number 3: Centrifugal Compressors with "Wet" \(Oil\) Seals"](#)
- 6) International Council on Combustion Engines (CIMAC), 2014. This paper provides details about methane in engine exhaust. ["CIMAC Position Paper, Methane and Formaldehyde Emissions of Gas Engines, April 2014"](#)
- 7) Climate & Clean Air Coalition, 2017. From the introduction: "This document provides technical guidance to Partners of the CCAC Oil and Gas Methane Partnership (OGMP). It is one in a series describing a core source of methane emissions from oil and natural gas production operations. The guidance documents introduce suggested methodologies for quantifying methane emissions from specific sources and describe established mitigation options that Partners should reference when determining if the source is "mitigated"". This document is specific to reciprocating compressors. ["Technical Guidance Document Number 4: Reciprocating Compressors Rod Seal/Packing Vents"](#)

Compressors & Engines

Sources of Information (continued)

- 8) Joint Institute for Strategic Energy Analysis, August 2015. From the Executive Summary: “Based on a review of recent research and analysis of the U.S. GHGI emission estimates, this report briefly summarizes the methods and results of the 2014 U.S. GHGI (EPA 2014a), discusses challenges to constructing the U.S. GHGI, and suggests some opportunities that could improve the accuracy of the methane emissions estimates”. ["Estimating U.S. Methane Emissions from the Natural Gas Supply Chain: Approaches, Uncertainties, Current Estimates, and Future Studies"](#)
- 9) INGAA, August 2018. From the introductory comments of the whitepaper: “This white paper supplements those commitments by explaining the sources of methane emissions for the interstate natural gas transmission and storage sector, which is comprised of a network of high-pressure pipelines, compressor stations, and storage assets (salt caverns and reservoirs), as well as the basis for the methane emissions commitments that INGAA members voluntarily adopted”. ["Improving Methane Emissions from Natural Gas Transmission and Storage"](#)
- 10) One Future/ICF International, May 2016. From the Executive Summary: “Our Nation’s Energy Future Coalition (ONE Future) 1 commissioned ICF to conduct this analysis of the marginal abatement cost (MAC) of various methane emission abatement technologies and work practices for the natural gas industry. The goal of this MAC analysis is threefold: (1) to identify the emission sources that provide the greatest opportunity for methane emission reduction from the natural gas system, (2) to develop a comprehensive listing of known emission abatement technologies for each of the identified emission sources, and (3) to calculate the cost of deploying each emission abatement technology and to develop a MAC curve for these emission reductions”. ["Economic Analysis of Methane Emission Reduction Potential from Natural Gas Systems"](#)
- 11) EPA & EC/R Inc., July 2011. From the forward: “This background technical support document (TSD) provides information relevant to the proposal of New Source Performance Standards (NSPS) for limiting VOC emissions from the Oil and Natural Gas Sector”. ["Oil and Natural Gas Sector: Standards of Performance for Crude Oil and Natural Gas Production, Transmission, and Distribution: Background Technical Support Document for Proposed Standards"](#)
- 12) EPA & GRI, June 1996. From the introduction: “This report describes how the emissions from compressor driver exhaust were determined. Section 3 discusses the data used to make the emission estimates. Section 4 presents the development of the emission factors for engines and turbines. Section 5 describes the development of the activity factors for each industry segment (production, processing, and transmission, including storage and generators). The annual emissions for each segment and the overall national emissions estimate are provided in Section 6. Conclusions are given in Section 7”. ["Methane Emissions from the Natural Gas Industry, Volume II: Compressor Driver Exhaust, Final Report"](#)
- 13) U.S. Natural Gas STAR Program. Voluntary methane emission reduction best practices used in the oil and natural gas industry for compressors and engines are identified in the following link. ["Recommended Technologies to Reduce Methane Emissions"](#).