Reducing Flaring & Venting Methane & CO2 Emissions

21st century ideas for lower emissions.

Gas Electric Partnership
February 5,6 2020
Houston, TX

AFGlobal

Introduction

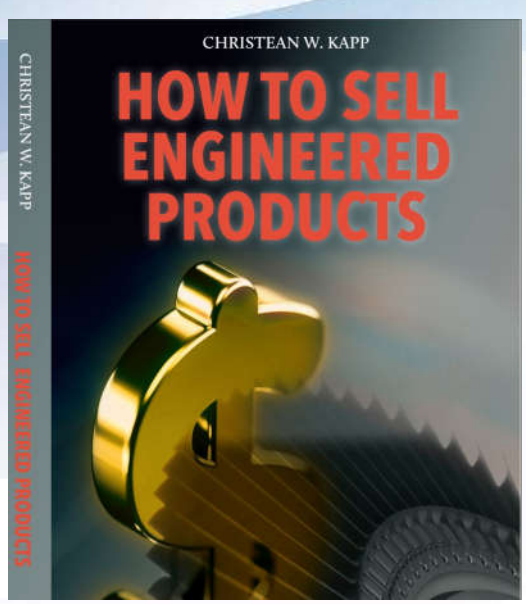
Chris Kapp has 30 years experience in the Turbomachinery Industry in all application areas of Oil & Gas as well as Industry living in the US, Europe and Asia with companies such as Demag-Delaval, Rolls-Royce, Siemens and Hoerbiger.

Chris has a MSc in mechanical & aerospace engineering from RWTH University in Aachen, Germany and the NIU in Trondheim, Norway and studied finance with KIAMS in Harihar, India.

Chris has consulted with the Dept of Energy, the EPA and API.

Currently Vice President Energy at AFGlobal, a packager of compressors and gas turbine gensets, Chris is also an author of the book focused on rotating equipment

- "*How to sell Engineered Products*" published by Pennwell.



Agenda

- Problem Statement: Sustainability, Perception, Satellites & Drones

- Flaring and Venting
  - DoE statistics
  - Pipelines
  - Size and numbers of flares in Texas

- Techniques:
  - Flares
  - Pneumatic Actuators
  - Vapor Recovery Compressors
  - CO2 & Nat Gas Enhanced Oil Recovery CNG/LNG/GTL
  - Compressors Packing & Dry Gas Seals
  - Micro & Radial Gas Turbines
  - Waste Heat Recovery
  - Reducing Blow Down

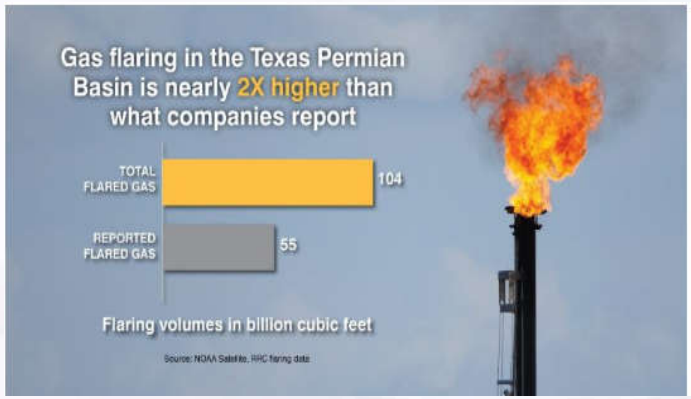
Problem Statement: Sustainability

- Most companies in O&G have statements that demonstrate how they will improve emissions
- According to Hydrocarbon Processing 51% of respondents to its latest survey stated they had a sustainability statement, another 20% were working on it.
- Many financing companies are looking for these statements and more and more investors are demanding an ever aggressive, increasing effort to reduce the carbon footprint.
- Equinor wants to make all O&G sites emissions free by 2050! (FuelFix Jan 12)
- Repsol who recently bought into the Eagle Ford will also cut ALL emissions by 2050

Pressure is mounting

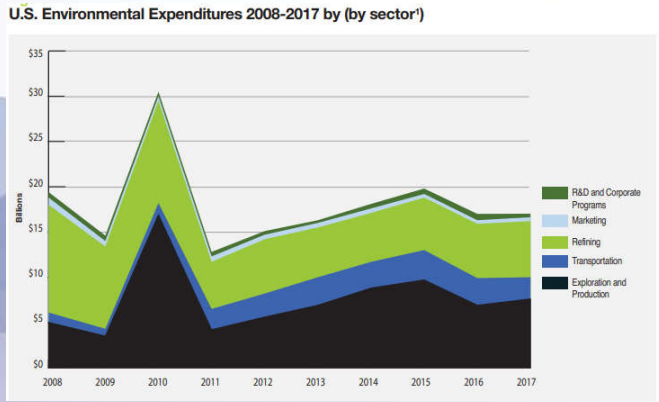
Problem: Perception Gas & Oil (API's 2020 State of the Energy Industry Event)

- A group of the world's largest oil companies pledged in 2018 to cut emissions to a quarter percent of their total natural gas production by 2025. One of the areas of largest concern is Texas and the Permian Basin, where producers hope a series of new pipelines will allow them to get more gas to market, instead of burning it off in an industry practice known as flaring.



EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work

Environmental Defense Fund, Colin Leyden Jan 2019 (2017 data)

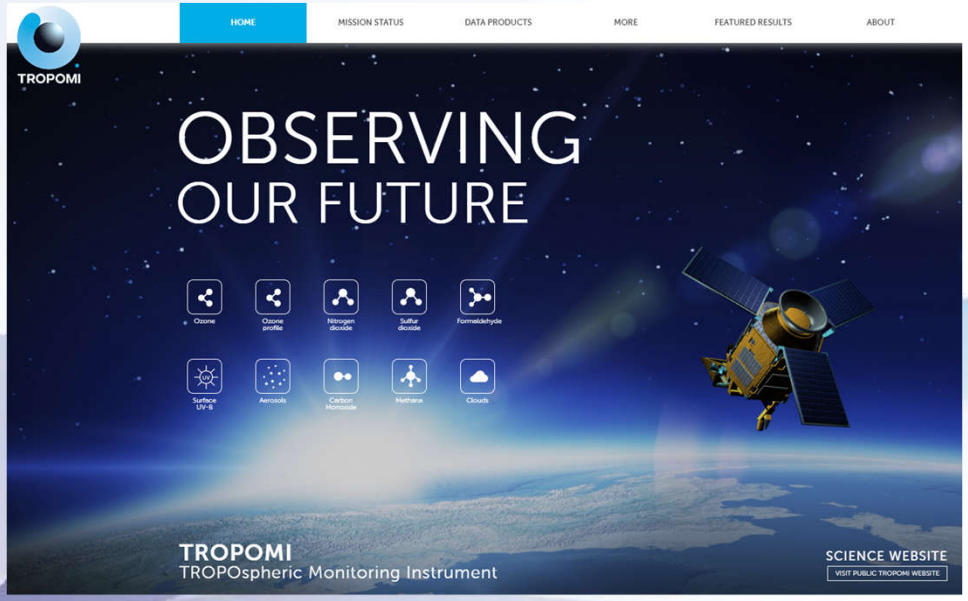


energy API

Environmental Expenditures by the US Oil & Natural Gas Industry, API 2019

At the very least the O&G Industry has a massive PR problem. Houston Chronicle Jan 12, 2020

Everybody is watching, You cannot hide….



In February 2018 ESA (European Space Agency) detected and measured a massive leak of 120 metric tons per hour methane in Belmont, OH. XTO reported a far smaller leak.

After that 6 super emitters were detected in the Permian. Drones are also being used.

Space Agencies can measure ppm methane from Mars orbit in their search for life.
They can certainly find large leaks on Earth.

Source: NYT Dec 2019

Dept. of Energy Greenhouse Gas Sources Statistics, June 2019

TABLE 1. EPA Greenhouse Gas Inventory for Methane Emissions from Oil and Gas Operations

Source	2013	2015	2016	2017	% of Total (2017)
Natural gas compressor stations emissions	1,902	2,163	2,143	2,219	41%
Pneumatic controllers at oil and gas producing locations	1,918	1,862	1,882	1,894	35%
Venting from abandoned oil and gas wells	282	285	289	277	5%
Natural gas engines at gas processing facilities	228	234	250	256	5%
Natural gas transmission pipeline blowdowns	217	216	215	215	4%
Natural gas gathering pipeline leaks	139	137	137	142	3%
Liquids unloading from stripper gas wells	234	161	131	117	2%
Natural gas engines at gas producing facilities	131	125	118	114	2%
Chemical injection pumps	84	86	83	82	1%
Oil storage tank vent emissions	53	68	102	61	1%
Natural gas well workovers	73	13	16	34	1%
Oil well production heaters	23	29	27	28	1%
Natural gas gathering pipeline blowdowns	15	15	15	20	0%
Hydraulically fractured oil well completions	243	74	15	13	0%
Oil well workovers	24	13	6	2	0%
Total (Thousand Tons CH_4)	5,566	5,481	5,429	5,474	100%
Total (Billion Cubic Feet CH_4)	354.5	349.1	345.8	348.7	
Total (Thousand Tons CO_2 Equivalent)	139,150	137,025	135,725	136,850	

FIGURE 2. Natural gas being flared at the Hess Corporation gas plant in Tioga, North Dakota, due to maintenance issues. *Photo credit Amy Dalrymple / Forum News Service* (Source)[2]

Compressor Station Emissions top the list

Gas Engines are #4 and #7

Transmission occupy #1, #5 and #6

Gas processing comes in at #8

Blowdowns are # 13

The “compression” industry owns most of the issues > 2/3 ! or 180 BCF Methane = total 350BCFY!

Dept. of Energy CO2 Greenhouse Gas Sources Statistics, June 2019

TABLE 2. EPA Greenhouse Gas Inventory for CO_2 Emissions from Oil and Gas Operations

Source	2013	2015	2016	2017	% of Total (2017)
Acid gas removal equipment flares	14,565	14,946	16,481	16,728	38%
Associated gas from oil production flares	10,384	13,955	8,587	10,506	24%
Natural gas processing facility flares	5,902	6,058	5,203	5,683	13%
Oil storage tank vent flares	5,937	7,598	5,894	4,422	10%
Miscellaneous flaring associated with oil production	2,606	3,571	2,201	2,631	6%
Hydraulically fractured oil well completions	2,214	1,913	1,162	1,619	4%
Misc. natural gas production flares	978	1,318	1,187	1,090	2%
Natural gas well storage tank flares	1,173	1,240	1,129	585	1%
Hydraulically fractured well flares	1,265	277	177	474	1%
Natural gas well workover flares	133	77	59	356	1%
Oil well workover flares	136	192	207	258	1%
Total (Thousand Tons)	45,293	51,145	42,287	44,352	100%

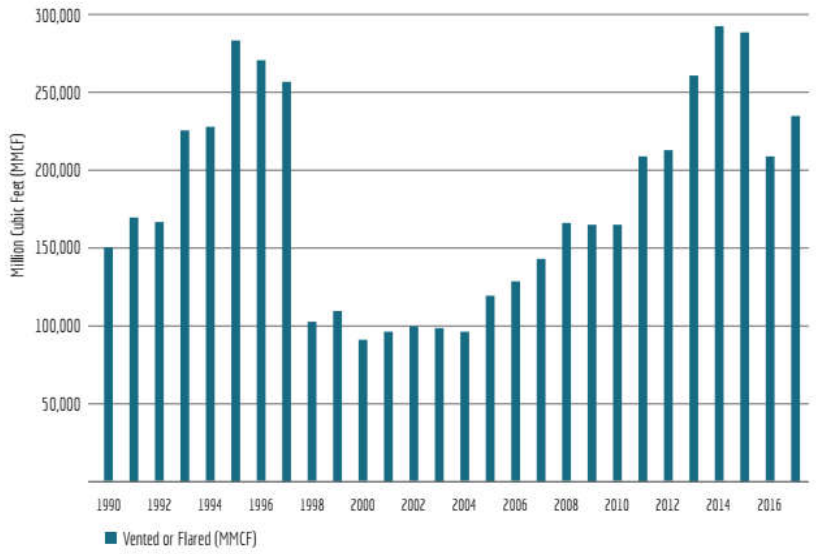


FIGURE 9. EIA venting and flaring data from 1990 thru 2017 (recent data from only 10 states, in some cases only for selected years). (Data Source: EIA)[12]

Wellhead and gas processing are the bad boys in CO2 emissions

Emissions are not improving

Major Pipelines coming into play will reduce “methane” flaring significantly

There are 97,000 permitted flares located in over 200 counties in Texas alone.

The number of new permits issued by the Texas Railroad Commission increased ten-fold in recent years.

The Wall Street Journal confirmed that no flare permits have been denied in Texas in 2018.

NOAA (National Oceanic & Atmospheric Ass.) and even ESA measure flare volumes from space.

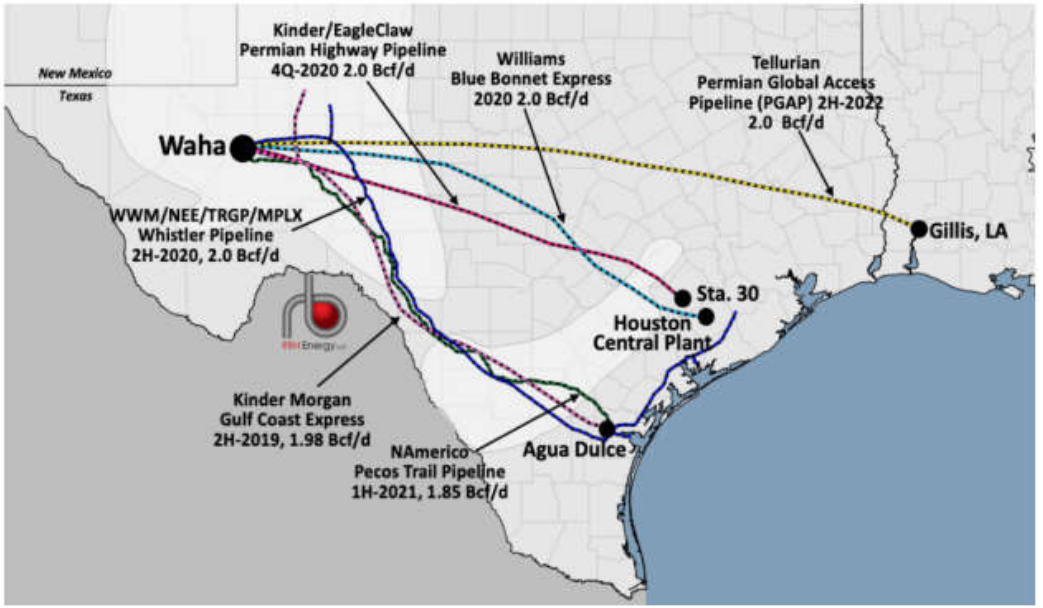


FIGURE 16. Map showing the routes for additional natural gas pipelines currently in development to connect the Permian Basin with Gulf Coast and Mexico markets. *Map courtesy of RBN Energy, LLC.* (Source)[47]

Does the press know and the public understand this ?!

How much is being flared per permitted site?

Lots of very small sources but surprisingly quite a few “large” sources, app. 400MCFD

400MCFD can provide app. 1.5 MW in power (radial gas turbine)

40 MCFD can provide app. 150 KW electrical power (micro gas turbine)

The whole range could be used for reciprocating engines

*depends on the quality of the gas, excludes large amounts of inerts

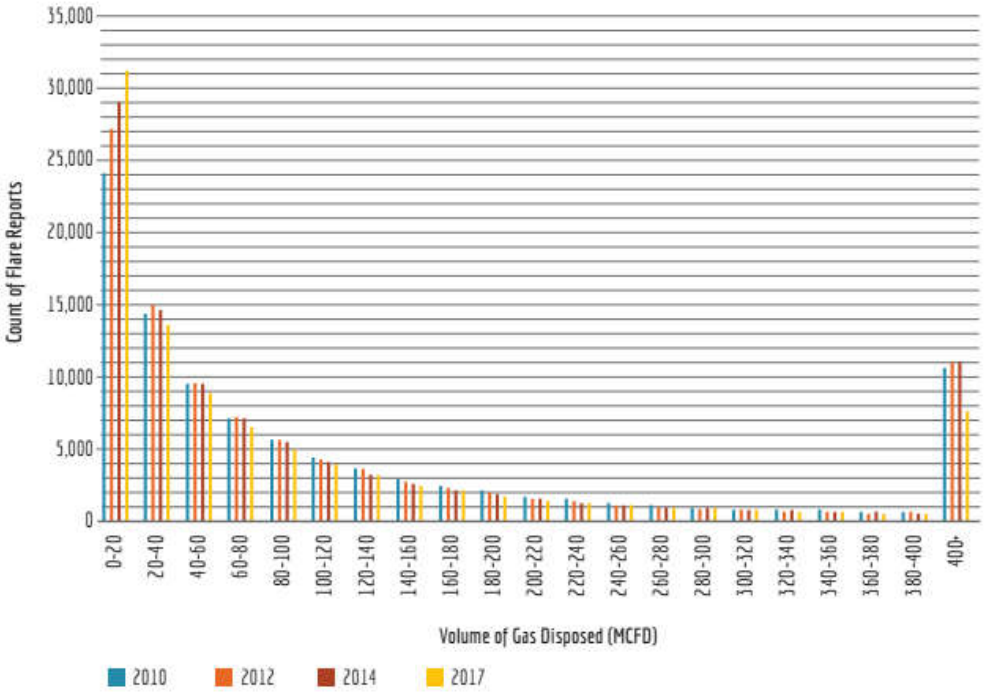


FIGURE A1. Plot of frequency distribution of number of flares binned by flared gas volume in Mcf/day.

Flare Gas Characteristics

- Flares can be found in every part of the Oil & Gas Values Chain.
- Typical compositions change from site to site and may be highly variable in flow (1:30!). This may require surge bottles to compensate.
- **Well Head:** High BTU, wet gas at the well head with some corrosive components
- **Gas processing:** High H2S and CO2
- **Transmission:** High Methane with occasional High Nitrogen (buffer gas)
- **LNG :** similar to gas processing
- **Refinery:** a volatile cocktail of next to anything incl. Hydrogen
- **Offshore:** similar to wellhead but may include significant amounts of Nitrogen and CO2

What to Do About Emissions ?

• Burn	Easy, light a match, create more emissions
• Recover	Recoup, offset investment by recovering valuable gas
• Reduce Losses	More efficient seals, offset not losing valuable gas
• Enhances Oil recovery, make Liquids	The big plant solution, costly.
• Change operational behavior (less blowdowns, more efficient operation)	
• Generate power	replace imported power

Techniques: Flares

Flares can be called Burners, Oxydizers or emission control devices (ECDs). An open flare will have a visible flame. Both open and enclosed flares are common.

Visibility of the flame and smoke development can be an issue if the flare volume and therefore the fuel / air ratio changes a lot.

Some significant design features include a flame arrestor, check valve, refractory lining and a stable air mixing system.

Performance testing ports may have to included to get to 98% Volatile Organic Compounds (VOC) destruction.

However while flares destroy greenhouse gases, they do at the cost of increasing NOx, CO emissions greatly. CO2, a combustion by product that is also a greenhouse gas is also increased.

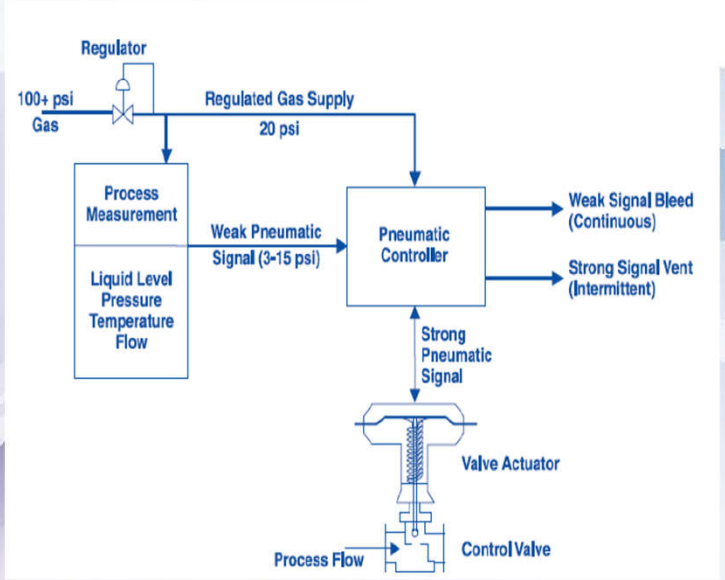
This will add an emissions footprint equal or greater to any engine or turbine without any production benefits.

Flares get rid of Methane but generate a large load of NOx and CO2 for no use

Stack Emissions-Natural Gas (1,000 Btu/CF)				
	PPMv (Corr to 3% O_2)	lb/MBtu	lb/hr @ Full Rate	Ton/Yr @ Full Rate
NO_x*	110	0.131	3.963	17.358
	30	0.036	1.081	4.734
	9	0.011	0.324	1.420
CO	50	0.037	1.11	4.870
CO_2	2.55 lb/lb fuel	119.76	3,624	15,874
H_20	2.03 lb/lb fuel	106.16	3,213	14,072

Techniques: Pneumatic Actuators

- Is one of the top three sources of greenhouse gas emissions in O&G.
- The EPA estimates there are 85,000 pneumatic devices in the transmission space alone
- It is estimated that 80% devices could be retrofitted with low bleed capabilities.
- Reductions of 45-260 Mcfy per device are claimed
- The use of instrument air, nitrogen or electrically controlled devices is encouraged where these utilities exist.



Hint: N2 membrane generators are often used near compressors

EPA Global Methane Initiative

Natural Gas STAR Program

CONTACT US SHARE

Recommended Technologies to Reduce Methane Emissions

Review our Lessons Learned Studies and Partner Reported Opportunities (PRO) Fact Sheets to see how the U.S. EPA's voluntary oil and gas methane program partners have implemented technologies and practices to cut methane emissions, reduce strategic and operational risk, and demonstrate their commitment to the environment.

Disclaimer of Endorsement: Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government.

https://www.epa.gov/natural-gas-star-program/recommended-technologies-reduce-methane-emissions

Compressors/ Engines | Dehydrators | Directed Inspection and Maintenance | **Pipelines** | Pneumatics/ Controls | Tanks | Valves | Wells | Other

Pipelines

Document Title	Capital Cost	Estimated Payback	Production	Gathering and Processing	Transmission	Distribution
Test and Repair Pressure Safety Valves, PRO Fact Sheet #602	< $1,000	0-1 year	Production	Gathering and Processing	Transmission	Distribution
Insert Gas Main Flexible Liners, PRO Fact Sheet #402	$1,000-$10,000	0-1 year				Distribution
Composite Wrap for Non-Leaking Pipeline Defects, Lessons Learned	$1,000-$10,000	0-1 year			Transmission	Distribution
Perform Valve Leak Repair During Pipeline Replacement, PRO Fact Sheet #601	$1,000-$10,000	0-1 year			Transmission	Distribution
Using Hot Taps for In Service Pipeline Connections, Lessons Learned	$10,000-$50,000	0-1 year			Transmission	Distribution
Recover Gas from Pipeline Pigging Operations, PRO Fact Sheet #505	$10,000-$50,000	0-1 year	Production	Gathering and Processing	Transmission	
Using Pipeline Pump-Down Techniques to Lower Gas Line Pressure Before Maintenance, Lessons Learned	> $50,000	0-1 year		Gathering and Processing	Transmission	Distribution

EPA Global Methane Initiative

Compressors/ Engines | Dehydrators | Directed Inspection and Maintenance | Pipelines | Pneumatics/ Controls | Tanks | Valves | Wells | Other

Compressors/Engines

Document Title	Capital Cost
Wet Seal Degassing Recovery System for Centrifugal Compressors, PRO Fact Sheet	$33,000 (one compressor); $90,000 (four comp
Replace Gas Starters with Air or Nitrogen, PRO Fact Sheet #101	< $1,000
Reduce Natural Gas Venting with Fewer Compressor Engine Startups and Improved Engine Ignition, PRO Fact Sheet #102	< $1,000
Reducing Methane Emissions from Compressor Rod Packing Systems, Lessons Learned	< $1,000
Test and Repair Pressure Safety Valves, PRO Fact Sheet #602	< $1,000
Reducing Emissions When Taking Compressors Off-Line, Lessons Learned	$1,000-$10,000
Eliminate Unnecessary Equipment and/or Systems, PRO Fact Sheet #504	$1,000-$10,000
Install Automated Air/Fuel Ratio Controls, PRO Fact Sheet #104	> $50,000
Install Electric Motor Starters, PRO Fact Sheet #105	$1,000-$10,000
Inject Blowdown Gas into Low Pressure Mains or Fuel Gas System, PRO Fact Sheet #401	$1,000-$10,000
Replace Compressor Cylinder Unloaders, PRO Fact Sheet #106	$10,000-$50,000
Install Electric Compressors, PRO Fact Sheet #103	> $50,000
Replacing Wet Seals with Dry Seals in Centrifugal Compressors, Lessons Learned	> $50,000

PRO Fact Sheet No. 102

Partner Reported Opportunities (PROs) for Reducing Methane Emissions

NaturalGas

Reduce Natural Gas Venting with Fewer Compressor Engine Startups & Improved Engine Ignition

Technology/Practice Overview

Description

Compressors driven by internal combustion engines are often equipped with gas expansion starters. Pressurized gas is expanded across the starter turbine spinning the engine and initiating the startup. The discharge header of the compressor is typically vented to the atmosphere so the compressor is unloaded before the engine is started. The gas used to turn the starter turbine is also vented. Starter gas may be either high-pressure natural gas stored in a volume tank, or pipeline gas diverted to the starter. In either case, the starter and header gas are usually vented to the atmosphere.

Reducing the frequency of compressor startups avoids blowdowns and therefore reduces the volume of gas vented to the atmosphere with each startup. Poorly maintained ignition systems increase the incidence of failed engine starts and can

- Compressors/Engines
- Dehydrators
- Directed Inspection & Maintenance
- Pipelines
- Pneumatics/Controls
- Tanks
- Valves
- Wells
- Other

Economic and Environmental Benefits

Methane Savings - Reduced frequency of compressor starts

Estimated annual methane emission reductions: *581 Mcf per compressor* [1]

[1] *Assumes 4.4 startups are eliminated each year, which would vent 132 Mcf per start*

Economic Evaluation

Estimated Gas Price	Annual Methane Savings	Value of Annual Gas Savings*	Estimated Implementation Cost	Incremental Operating Cost	Payback (months)
$7.00/Mcf	581 Mcf	$4,326	Minimal training	$0	Immediate
$5.00/Mcf	581 Mcf	$3,080	Minimal training	$0	Immediate
$3.00/Mcf	581 Mcf	$1,848	Minimal training	$0	Immediate

** Whole gas savings are calculated using a conversion factor of 94% methane in pipeline quality natural gas.*

Additional Benefits: ■ Greater overall efficiency of compressor operations ■ Reduces fuel usage

Methane Savings - Improved ignition and automated control systems

Estimated annual methane emission reductions: *800 Mcf per compressor system*

Economic Evaluation

Estimated Gas Price	Annual Methane Savings	Value of Annual Gas Savings*	Estimated Implementation Cost	Incremental Operating Cost	Payback (months)
$7.00/Mcf	800 Mcf	$6,440	$1,750	$0	3.3 Months
$5.00/Mcf	800 Mcf	$4,600	$1,750	$0	4.6 Months
$3.00/Mcf	800 Mcf	$2,600	$1,750	$0	8.1 Months

** Whole gas savings are calculated using a conversion factor of 94% methane in pipeline quality natural gas.*

Additional Benefits:

■ Reduces labor and O&M costs ■ Improves safety and efficiency of operations ■ Reduces fuel usage

Applicable Sector(s)

- Production
- Processing
- Transmission
- Distribution

Other Related Documents:

Replace Gas Starters with Air or Nitrogen, PRO No. 101

Install Electric Compressors, PRO No.103

Install Electric Motor Starters, PRO No. 105

Techniques: Vapor Recovery Compression

A common solution but requires equipment that is more expensive than a flare and more maintenance. This may still require a flare as a backup !

However the great advantage is that all gas is recovered minus the amount required for the compressor engine. Combustion emissions are created but certainly far less than in a flare.

However there are limits for very small compressors and the pressure ratio they can reliably boost too. Feeding atmospheric gas into a high-pressure pipeline of a turbine fuel system are possible.

Recips, rotary vane and screw compressors are common

Operational issues may include oil thinning
and temperature control of the compressor when starting up on rich gas.

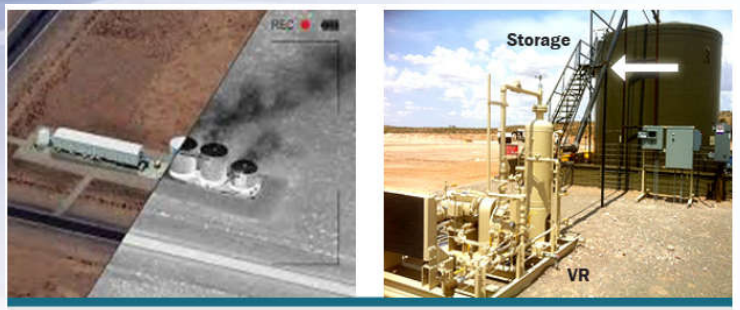


FIGURE 6. Aerial infrared photo showing crude oil tank vent emissions (left) and photo of vapor recovery (VR) unit installed on storage tank to prevent emissions (right, with connection line identified). *Photo courtesy of HY-BON/EDI* (Source)[7]

Techniques: CO2/Natural Gas Injection & LNG/CNG

• CO2 reinjection	Kinder Morgan and Denbury do this a lot for enhanced oil recovery
• Gas to Methanol	GasTechno / Primus Green Energy
• CNG • (Compressed Natural Gas)	Many different players
• LNG • (Liquefied Natural Gas)	Many different players,
• GTL • (Natural Gas to Liquids)	Compact GTL and Calvert Energy

These solutions require relatively large gas volumes and are CAPEX intensive.

Techniques: Compressor Venting Reduction & Avoidance Strategies

Dry Gas Seals

A centrifugal compressor with a dry gas seal may “leak” up to 5 SCFM gas per seal. The natural gas is then mixed with N2/air seal gas. Often flared or just vented, it should be either recompressed into the fuel system or burned for power generation. Increasing the backpressure reduces or sometimes eliminates the recompression requirement.

Recip Compressor Packing

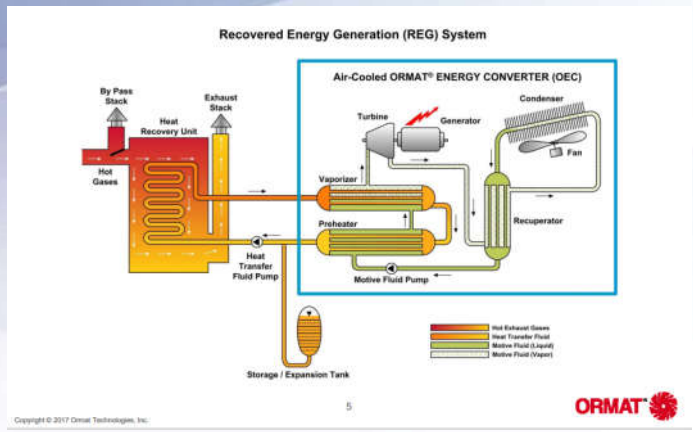
All packings leak however all OEMs and their major suppliers have premium packing that can reduce leakage dramatically and last far longer than standard. They are mostly retrofittable in the same packing cases and are an affordable solution to reduce compressor vents. New designs are coming out to reduce/eliminate blowdown in standstill conditions.

Problem is you have to ask for them, they are not default OEM standard
Most rental fleet operators do not use them as they are not selectable in OEM program

OEMs and Service providers can be more proactive in suggesting low emission options

Techniques: Conversion of Waste Heat to Electricity

- FERC often requires the study of waste heat recovery on pipelines
- However efficiency benefits often do not remain with the pipelines but may revert to the shipper
- Thermoelectric (Solid State) Waste Heat Recovery (Alphabet Energy E1) takes exhaust heat and produces electricity.
- Ormat, (Rankine Cycle) has been used on Rolls-Royce and Solar Gas Turbines with success



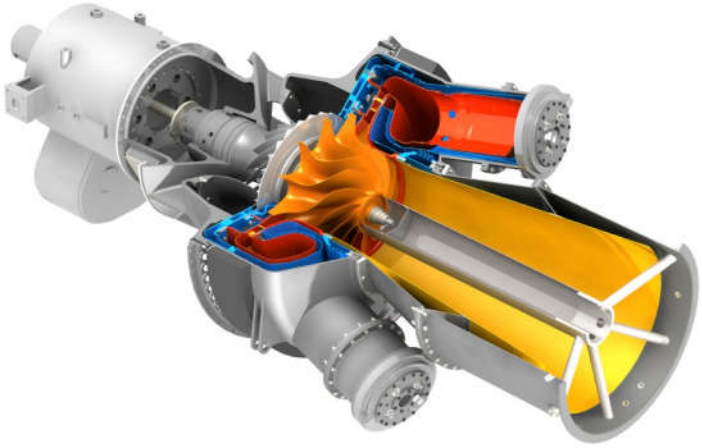
Saturated Steam systems are not used in O&G, but common in the industrial world

Power Generation of Flare Gas with Micro and Radial Gas Turbines

- Capstone Microturbines 30, 65 or 200 KW (ISO) production per unit. 3, or 4 packs are available

- Flex Energy Radial Turbines 333 KW (ISO) per unit, 4 packs are available

- AFGlobal/OPRA Radial Turbine 1,800 KW (ISO) per unit



Fuel cells are great future ideas

Power Generation

- Fuel Gas Suitability & Emissions Performance

	Flow [MCFD]	Non-Pipeline Gas Capability	Changing BTU Fuel Tolerance	Start Capability High BTU	H2S ?	Operating Range	Fuel gas Pressure	NOx
Recip. Engines	Full coverage	Limited, rich burn are more tolerant	Frequent Retuning required	limited	No	50-100%	Atmospheric	>75 vppm (0.5 ghp, no catalyst). Rich Burn are lower
Micro Gas Turbine	10-80	Limited to 35 and 65 KW	Yes	Partially	7%	No load-100%	100-200 PSIG	5-9 vppm
Radial Gas Turbines	100-400	No issue	Yes, wide operating range	Yes	4-7%	No load - 100%	100-200 PSIG	9-25 vppm
Axial Gas Turbines	> 1,000	Yes, depending on combustor	depends on NOx system	Depends on model	4-100 vppm	5-6 MW No Load-100%	350-750 PSIG	9-25 vppm

There are variations to stated figures. Confirm all details with your selected OEM and actual site and fuel conditions

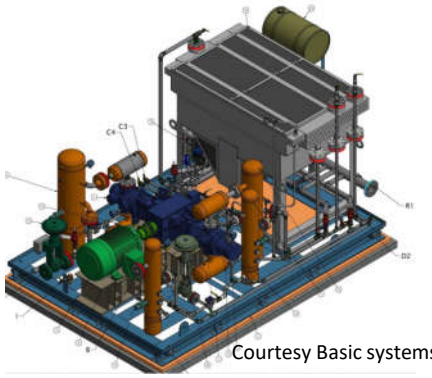
Power Generation

- Package & Convenience

	Flow [MCFD]	Mobile Packages	Single Day Setup	Load Start Capability	Maintenance	Reliability	NOx
Recip. Engines	Full coverage	Trailer & Skid	Yes	Limited	High	94-95%	>75-100 vppm (0.5 ghp, no catalyst)
Micro Gas Turbine	10-80	Trailer & Skids	Yes	Limited	Low	98-99%	5-9 vppm
Radial Gas Turbines	100-400	Mobile Skids	Yes	Yes	Low	98-99%	9-25 vppm
Axial Gas Turbines	> 1,000	5-6 MW models on Trailers	5-6 MW Yes	Yes	Medium to High	97-99%	9-25 vppm

Confirm all details with your selected OEM and actual site and fuel conditions

Large Gas Pipeline Mainline Station

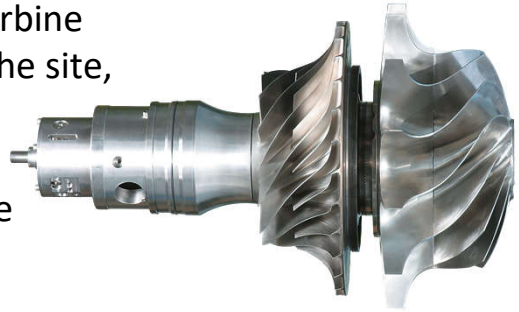

Courtesy Basic systems

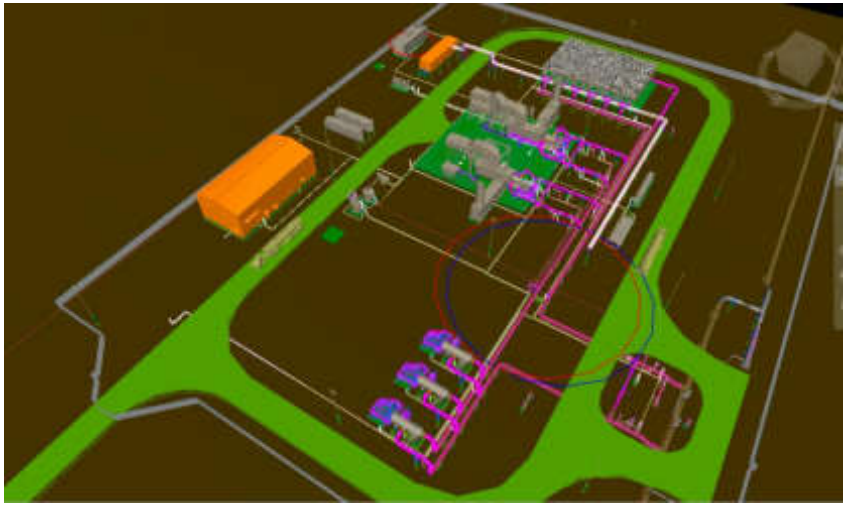
Situation: 2 large gas turbines each > 20 MW driving turbo compressor pipeliners

Demand of 1 MW Power for after-coolers and associated station equipment
Power from Grid for reliability reasons

Base Solution: Vapor Recovery System plus flare (app 400mscfd in total)

Better Environmental Solution:
Backpressure from Dry Gas Seal system,
feeds directly into radial/micro gas turbine
Generate all the power required for the site,
use utility as backup.





Lower operational costs and eliminate
400 mscfd emissions with a
nominal amount pf NOx
(app. 4tons/year) but replace higher emissions at
main power plant (utility) plus electrical transmission losses.

Accounting for “losses” and efficiency gains to the shipper requires some creativity

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Energy Solutions

Pumping, Compression & Energy Solutions

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