Panel 2: Natural Gas Market Assessment and Methane Leakage

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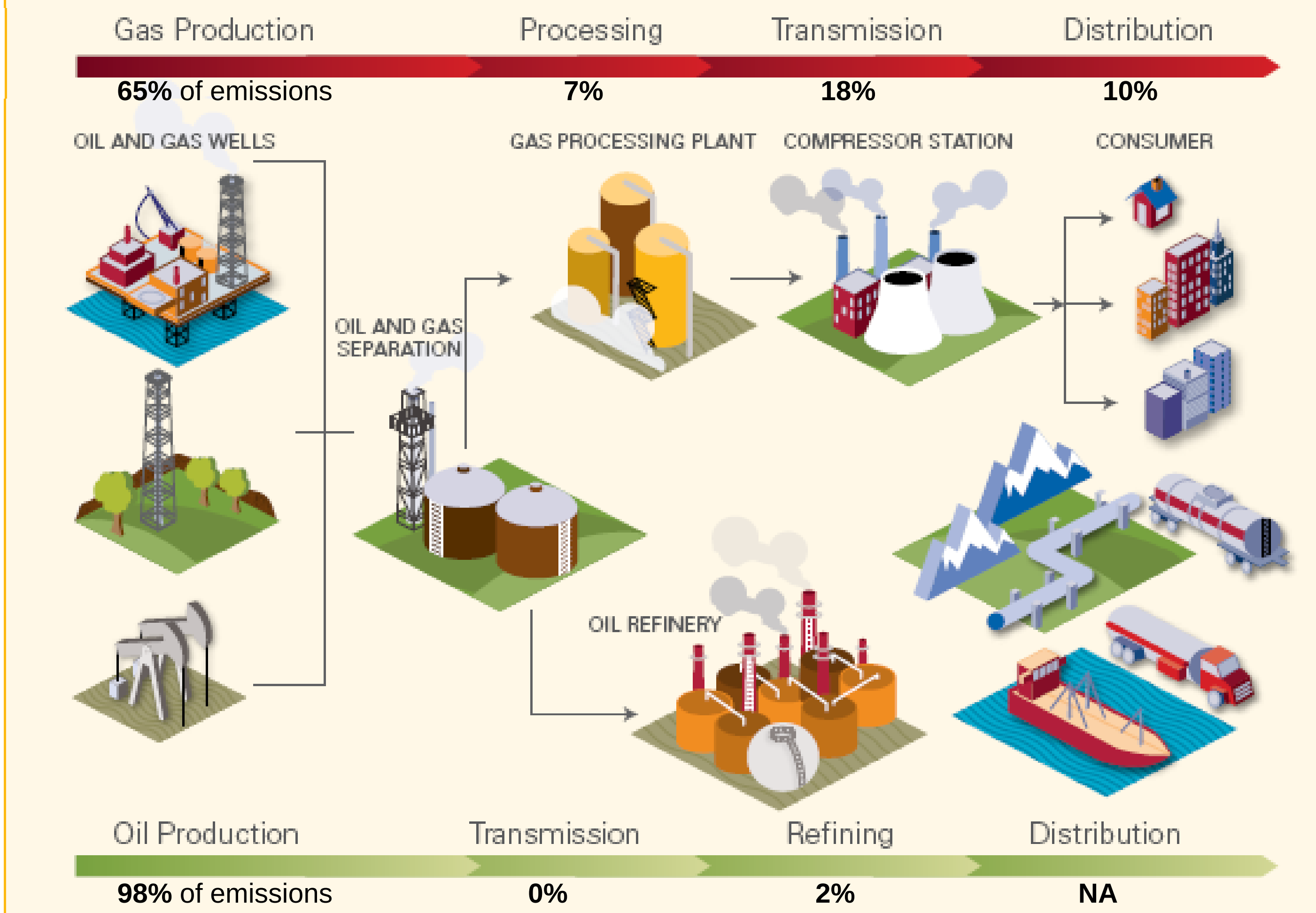
IEPR: Electric and Natural Gas Vehicles

June 23, 2014

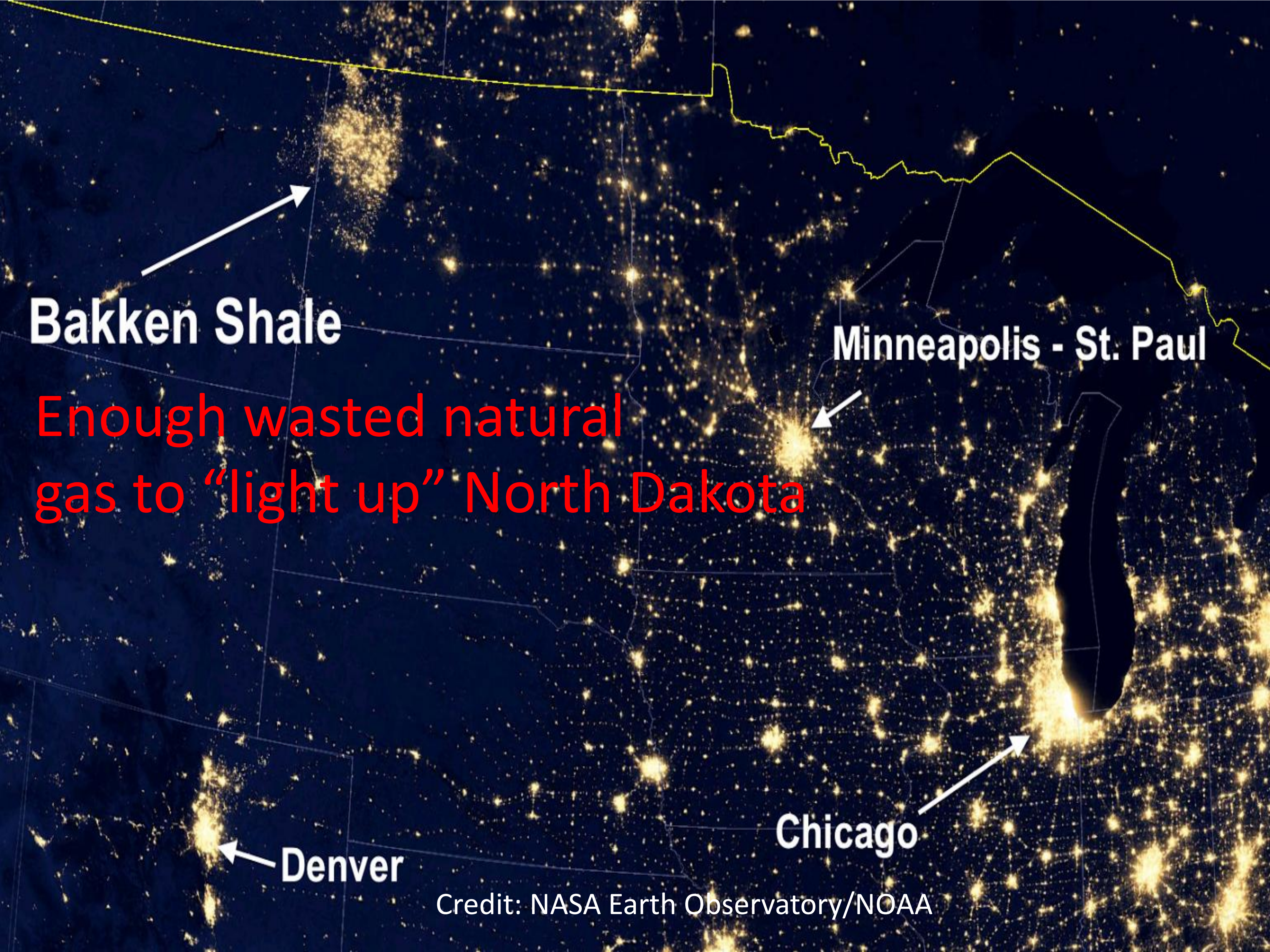
Wyoming's Jonah Field. Courtesy: National Geographic

Oil and natural gas systems are major sources of methane emissions

Oil and Gas Production, Processing, Transmission, Refining, and Distribution System Simplified Schematic



Source: Leaking Profits, NRDC, available at http://www.nrdc.org/energy/leaking-profits.asp. If not specified, other graphics in presentation are also from Leaking Profits.



Credit: NASA Earth Observatory/NOAA


Dallas
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Houston
San Antonio
Eagle Ford Shale
Corpus Christi

Methane emissions: Knowns and unknowns

Knowns:

- Methane is a powerful global warming pollutant
- Emissions are significant and a growing concern
- Leaking Profits: Cost-effective technologies could address most of these emissions

We need additional and better information on:

- Inventory: likely underestimated by 25 to 75%?**

- Leakage assessment: just how much and from where?

- Fuel-cycle assessment: GHG emissions of natural gas vehicles versus diesel vehicles, given the above?

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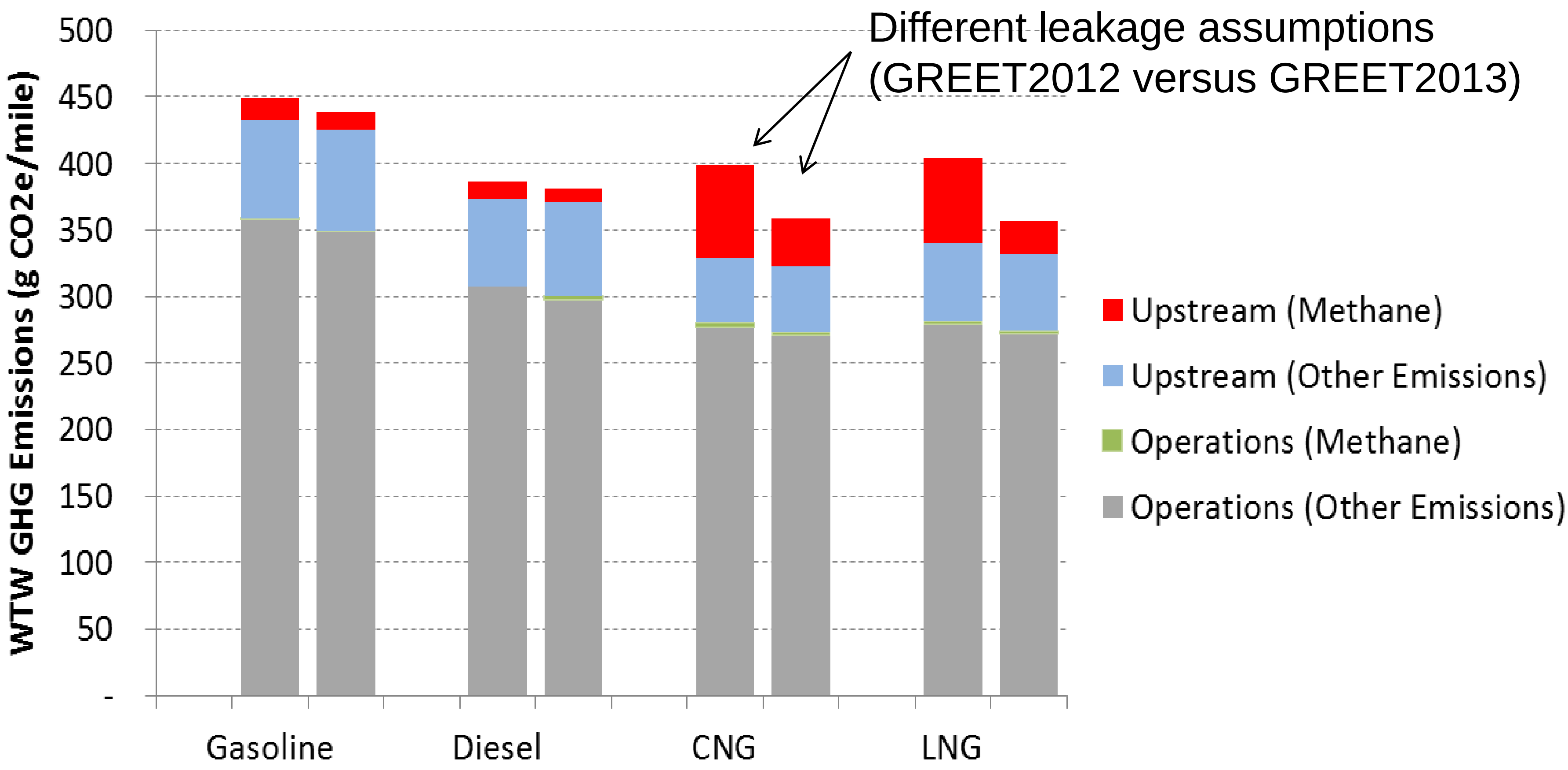
** Brandt, A.R., *et al.*, *Methane Leaks from North American Natural Gas Systems*, Science, Vol. 343, no. 6172 at pp. 733-735 (Feb. 14, 2014),

Vehicles fueled with fossil-based natural gas may have higher or lower emissions



- Results for CNG and LNG depend largely on leakage rates. GREET results shown for passenger cars, using IPCC 2007 GWP values over a 100-year time horizon.
- Versions reflect differences including changes between EPA (2011) and EPA (2013) inventories. See Burnham (2013) et al. (https://greet.es.anl.gov/files/ch4-updates-13)

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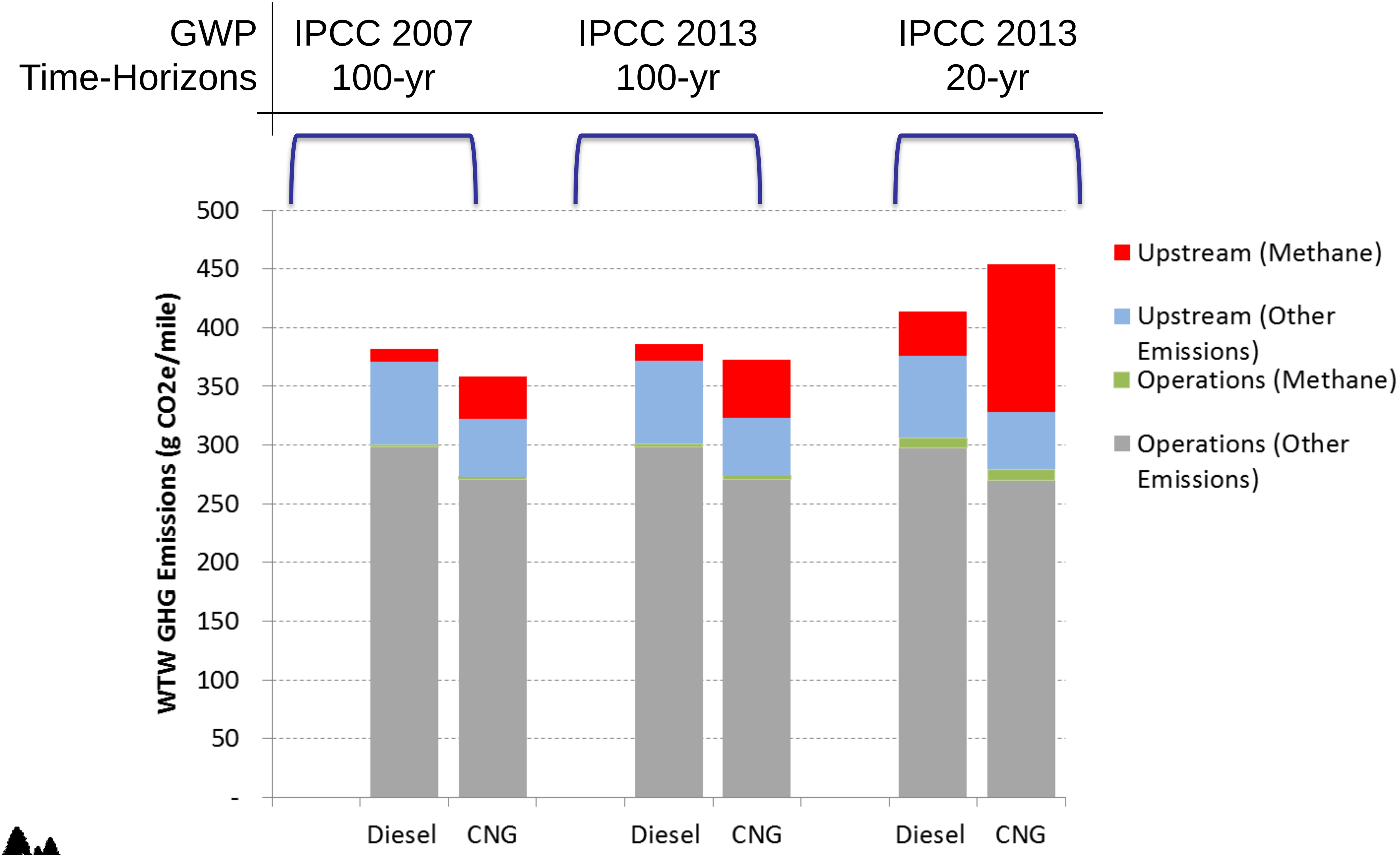
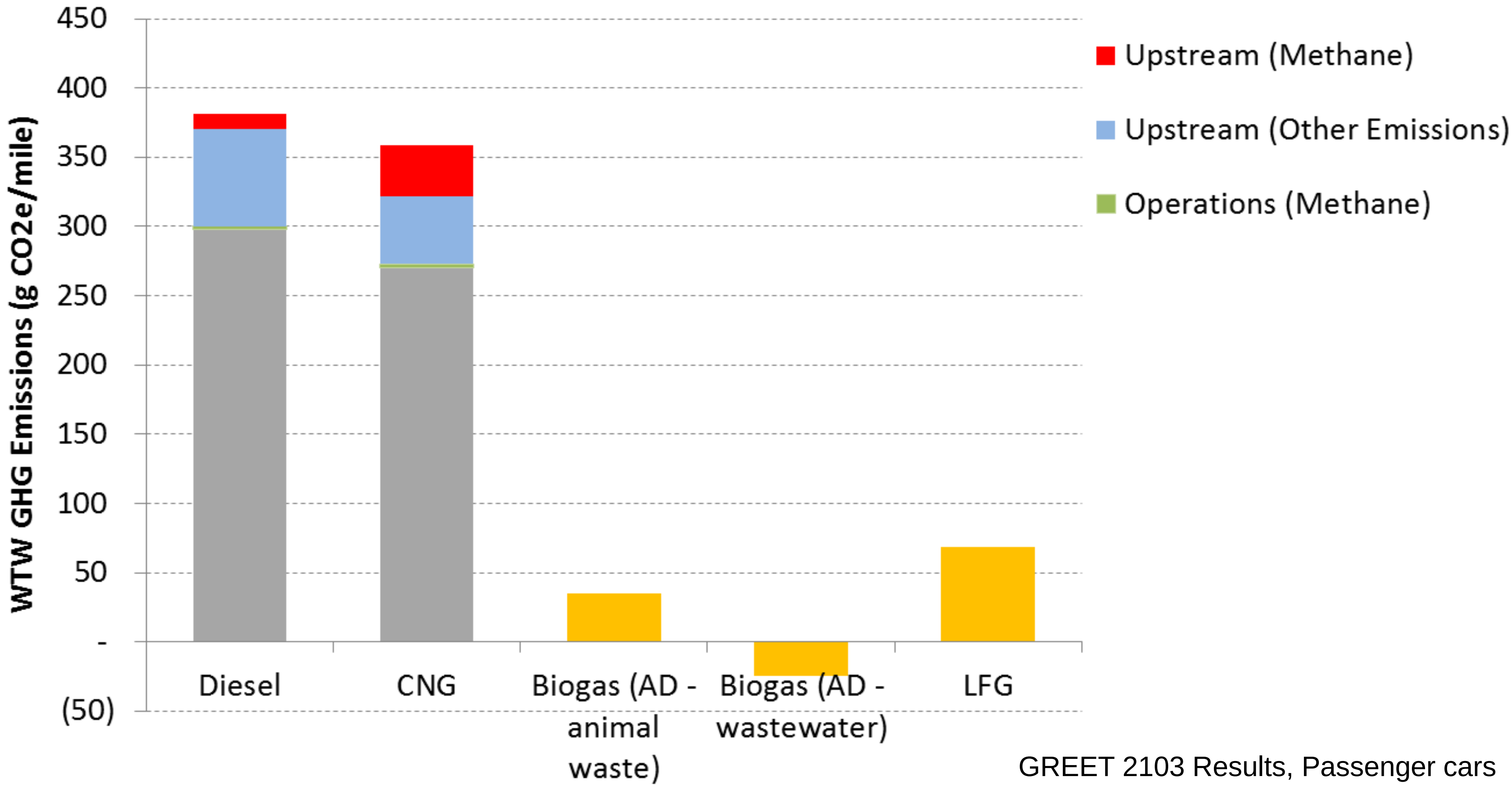
Sensitivities: Global warming potential and time-horizon



GREET 2013 results for passenger cars

Sensitivities: Shifting to biogas and landfill gas capture



GREET 2103 Results, Passenger cars
IPCC 2007 GWP, 100-yr time horizon

- LCFS critical to fuel switching to biogas and landfill gas capture
- Potential volume limitations?

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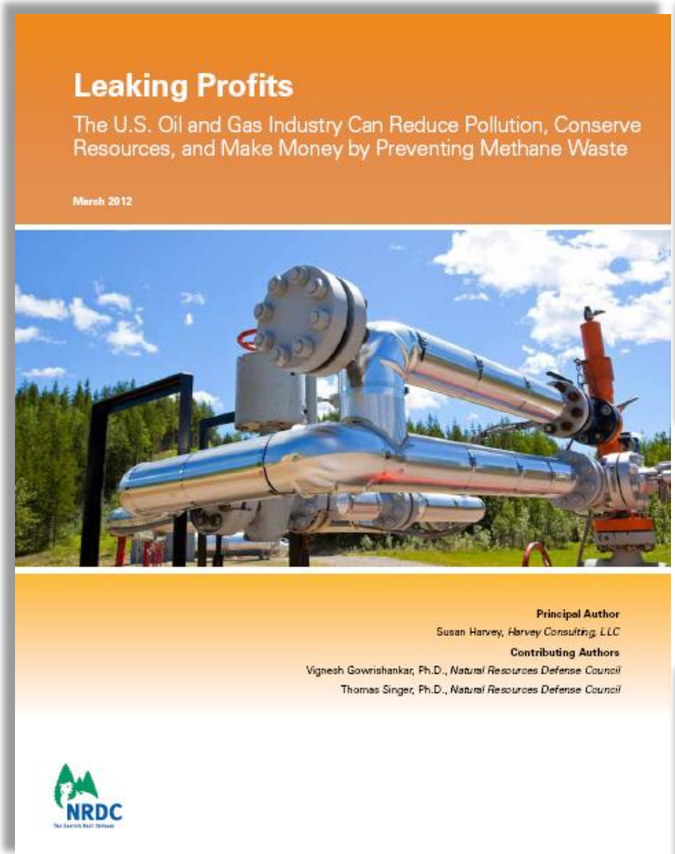
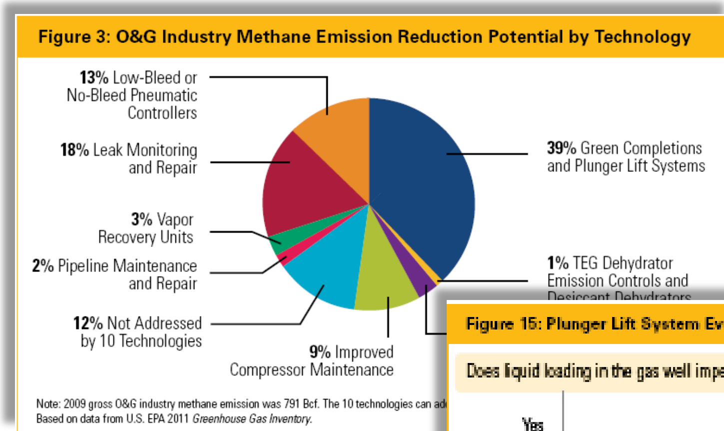
Leaking Profits covers ten profitable technologies with greatest emissions reduction potential





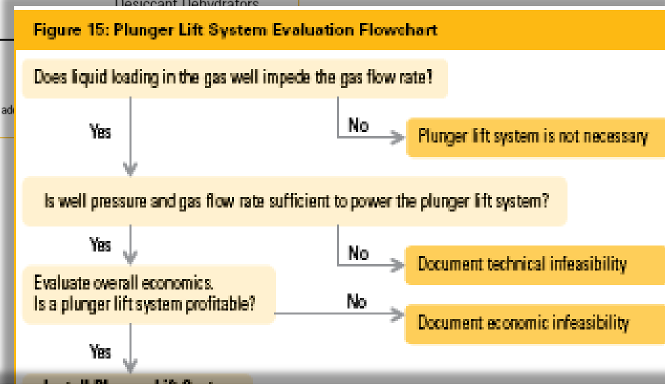


Table A5: Cost-effectiveness of replacing wet seals in centrifugal compressors with dry seals

			#	$	$ / yr	Mcf	$ /Mcf	$/ yr	$/ yr	$ / yr	Years	$ / yr	$ / y
Source	Year	Type	# devices	Total investment	Annual investment expense	Volume of saved NG	Price of NG	Revenue from NG	O&M savings per year	Total revenue plus savings per year	Payout	Operating profit (ex depr) per year	Operating profit per year
EPA Lessons Learned	2006	Avg.		324,000	46,129	45,120	4	180,480	102,400	282,880	1.15	282,880	236,751
EPA NG STAR	2006	Max (savings)		324,000	46,129	100,000	4	400,000	120,000	520,000	0.62	520,000	473,871
Petroleos Mexicanos	2008	Avg.				35,000	4	140,000		140,000+		140,000+	
Targa	2006	Avg.		90,000	12,814					300,000	0.36	300,000	287,186
(EPA NSPS TSD estimates below not utilized to inform the range of costs and benefits in this report; only provided for completeness)													
EPA – NSPS TSD	2008	Processing		75,000	10,678	11,527	4	46,108	88,300	134,408	0.56	134,408	123,730
EPA – NSPS TSD	2008	Trans. / Storage		75,000	10,678	6,372			88,300	88,300	0.85	88,300	77,622
EPA – NSPS TSD	2008	Simple avg.		75,000	10,678	8,949		23,054	88,300	111,354	0.67	111,354	100,676

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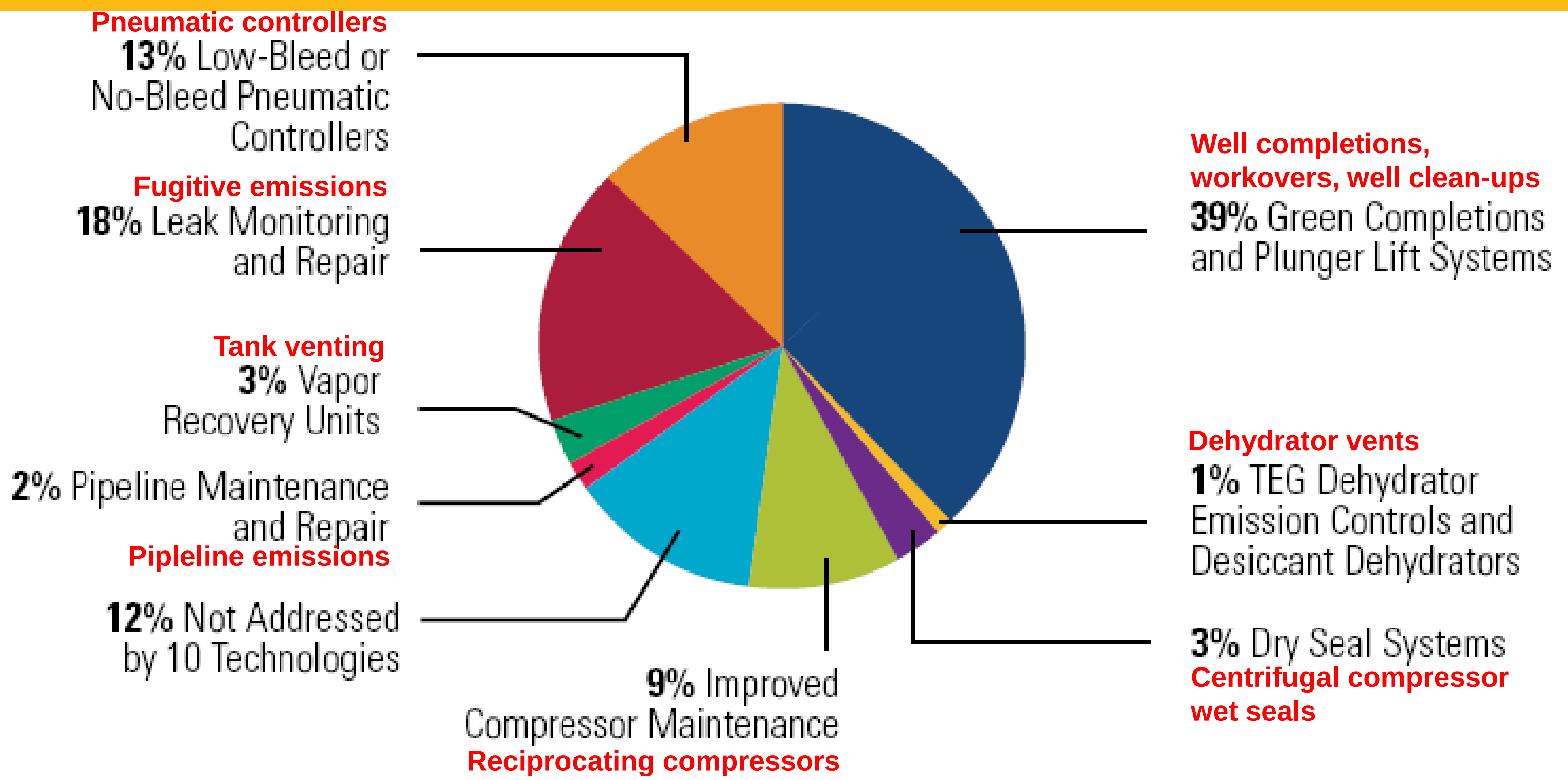
http://www.nrdc.org/energy/leaking-profits.asp

Ten technologies can address most of the methane emissions from O&G Industry

O&G Industry Methane Emissions Reduction Potential by Technology



Note: 2009 gross O&G industry methane emission was 791 Bcf. The 10 technologies can address all but 12 percent of these emissions. Based on data from U.S. EPA 2011 *Greenhouse Gas Inventory*.

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Red text indicates source of emissions

…and these ten technologies are commercially viable and profitable with short payback periods

Methane Capture Technology Costs and Benefits

#	Technology	Investment Cost	Methane Capture	Profit	Payout
1	Green Completions	$8,700 to $33,000 per well	7,000 to 23,000 Mcf/well	$28,000 to $90,000 per well	< 0.5 – 1 year
2	Plunger Lift Systems	$2,600 to $13,000 per well	600 to 18,250 Mcf/year	$2,000 to $103,000 per year	< 1 year
3	TEG Dehydrator Emission Controls	Up to $13,000 for 4 controls	3,600 to 35,000 Mcf/year	$14,000 to $138,000 per year	< 0.5 years
4	Desiccant Dehydrators	$16,000 per device	1,000 Mcf/year	$6,000 per year	< 3 years
5	Dry Seal Systems	$90,000 to $324,000 per device	18,000 to 100,000 Mcf/year	$280,000 to $520,000 per year	0.5 – 1.5 years
6	Improved Compressor Maintenance	$1,200 to $1,600 per rod packing	850 Mcf/year per rod packing	$3,500 per year	0.5 years
7	Pneumatic Controllers Low-Bleed	$175 to $350 per device	125 to 300 Mcf/year	$500 to $1,900 per year	< 0.5 – 1 year
	Pneumatic Controllers No-Bleed	$10,000 to $60,000 per device	5,400 to 20,000 Mcf/year	$14,000 to $62,000 per year	< 2 years
8	Pipeline Maintenance and Repair	Varies widely	Varies widely but significant	Varies widely by significant	< 1 year
9	Vapor Recovery Units	$36,000 to $104,000 per device	5,000 to 91,000 Mcf/year	$4,000 to $348,000 per year	0.5 – 3 years
10	Leak Monitoring and Repair	$26,000 to $59,000 per facility	30,000 to 87,000 Mcf/year	$117,000 to $314,000 per facility per year	< 0.5 years

10

Short paybac period

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Moving forward:

- Clean up existing fuel production: Strong federal and state regulations are vital to controlling methane emissions effectively

- Improve vehicle efficiencies, regardless of fuel-type

- Fuel switching to lower carbon-intensity fuels, including electricity, biogas, and sustainably produced biofuels

- Shift to more efficient transport modes (e.g. trains and barges)

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Appendix

Strong regulations are important to control methane emissions effectively

The 10 technologies are profitable, but companies may nonetheless not implement them because they:

- May lack awareness and technical know-how of these technologies
- Have limited capital that other profitable investments compete for (coupled with aggressive internal hurdle rates)
- May lack, depending on history, corporate commitment to sustainability
- May not have appropriate incentive structures

Strong regulations are required to control methane emissions. Elements of strong regulations include:

- **Ensure coverage of all major sources**
- **Control both existing sources and new sources of methane** (unlike U.S., only new source regs)
- **Control methane emissions directly** (not using volatile organics or other emissions as a proxy)
- Specify particular control technologies (as a minimum): Green completions, plunger lifts, dehydrator controls, dry seals, compressor maintenance, reduced-bleed pneumatic controllers, VRUs, pipeline maintenance, leak detection and repair
  (OK in this case as control technologies are known)
- Require emissions reporting
- Consider including technology / best-practice sharing mechanism or forum
- Impose minimum national regulations with and option for regional overlay to account for region-specific issues

EPA's 2012 regulations to control air emissions will only address about 20% of the methane emissions in the near term

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	New sources	Existing sources
Uncontrolled	• **Completions, recompletions** (e.g., hybrid wells) • **Liquids unloading (well clean-ups)** • **Dehydrators** (e.g., tighten standards) • **Centrifugal compressors** (e.g., well site, distribution) • **Reciprocating compressors** (e.g., well site, distribution) • **Pneumatic controllers** (e.g., distribution, tighten standards) • **Pipeline emissions** (e.g., all) • **Tanks** (e.g., tighten standards) • **Fugitive emissions** (e.g., in all sectors) **~5%** of total methane emissions	• **Liquids unloading (well clean-ups)** • **Dehydrators** (e.g., tighten standards) • **Centrifugal compressors** • **Reciprocating compressors** • **Pneumatic controllers** • **Pipeline emissions** • **Tanks** (e.g., tighten standards, threshold) • **Fugitive emissions** (e.g., in all sectors) **75%** of total methane emissions
Controlled (NSPS/NESHAPs)	• Completions (very large %) • Dehydrators (NESHAPs, small %) • Centrifugal compressors (2%) • Reciprocating compressors (<1%) • Pneumatic controllers (5%) • Tanks (3%: NSPS, NESHAPs) • Fugitive emissions (<0.1%) **10-15%** of total methane emissions	• Recompletions (large %) • Dehydrators (NESHAPs, small %) • Tanks (3%: NESHAPs) • Fugitive emissions (<0.1%) **<5%** of total methane emissions

- Over time as existing fleet is repaired or replaced, NSPS will have more effect (up to about 25-30% by 2035)

Technologies in more detail

❶ Green completions can control almost all methane emissions from initial phases of gas production from unconventional (e.g., shale) wells

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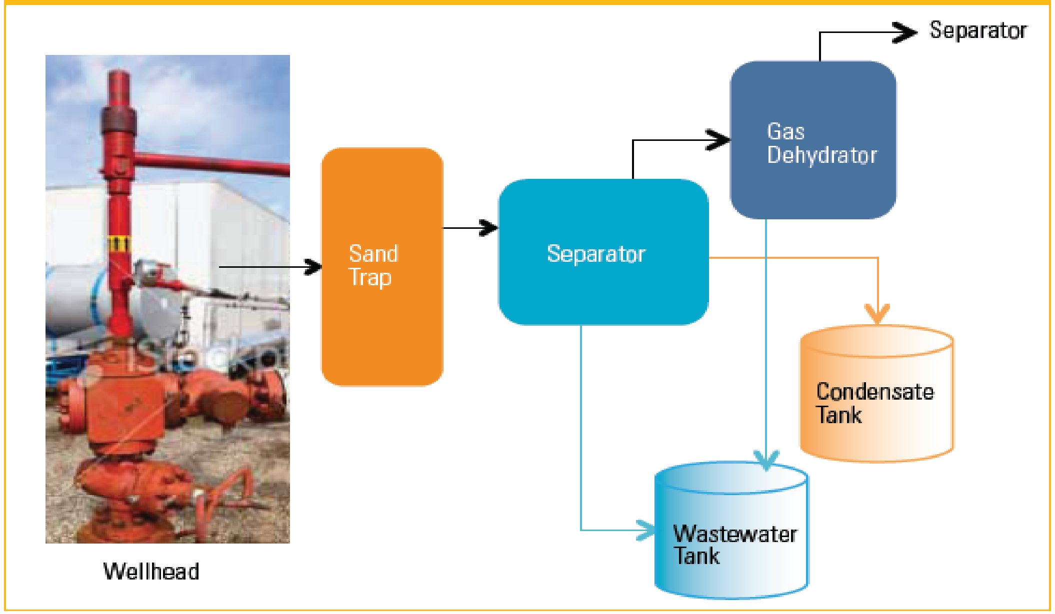
Technology	Investment Cost	Methane Capture	Profit	Payout
Green Completions	$8,700 to $33,000 per well	7,000 to 23,000 Mcf/well	$28,000 to $90,000 per well	< 0.5 – 1 year

Green Completion Equipment Schematic



Green Completion Equipment

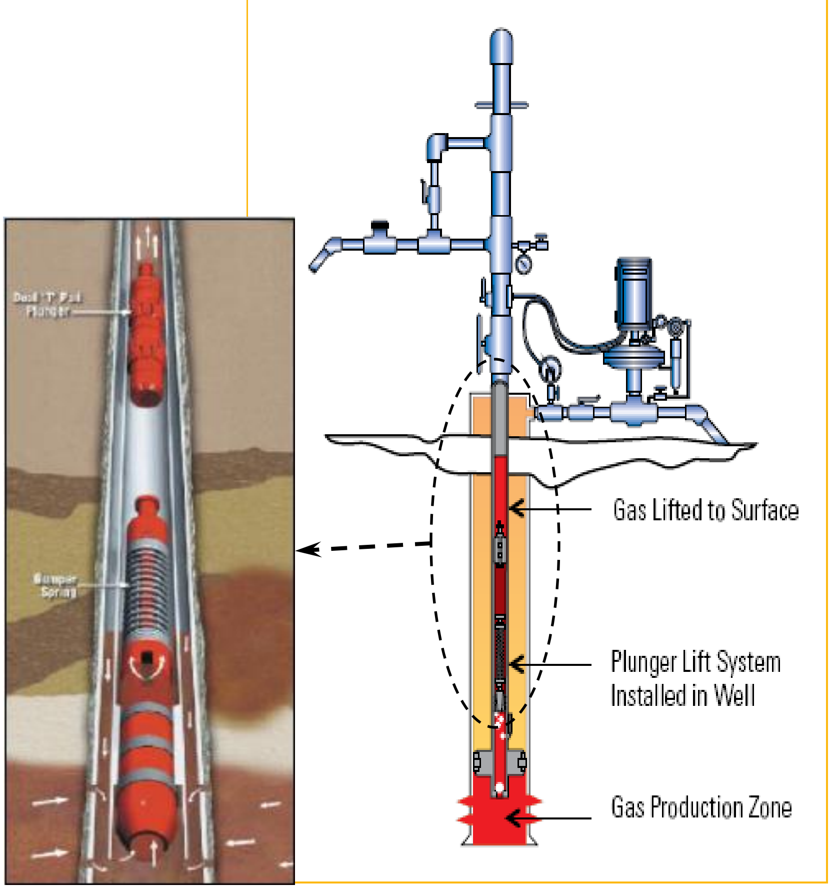
Colorado Oil & Gas Conservation Commission, "Proposed Rules for Green Completions" presentation June 27, 2008

- Features:
  - All wells need some kind of completion during wellbore cleanup and before gas sent for processing
  - Green completions require some additional equipment (e.g., sand trap); equipment usually portable
  - Enormous methane savings (green completions capture methane, normal completions do not)
  - Reduces VOCs and air toxics; reduces need for flaring; improves well cleanup and productivity
- Limitations: Not cost-effective in low pressure wells, or in exploratory wells not close to pipelines.
- Required under new US EPA regulations, where technically feasible.

Plunger lift systems are a low-cost route to reduce methane emissions and increase productivity from older wells

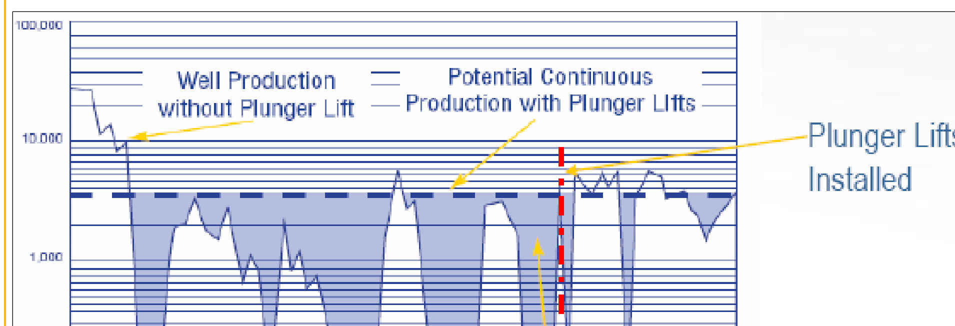
Technology	Investment Cost	Methane Capture	Profit	Payout
Plunger Lift Systems	$2,600 to $13,000 per well	600 to 18,250 Mcf/year	$2,000 to $103,000 per year	< 1 year

Plunger Lift System Schematic



Courtesy: Weatherford

- Features:
  - Used instead of well blowdown or liquids cleanup
  - Used in older wells, to increase productivity (10 – 20%)
  - Is deliquification method, which does not need power (other deliquification methods exist, but need power)
  - Reduces VOCs and air toxics
  - Reduces downtime of wells and need for bore cleaning
- Limitations:
  - Needs sufficient gas volume and pressure
  - Not usable in well with changing bore diameters

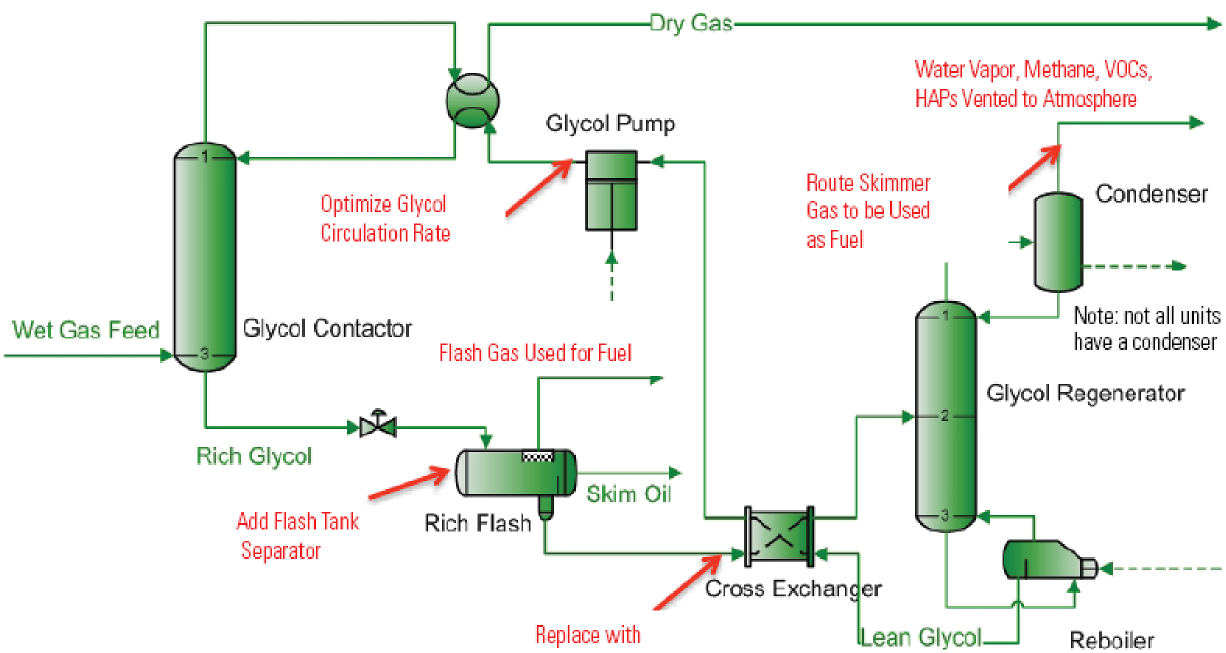


Courtesy: Production Control Services

3 Emissions controls for dehydrators are profitable , and address a small portion of the emissions

Technology	Investment Cost	Methane Capture	Profit	Payout
TEG Dehydrator Emission Controls	Up to $13,000 for 4 controls	3,600 to 35,000 Mcf/year	$14,000 to $138,000 per year	< 0.5 years

Glycol Dehydration Unit Schematic



Source: Wikimedia Commons, Wikipedia: Glycol Dehydration

Methane Capture Potential from TEG Dehydrator Controls

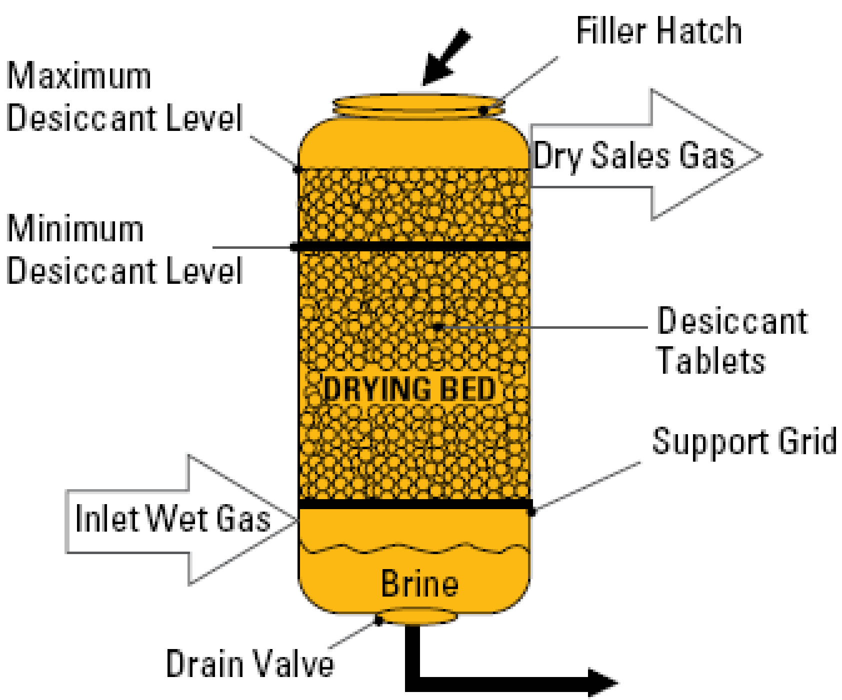
Technology	Methane Capture Mcf/year
Flash Tank Separator	3,650
Optimize Glycol Circulation Rate	18,250
Reroute Skimmer Gas	7,665
Install Electric Pump	5,000
Potential Methane Capture Range	**3,650 to 34,565**

- Features:
  - Best suited for high flow dehydrators
  - Variety of options to control emissions from TEG dehydrators – some are no cost
  - Reduces air toxics, especially benzene
- Limitations: Some components needs electricity

❹ …and desiccant dehydrators provide another profitable alternative

Technology	Investment Cost	Methane Capture	Profit	Payout
Desiccant Dehydrators	$16,000 per device	1,000 Mcf/year	$6,000 per year	< 3 years

Desiccant Dehydrator Schematic

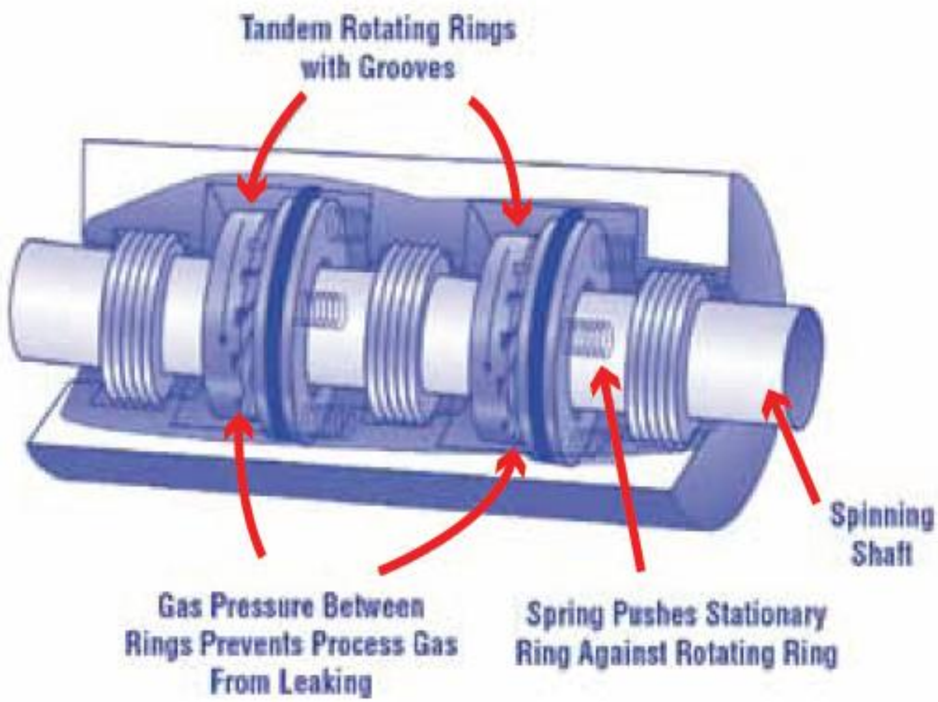


- Features:
  - Very low emissions (99% removed)
  - Simpler system
  - Reduces VOCs and air toxics
- Limitations:
  - Not suitable for high-flow systems, or high-pressure systems, or high temperatures (> 70 deg F)

Dry seal systems for centrifugal compressors can address a small portion of the emissions, and are very profitable

Technology	Investment Cost	Methane Capture	Profit	Payout
Dry Seal Systems	$90,000 to $324,000 per device	18,000 to 100,000 Mcf/year	$280,000 to $520,000 per year	0.5 – 1.5 years

Centrifugal Compressors Dry Seals



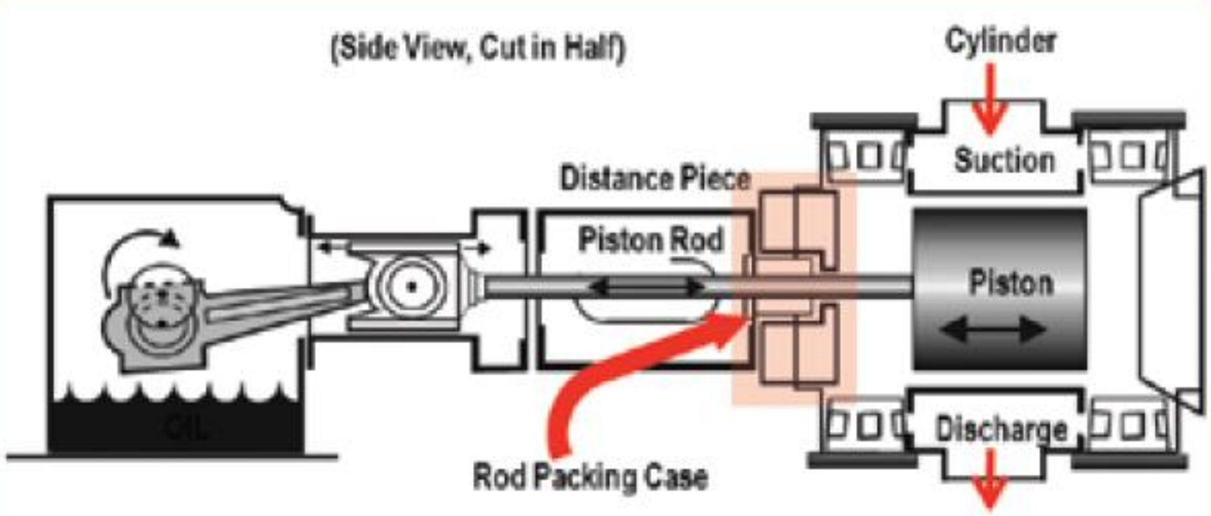
Adapted from EPA Lessons Learned, Replacing Wet Seals with Dry Seals in Centrifugal Compressors.

- Features
  - Use high-pressure gas to seal between rings and shaft (typically tandem seals)
  - Wet seals are already being phased out in the market
  - Very favorable economics (saves methane, reduces maintenance cost and downtime)
- Limitations
  - Dry seals are not possible with certain housing designs

❻ Replacing worn rod packing in reciprocating compressors can address about one tenth of all methane emissions

Technology	Investment Cost	Methane Capture	Profit	Payout
Improved Compressor Maintenance	$1,200 to $1,600 per rod packing	850 Mcf/year per rod packing	$3,500 per year	0.5 years

Reciprocating Compressor Rod Packing Leaks Schematic



Adapted from EPA 2009 Methane to Market Presentation.

- Features
  - Regular monitoring and replacement of worn rod packing will have savings
  - Methane savings, reduced piston wear
  - Also improves air quality and safety of work site
- Limitations
  - Small facilities may require a complete shutdown to perform maintenance

7 Converting widely prevalent pneumatic controllers to low-bleed or no-bleed versions can reduce more than a tenth of total methane emissions

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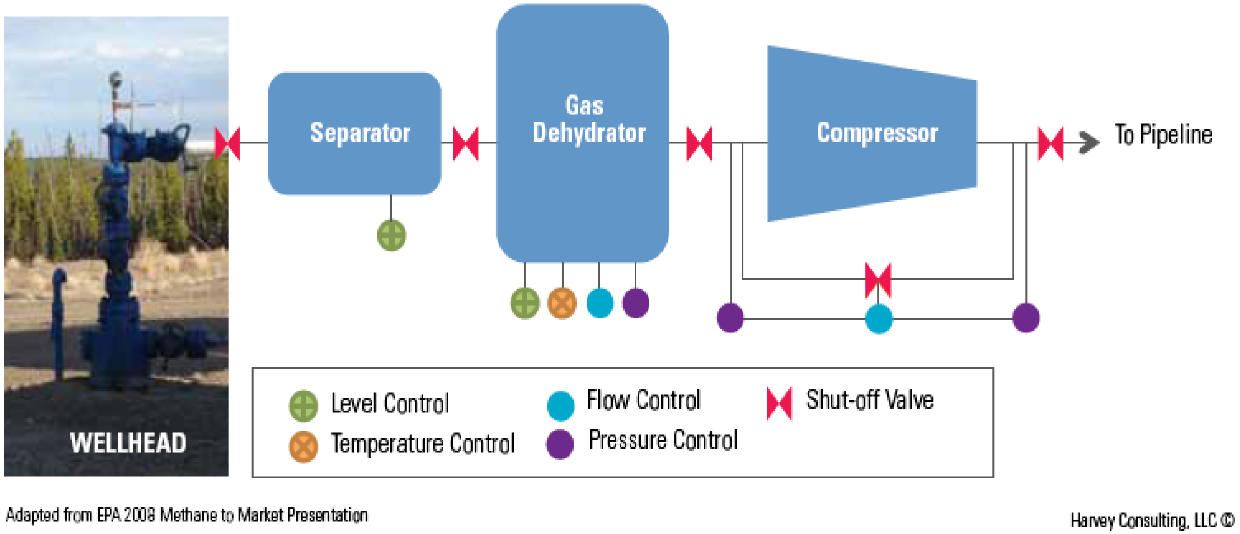
Technology	Investment Cost	Methane Capture	Profit	Payout
Pneumatic Controllers Low-Bleed	$175 to $350 per device	125 to 300 Mcf/year	$500 to $1,900 per year	< 0.5 – 1 year
Pneumatic Controllers No-Bleed	$10,000 to $60,000 per device	5,400 to 20,000 Mcf/year	$14,000 to $62,000 per year	< 2 years

Pneumatic Controller

Pneumatic Controller Locations in Natural Gas Production

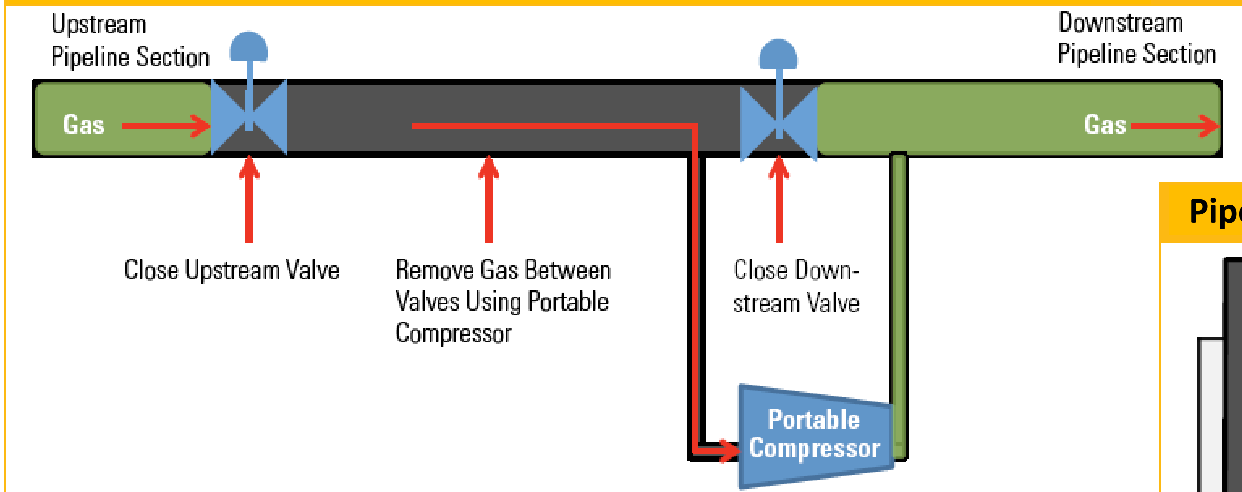


- Features
  - Compressors naturally leak gas to control pressure, flow rate and temperature: convert to low- or no-bleed (instrument air)
- Limitations
  - About 20% of controllers (in the US) may not be suitable for retrofitting or replacement. (Need not be case in China)

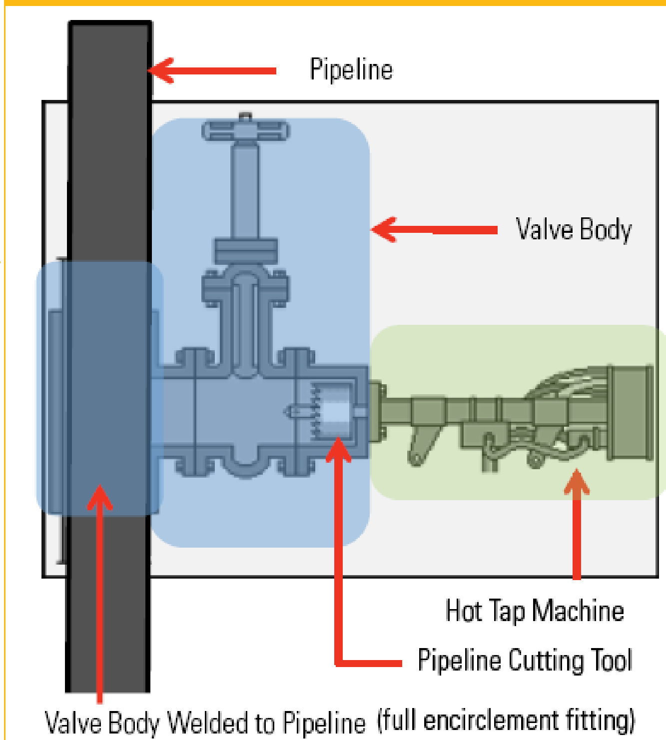
Advanced pipeline maintenance and repair solutions can profitably prevent methane leaks

Technology	Investment Cost	Methane Capture	Profit	Payout
Pipeline Maintenance and Repair	Varies widely	Varies widely but significant	Varies widely by significant	< 1 year

Pipeline Pump-Down Technique Using Portable Compressor Schematic



Pipeline Hot Tapping Schematic



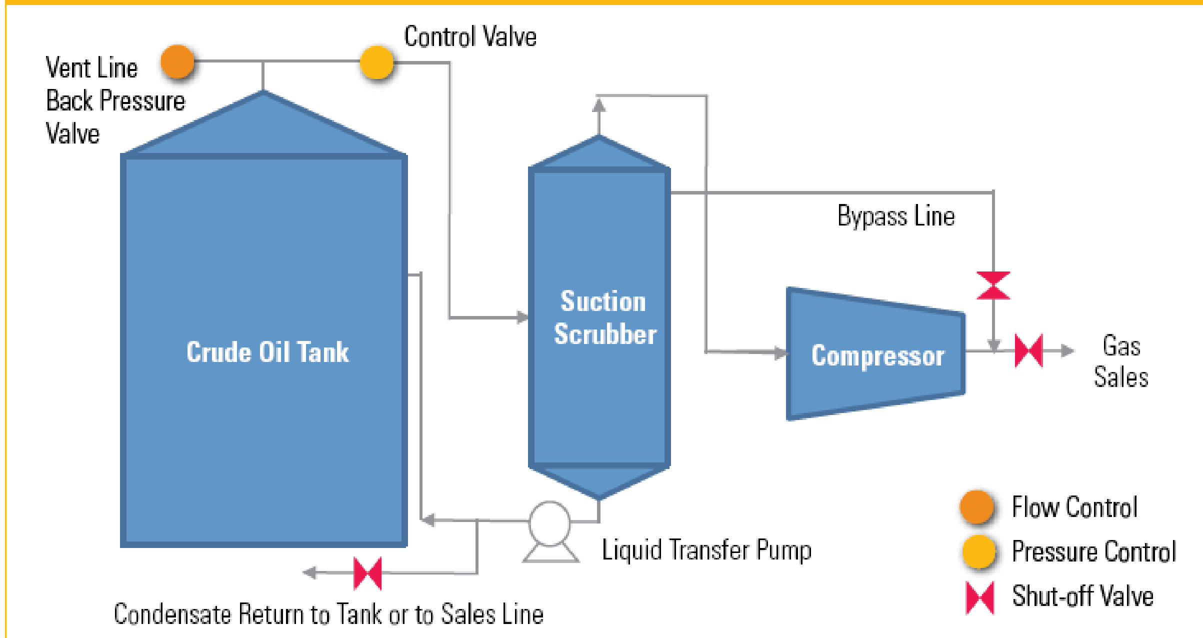
- Features
  - Three main solutions
    - Pipeline hot-tapping – make a connection
    - Pipeline pump-down – undertake repairs
    - Reroute gas to fuel system – perform maintenance
  - Saves methane and minimizes disruption to service
- Limitations
  - Some options require safety review and trained personnel

Vapor Recovery Units are an easy and highly profitable way to reduce emissions from storage tanks

Technology	Investment Cost	Methane Capture	Profit	Payout
Vapor Recovery Units	$36,000 to $104,000 per device	5,000 to 91,000 Mcf/year	$4,000 to $348,000 per year	0.5 – 3 years

Vapor Recovery Unit

Vapor Recovery Unit Schematic



- Features
  - Vapor Recovery Units can save 95% of methane otherwise vented (working, standing losses)
  - Has ozone benefits. Captures VOCs and air toxics
- Limitations
  - Typically pipeline proximity is needed to utilize the captured methane
  - Oxygen entrainment (entrapment) should be avoided as it poses a corrosion hazard

10

Leak monitoring and repair relies on changing procedures at natural gas facilities and monitoring equipment, and can reduce emissions considerably

Technology	Investment Cost	Methane Capture	Profit	Payout
Leak Monitoring and Repair	$26,000 to $59,000 per facility	30,000 to 87,000 Mcf/year	$117,000 to $314,000 per facility per year	< 0.5 years

Remote Methane Leak Detector

Courtesy: FLIR

- Features
  - 2-part practice: Monitoring & Repair
  - Many ways to monitor: electronic gas detectors, acoustic/ ultrasound leak detectors, flame ionization detectors, calibrated bagging, high volume sampler, end-of-pipe flow measurement, toxic vapor analyzers, and infrared optical gas detectors.
  - Fugitive emissions from valves, drains, pumps, connections, pressure relief devices, open-ended valves, sample points
  - 75 – 85% of leaks are economic to repair
  - Top 10 leaks > 80% of emissions (older facilities have most leaks)

Questions

Wyoming's Jonah Field. Courtesy: National Geographic