METHANE
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PRINCIPLES

Methane Guiding Principles

Outreach Programme

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Antitrust law compliance reminder

- Some attendees at this meeting may be competitors and should avoid even the appearance of impropriety. Every attendee has his or her own responsibility to ensure they do not discuss anything inappropriate under antitrust /competition law.

- Participants should not discuss anything that could affect market behavior in relation to products or services where they compete, such as:
  - Pricing or pricing elements (including price differentials, margins, price changes, price mark-ups, discounts, allowances, rebates, commission rates, credit terms, price changes, etc.)
  - Non-public plans or strategic intentions (including investments or divestments, expansion plans or market entry or exit, etc.).
  - Which territories or end-customers we intend to sell products into/to.
  - Market conditions for particular products.
  - Intentions to enter into bids / tenders or discussions on the terms of a bid.
  - Costs or elements thereof (including production or distribution costs, cost accounting formulae, methods of computing costs, individual company figures on sources of supply, inventories, sales etc.).
  - Volume information related to production and sales.
  - Intentions to deal or not to deal with certain suppliers or customers.

- If you feel uncomfortable at any point, please raise this to the course facilitator.

Safety Moment

- Incident
  - At Imperial's International Centre for Advanced Materials
  - Researcher plugged a heat block into a power point inside a biosafety cabinet
  - It did not light up, so researcher checked the connection, and received an electric shock
  - On 1st investigation an electrician reported all was well, but the researcher insisted on a 2nd opinion, upon which it emerged that earth and live wires had be mixed up at installation
- Key messages
  - Do not work on or do something that you do not think is safe
  - If something does not feel right, speak up
  - Immediately report incidents

Agenda

8:30 - Arrival and welcome coffee

9:00 – 11:00

- *Short introduction*
- *The Methane Emissions Reduction Business Case*
- *Reducing methane emissions: Understanding methane*
- *Introducing the Reducing Methane Emissions Best Practices - Overview*
- *RMEBP and Case Study: Venting*
- *RMEBP and Case Study: Pneumatic devices*

11:00 – Coffee break

11:15 – 12:45

- *RMEBP and Case Study: Flaring*
- *RMEBP and Case Study: Equipment Leaks*
- *RMEBP and Case Study: Operational Repairs*
- *Interactive session: Methane mitigation decision making- the RMEBP Cost Model*

12:45 – Lunch break

14:00 – 16:00

- *RMEBP and Case Study: Energy Use*
- *RMEBP and Case Study: Engineering Design and Construction*
- *RMEBP: Continual Improvement*
- *Interactive session: Methane management in action- the RMEBP Gap Assessment Tool*

16:00 - Closure of the training programme

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Methane Guiding Principles

An overview of the initiative

Rationale for the Methane Guiding Principles

- Providing access to energy, while addressing global climate change, is one of the greatest challenges of the 21st century.
- Methane is a potent greenhouse gas.
- A concerted, value-chain wide, industry response is needed.

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Methane Guiding Principles

1

Continually reduce methane emissions

2

Advance strong performance across gas value chains

3

Improve accuracy of methane emissions data

4

Advocate sound policy and regulations on methane emissions

5

Increase transparency

Signatories and supporting organisations

TOTAL
ExxonMobil
REPSOL
GAZPROM
Woodside
SOCAR
gasunie
crossing borders in energy
bp
equinor
eni
enagas
wintershall dea
قطر للبترول
Qatar Petroleum
Chevron
snam
BAKER HUGHES
a GE company
ROSNEFT
北京燃气
BEIJING GAS
TransCanada

IGU
ipieca
IOGP International Association of Oil & Gas Producers
energy institute
EDF ENVIRONMENTAL DEFENSE FUND
Finding the ways that work
UN environment
iea
ROCKY MOUNTAIN INSTITUTE
eurogas
Fuelling the future
teri
OGCI CLIMATE INVESTMENTS
gie
marcogaz
TECHNICAL ASSOCIATION
OF THE EUROPEAN NATURAL GAS INDUSTRY

Global outreach programme disclaimer

The Global Outreach Programme course content has been developed by researchers from the Sustainable Gas Institute at Imperial College London, working independently through Imperial Consultants - and funded by the Methane Guiding Principles partnership. The information included is accurate to the best of the authors’ knowledge but does not necessarily reflect the views or positions of all Signatories to or Supporting Organisations of the Methane Guiding Principles partnership, and course participants will need to make their own evaluation of the information provided. No warranty is given to course participants concerning the completeness or accuracy of the information included in the course by Imperial Consultants, Sustainable Gas Institute, the Methane Guiding Principles partnership or its Signatories or Supporting Organisations.

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Reducing Methane Emissions: The Business Case

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Reducing methane emissions: The role of gas

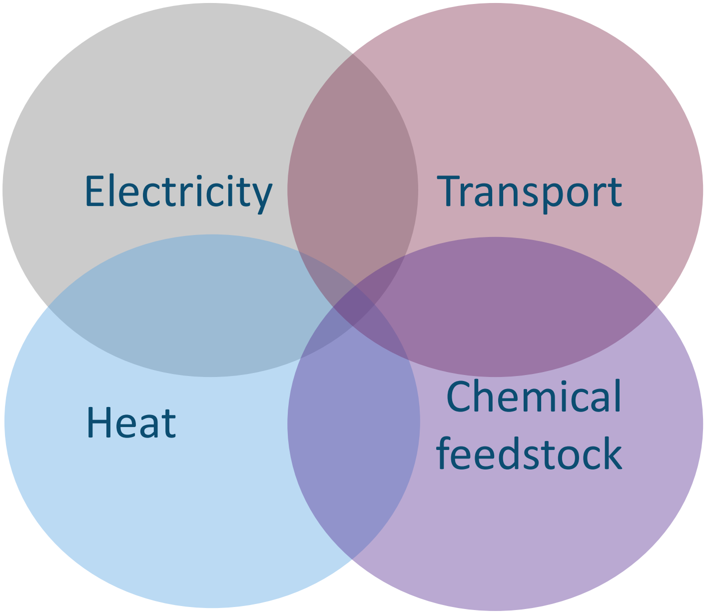
Natural gas qualities:

- Low cost
- Provides flexibility
- Increase energy access

Environmental credentials:

- Lowest carbon fossil fuel
- Reduces reliance on coal
- Air quality benefits relative to coal
- But methane emissions reduce this benefit

Natural gas services:



The credibility of gas in decarbonising energy systems depends on minimising methane emissions

Reducing methane emissions: the business case

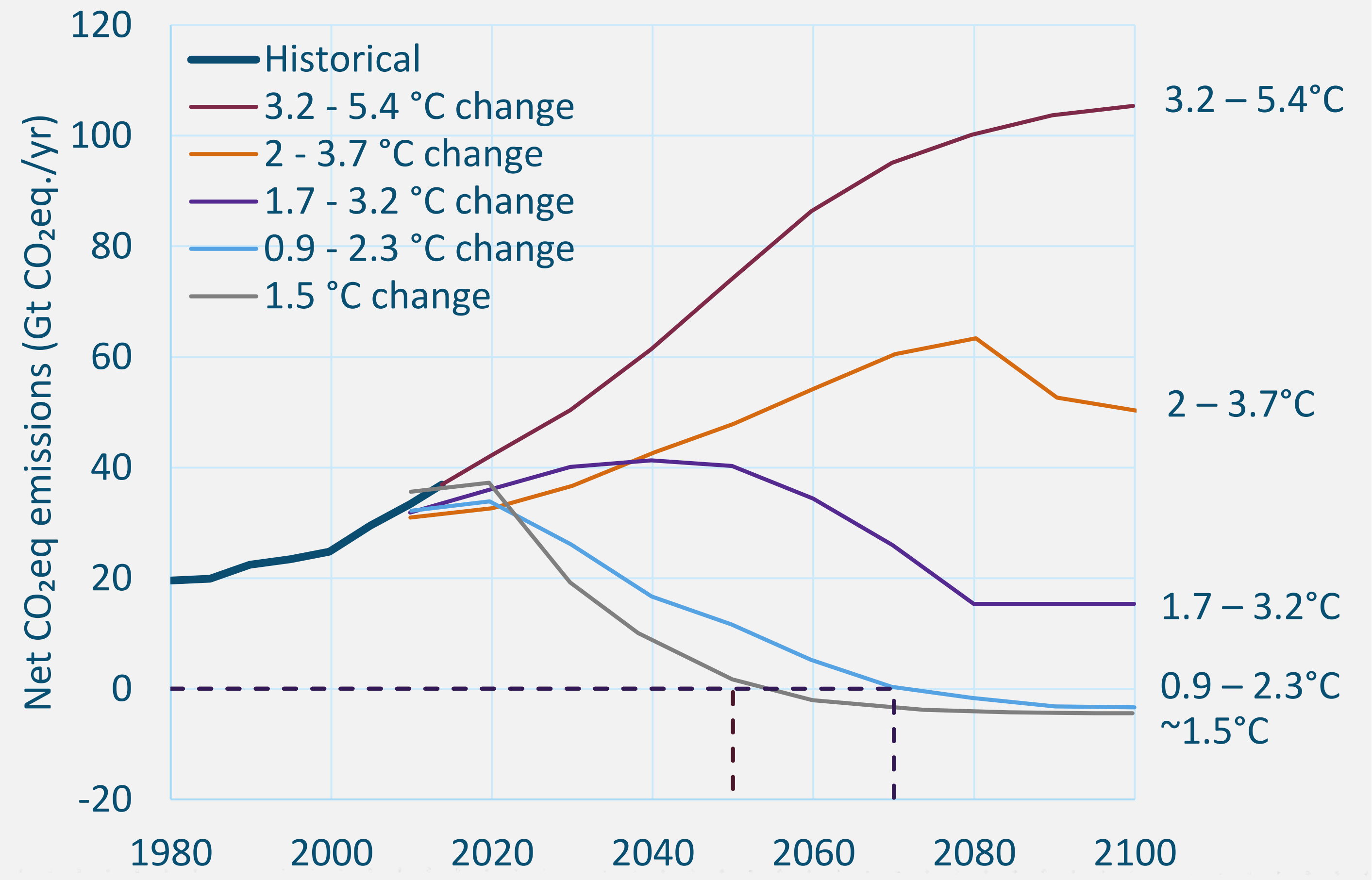
1. Climate change
2. Safety
3. Social licence
4. Revenue

Reducing methane emissions: the business case

1. **Climate change**
2. Safety
3. Social licence
4. Revenue

The business case: climate change

- IPCC decarbonisation pathways to 2100
- Dramatic reductions in greenhouse gas (GHG) emissions required to meet 2 or 1.5 °C targets
- Net zero emissions required by: 2070 for 2°C; 2050 for 1.5°C

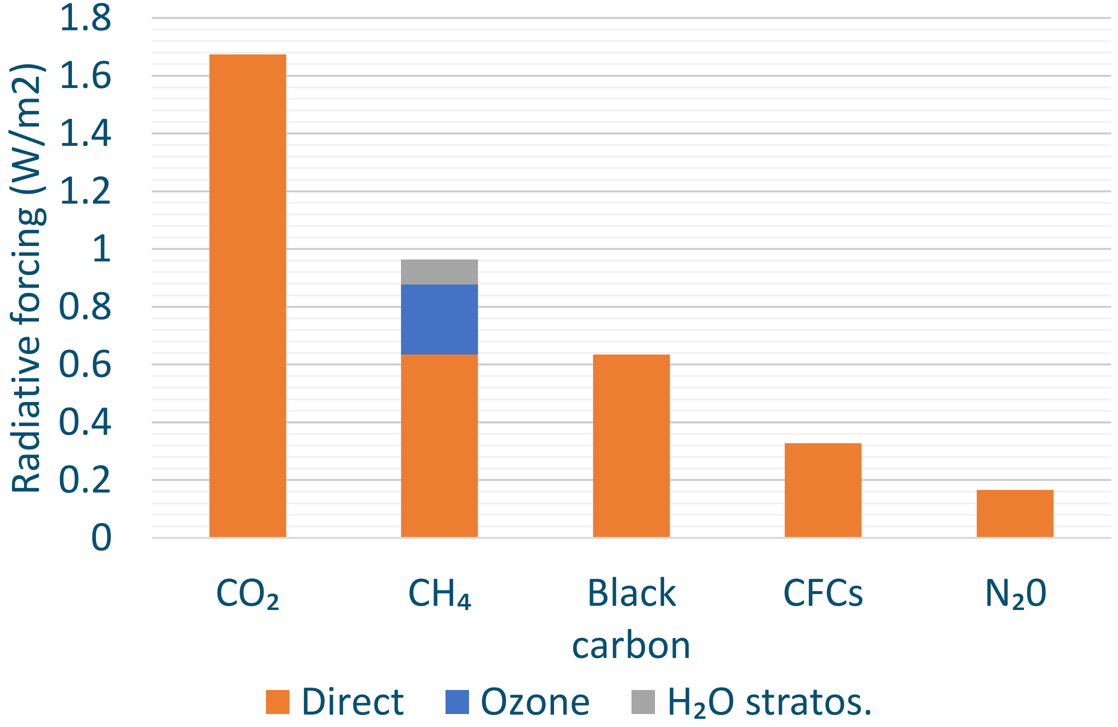


Source: IPCC 5th Assessment Report, Working Group 1; IPCC Special 1.5 °C Report

Methane's contribution to climate change

- Methane contributes ~25% of today's man-made warming
- This is 60% of the impact from CO_2
- This includes both direct and indirect climate impacts for methane (e.g. ozone creation and stratospheric water)

Contribution of greenhouse gases to total climate forcing

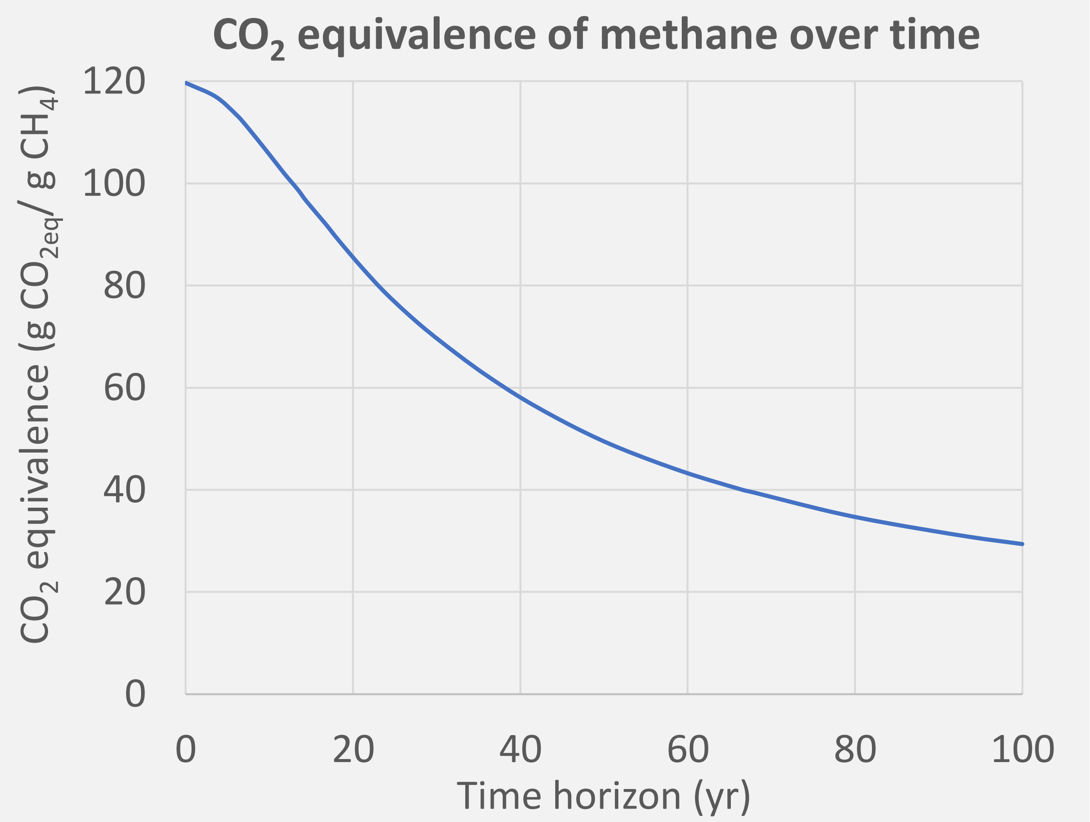


Source: IPCC 5th Assessment Report, Working Group 1

Methane is a potent but short-lived greenhouse gas

Metric	**CH_4**	**CO_2**
Instantaneous climate forcing (compared to CO_2)	120	1
Atmospheric lifespan (years)	8 - 12	100s*
Global Warming Potential (GWP 20 years)	84 - 87	1
Global Warming Potential (GWP 100 years)	28 - 36	1

- As near-term warming becomes higher priority, so does methane reduction
- Both short term and long term climate impacts are important



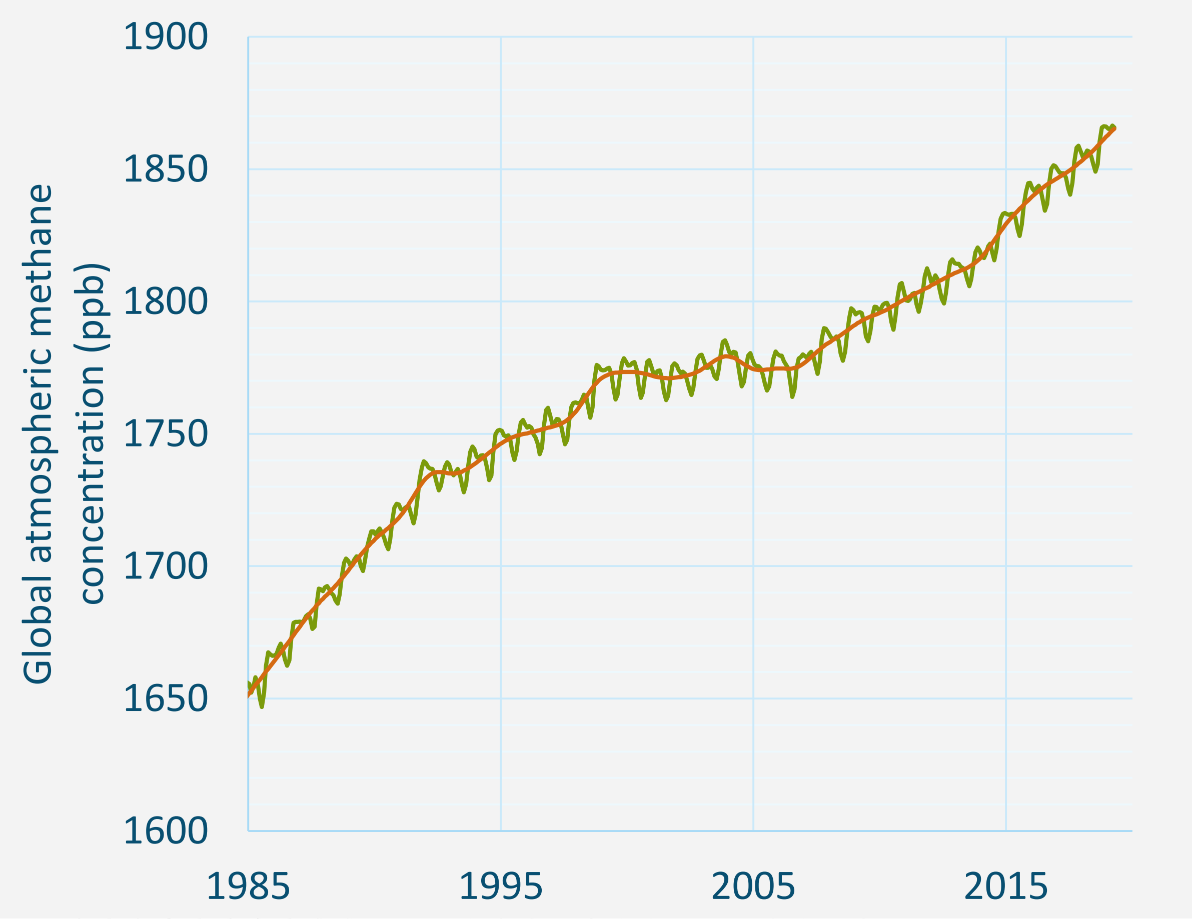
*CO_2 removal is more complicated, but 50% of a CO_2 emission is removed from the atmosphere within 37 years, whilst 22% of the emission effectively remains indefinitely

Global concentrations of methane are rising

- The concentration of methane in the atmosphere has increased

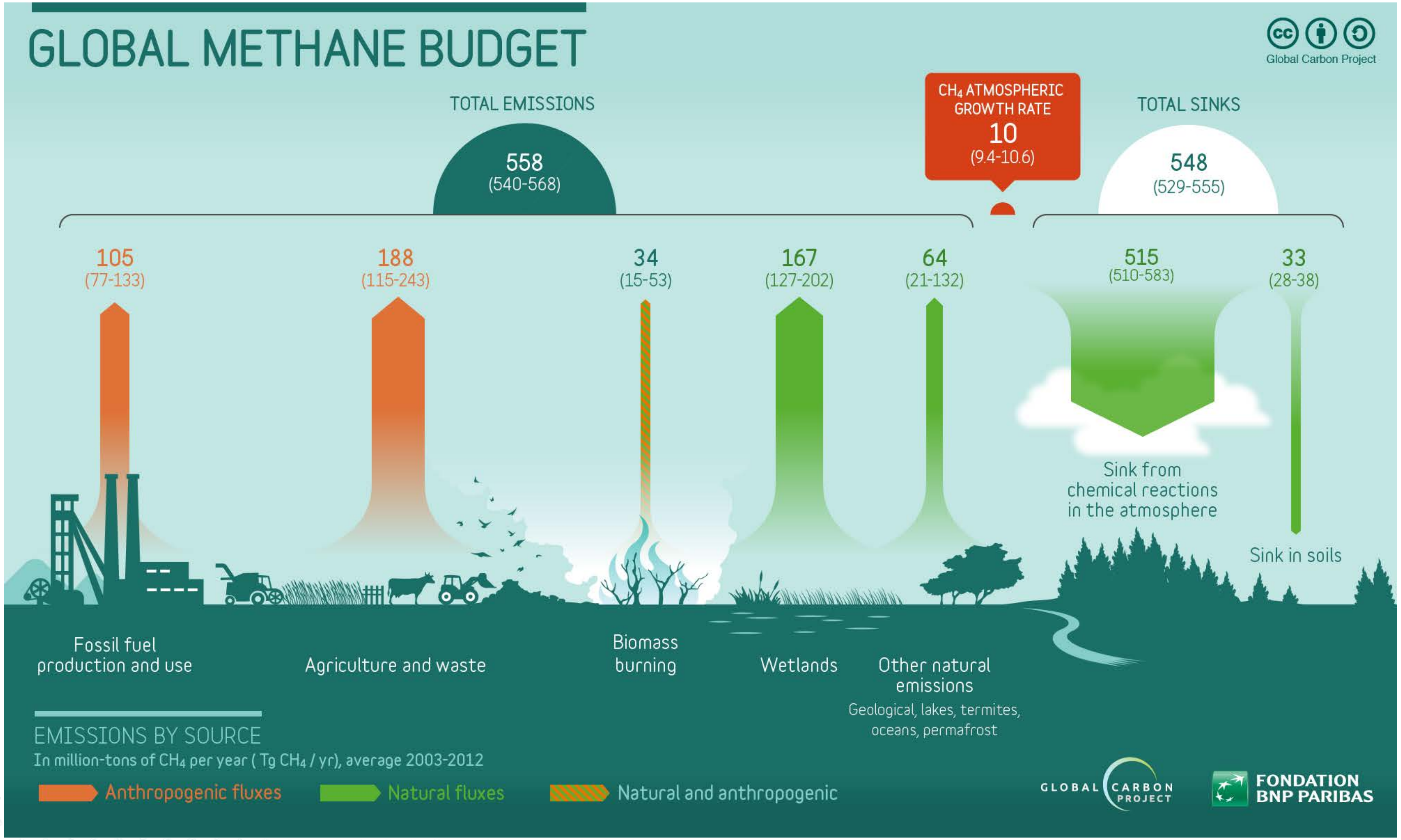
- An average year-on-year increase of 0.3-0.5% in the last decade

- Concentrations and total net emissions are well understood, but attributing to specific sources is more difficult: **high uncertainties…**



Source: https://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/

Sources of methane emissions

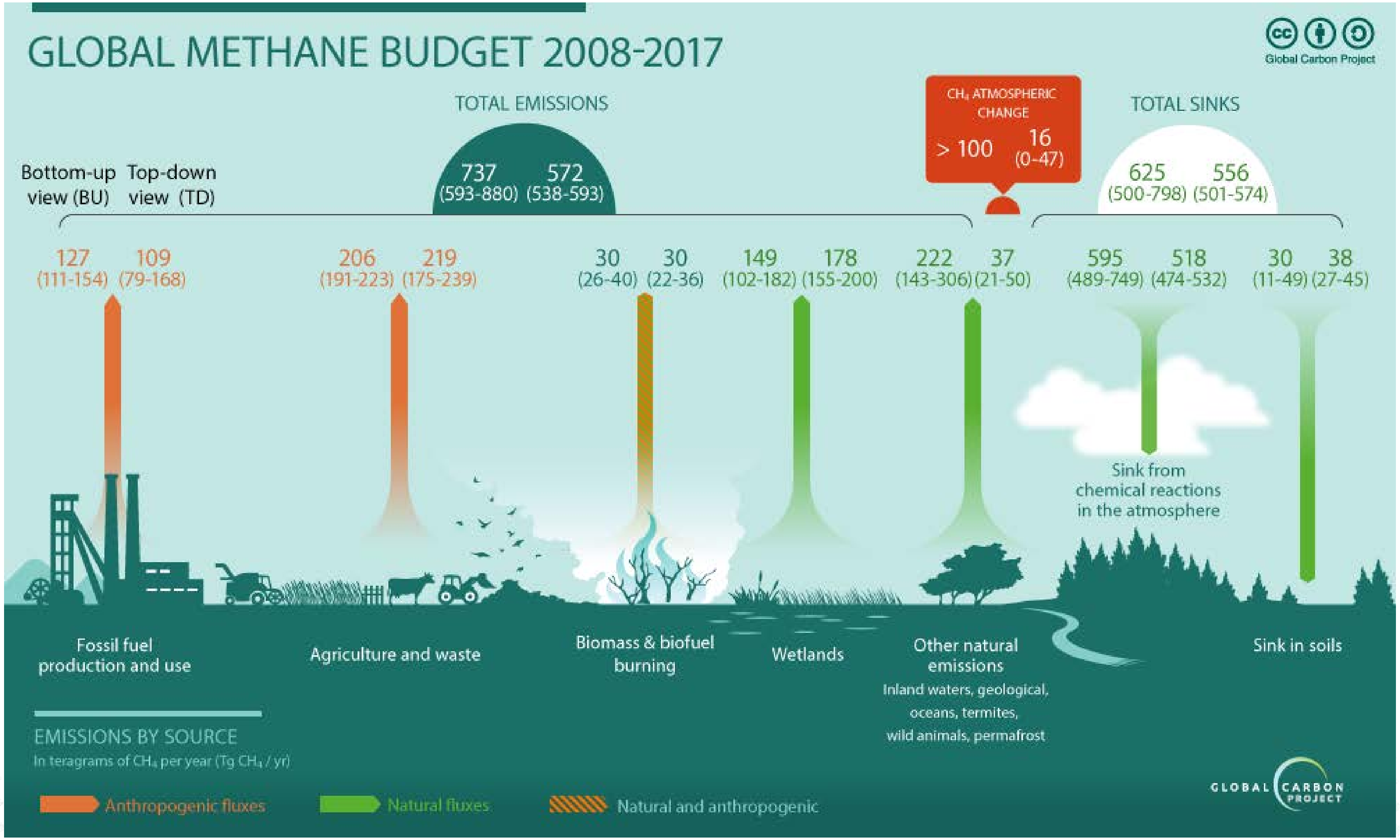


- The Global Methane Budget shows average estimates of atmospheric methane sources and sinks over the decade 2003 – 2012

- The net change (10 Mt CH$_4$) is well understood, but specific sources and sinks are less certain.

Source: Global Methane Budget www.globalcarbonproject.org/methanebudget/16/files/MethaneInfographic2016.png

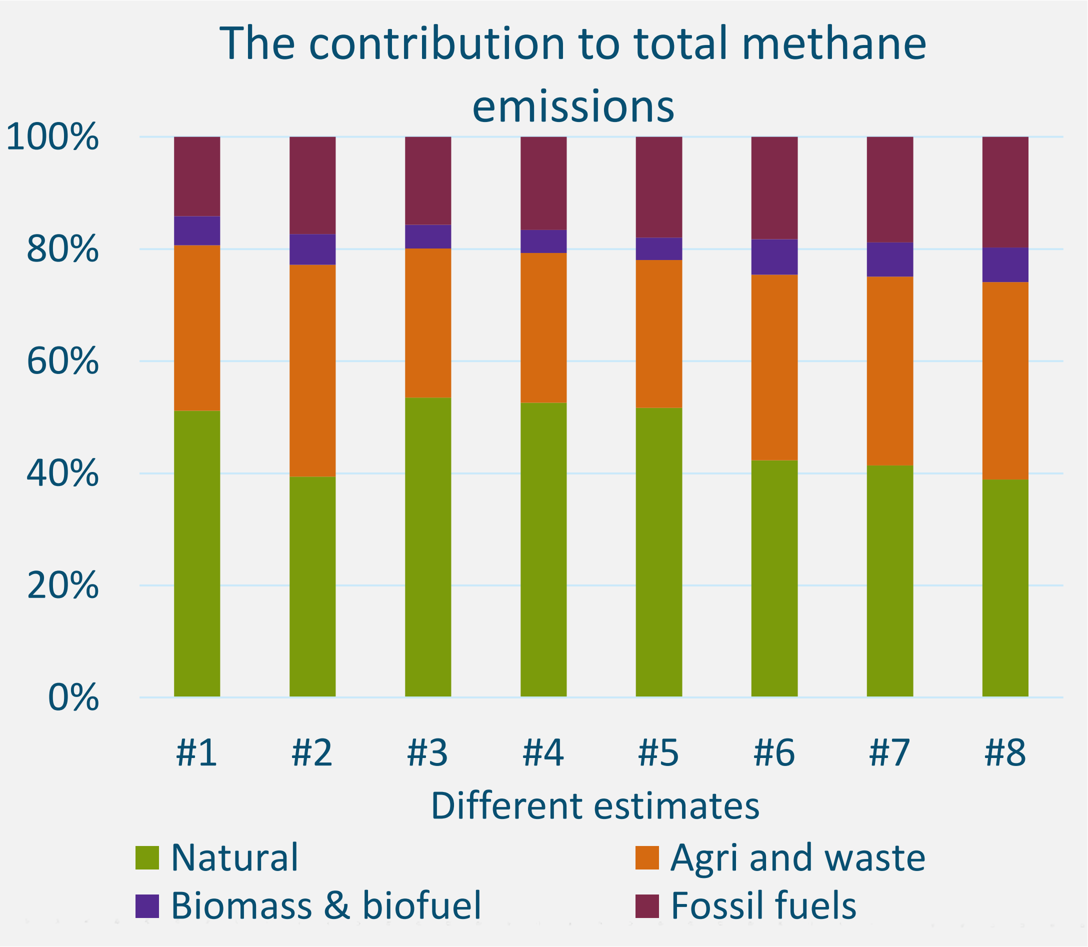
Sources of methane emissions



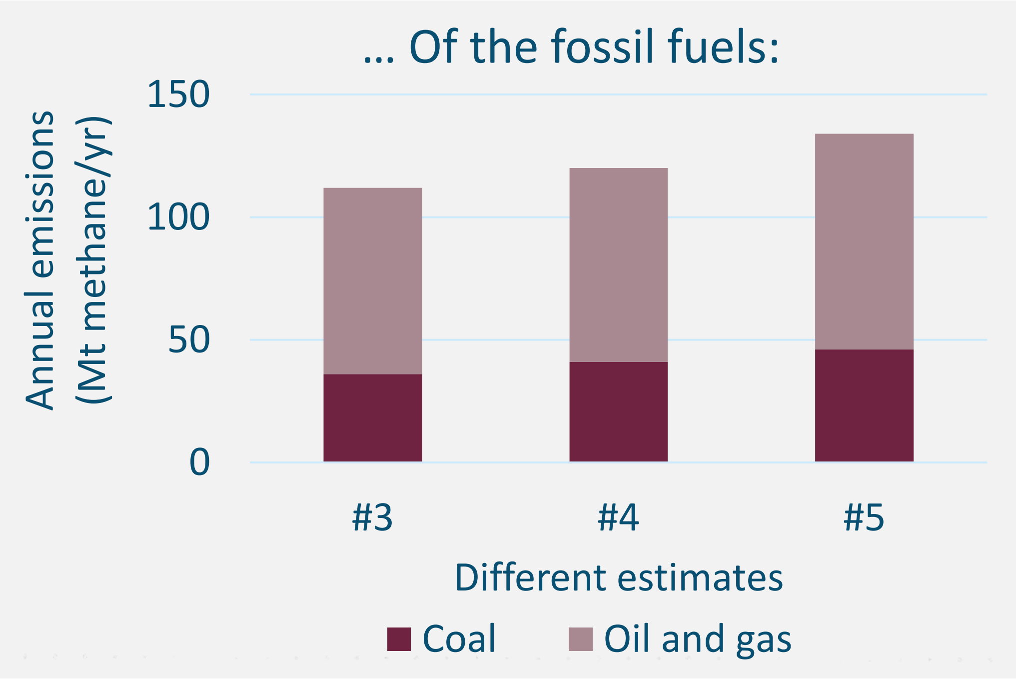
- Global Methane Budget for 2008 – 2017. Bottom-up (left) and top-down (right) estimates are provided for each emission and sink in Mt CH_4/yr.
- There are large differences between top-down and bottom-up methods

Source: Global Methane Budget 2000 – 2017- https://www.earth-syst-sci-data-discuss.net/essd-2019-128/

Sources of methane emissions



- Natural sources = 40-50%
- Fossil fuels = 15-20%
- Where are the best reduction opportunities?



Source: Saunois, M., et al., The global methane budget 2000–2012. Earth Syst. Sci. Data, 2016. **8**(2): p. 697-751.

Methane emissions govern the environmental credibility of gas

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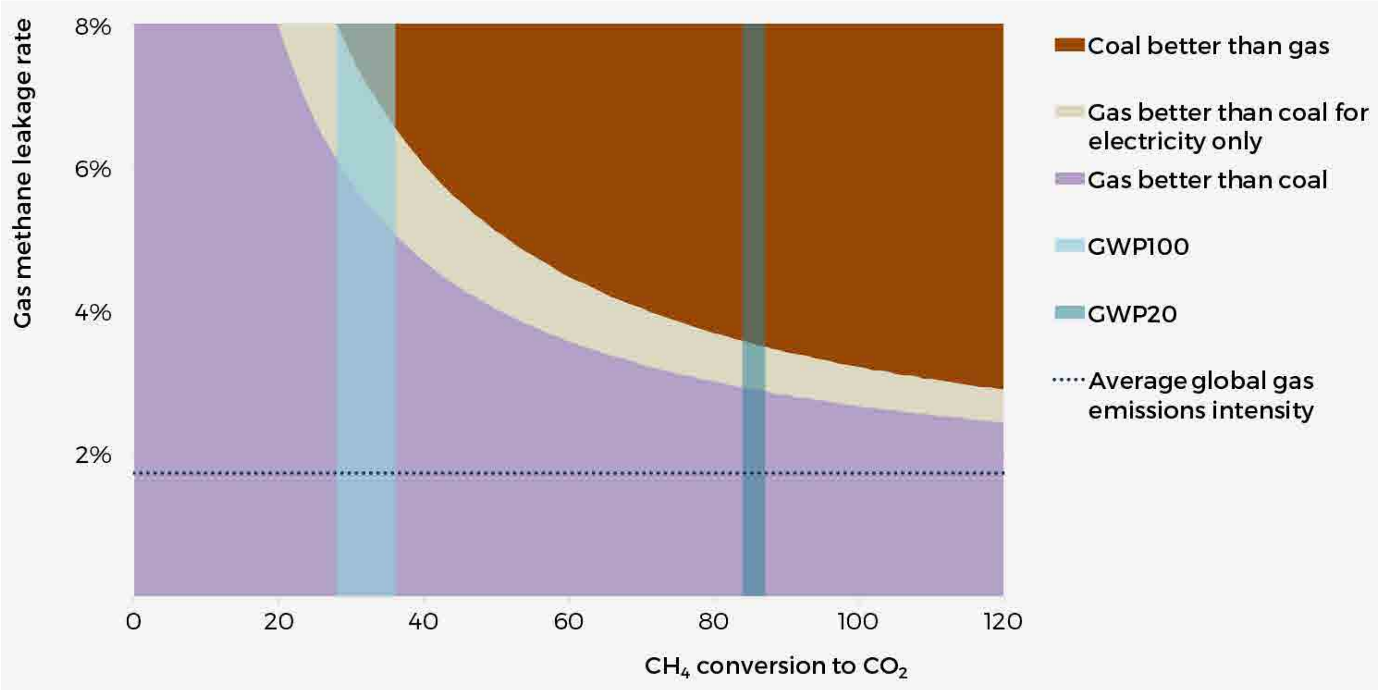
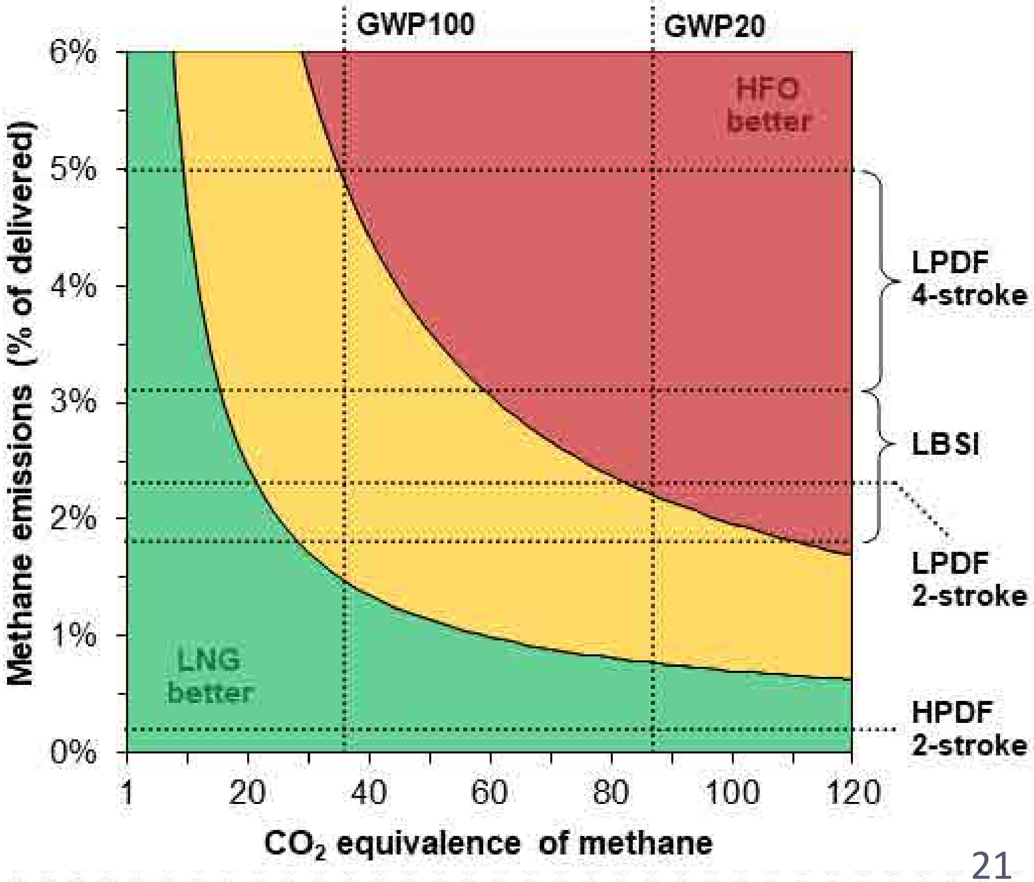
Natural gas vs. coal

- At high emission rates gas is worse than coal

Natural gas vs. heavy fuel oil for marine fuel

- At moderate emission rates required for gas to be worse than heavy fuel oil (HFO)





Source: IEA 2017 (left), and SGI 2019 (right)

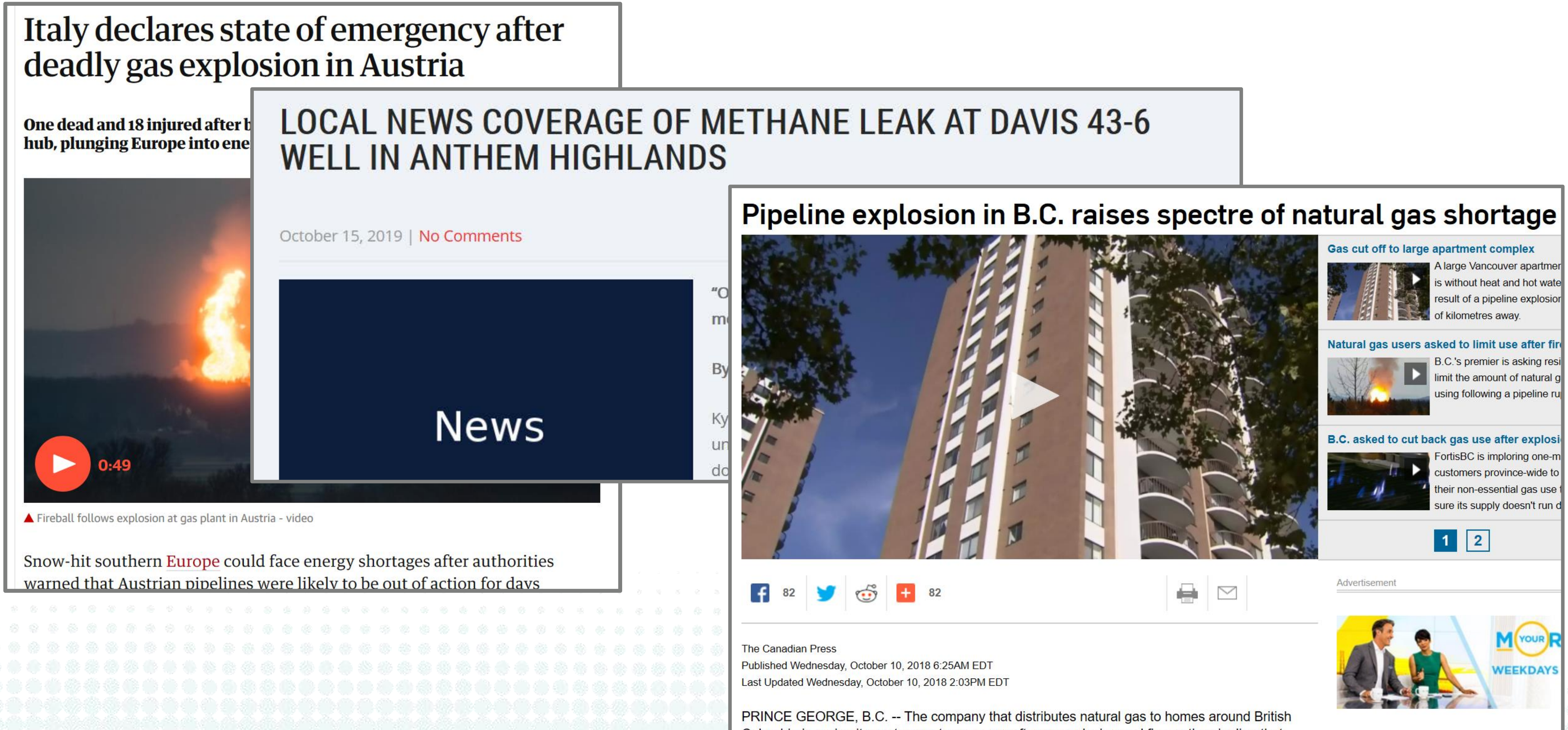
Reducing methane emissions: the business case

1. Climate change
2. Safety
3. Social licence
4. Revenue

Reducing methane emissions: the business case

1. Climate change
2. **Safety**
3. Social licence
4. Revenue

Methane safety in the news



Italy declares state of emergency after deadly gas explosion in Austria

One dead and 18 injured after b
hub, plunging Europe into ene

▲ Fireball follows explosion at gas plant in Austria - video

Snow-hit southern Europe could face energy shortages after authorities warned that Austrian pipelines were likely to be out of action for days

LOCAL NEWS COVERAGE OF METHANE LEAK AT DAVIS 43-6 WELL IN ANTHEM HIGHLANDS

October 15, 2019 | No Comments

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Pipeline explosion in B.C. raises spectre of natural gas shortage

Gas cut off to large apartment complex

A large Vancouver apartmer
is without heat and hot wate
result of a pipeline explosior
of kilometres away.

Natural gas users asked to limit use after fir

B.C.'s premier is asking resi
limit the amount of natural g
using following a pipeline ru

B.C. asked to cut back gas use after explosi

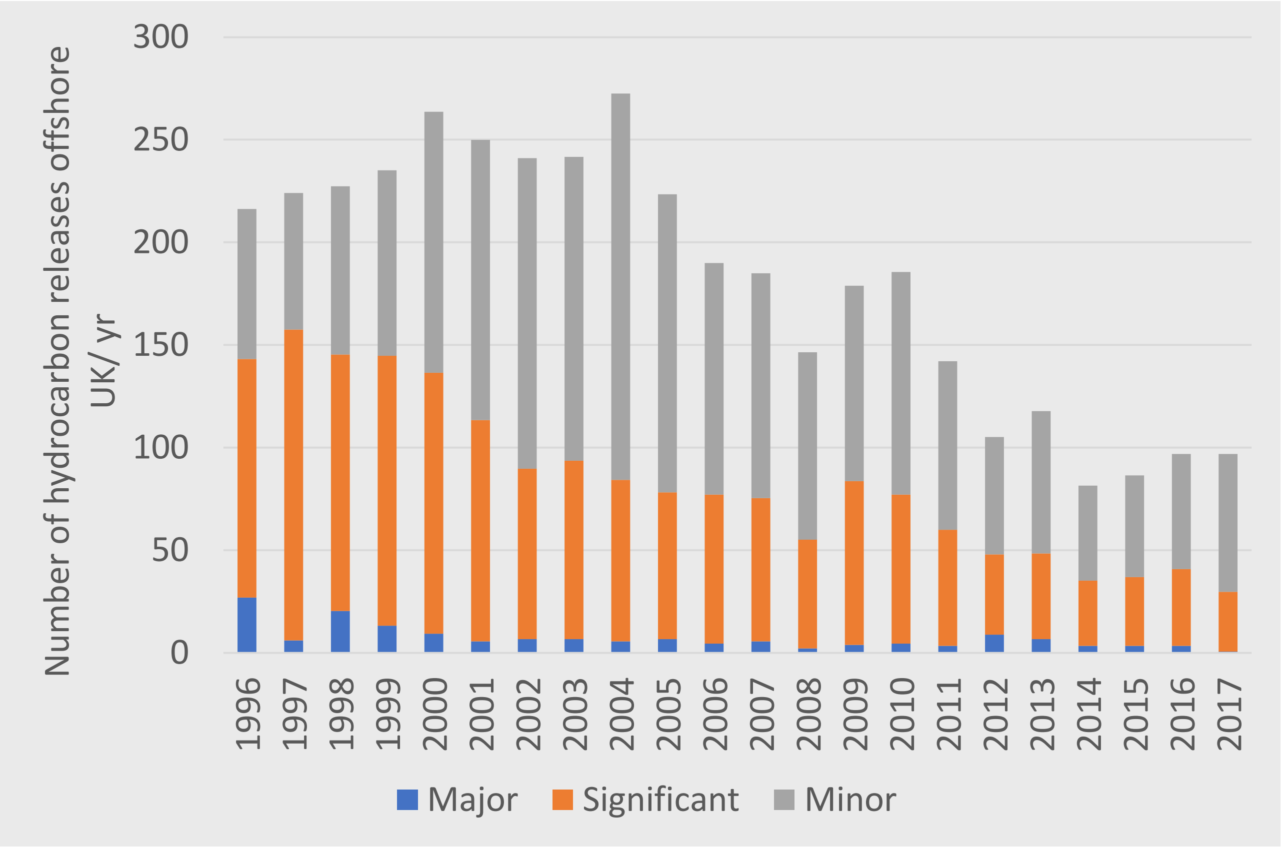
FortisBC is imploring one-m
customers province-wide to
their non-essential gas use t
sure its supply doesn't run d

The Canadian Press
Published Wednesday, October 10, 2018 6:25AM EDT
Last Updated Wednesday, October 10, 2018 2:03PM EDT

PRINCE GEORGE, B.C. -- The company that distributes natural gas to homes around British

The safety case

- For many years, safety has been the primary motivation for reducing methane vents and fugitive emissions
- E.g. The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR), ATEX equipment, Hazardous Area Classification (HAC)
- Safety philosophy has been a success story for the industry
- E.g. UK hydrocarbon releases halved in 20 years



Source: Oil and Gas UK Health and Safety Report 2018: https://oilandgasuk.co.uk/product/health-safety-report/

The safety case

- The safety driver has already reduced methane emissions
- However, to combat the climate impacts of methane, further reductions are needed: only small releases are required to produce substantial climate impact
- Can we engender the prioritisation of safety philosophy in to further eliminating methane emissions?

IOGP International Association of Oil & Gas Producers

REPORT 459 | AUGUST 2018

IOGP Life-Saving Rules

lead

together

Reducing methane emissions: the business case

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Reducing methane emissions: the business case

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Methane emissions in the news…

California methane leak 'largest in US history'

By Matt McGrath
Environment corre

26 February 201

Climate change

The site of the m

A scientific ana
the biggest in U

Fracking’s methane leaks drive climate heat

August 14th, 2019, by Paul Brown

A US fracking sit
Doubek, via Wiki

The
Conversation

By –
Dan
Zimmerle,
The
Conversation

The U.S. natural gas industry is leaking way more methane than previously thought

Science Jul 4, 2018 10:00 AM EST

s is **displacing coal**, which could help fight climate change because
roduces fewer carbon emissions. But producing and transporting

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The Natural Gas Industry Has a Leak Problem

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thane
e than twice the previously reported rates. KORT/UNIVERSITY OF MICHIGAN

or U.S. cities are leaking methane at twice the rate viously believed

erkins | Jul. 19, 2019 , 2:30 PM

g touted as a cleaner burning alternative to coal, has a leakage problem. A new

---

Methane leak in Brighton worries homeowners

Strange smell i

How Bad Are Oil and Gas Methane Leaks?

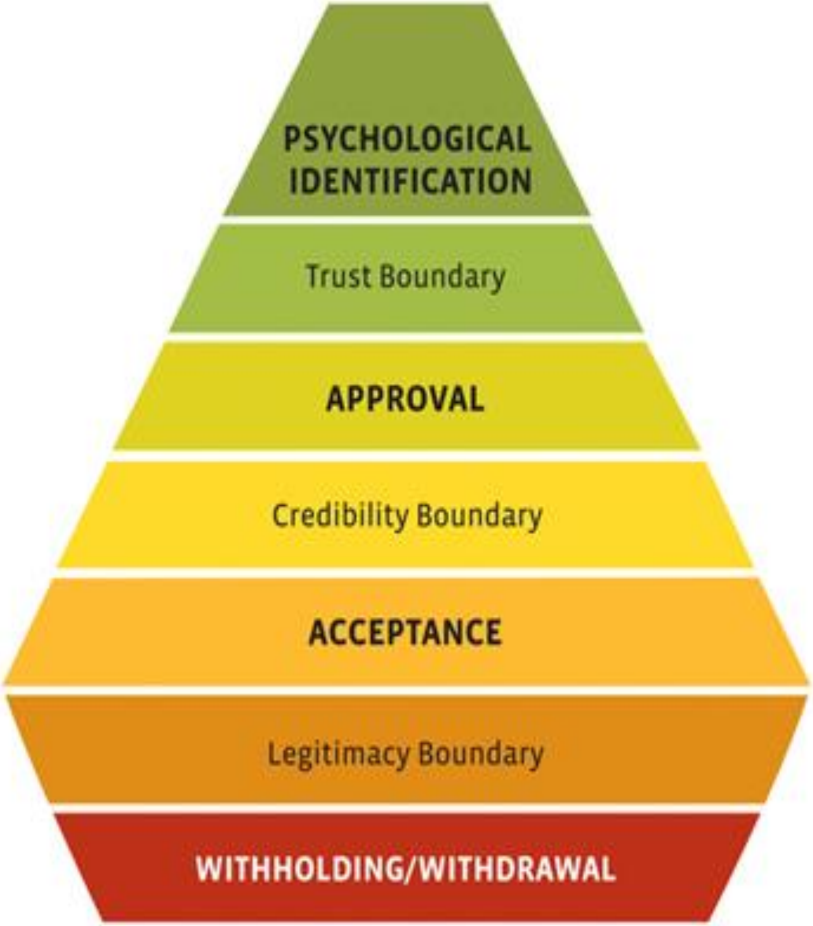
On this week’s Interchange podcast: how industry is under pressure to deal with methane leaks from fracking.

The business case: social licence

- The role of gas in future energy systems may be crucial, for example:

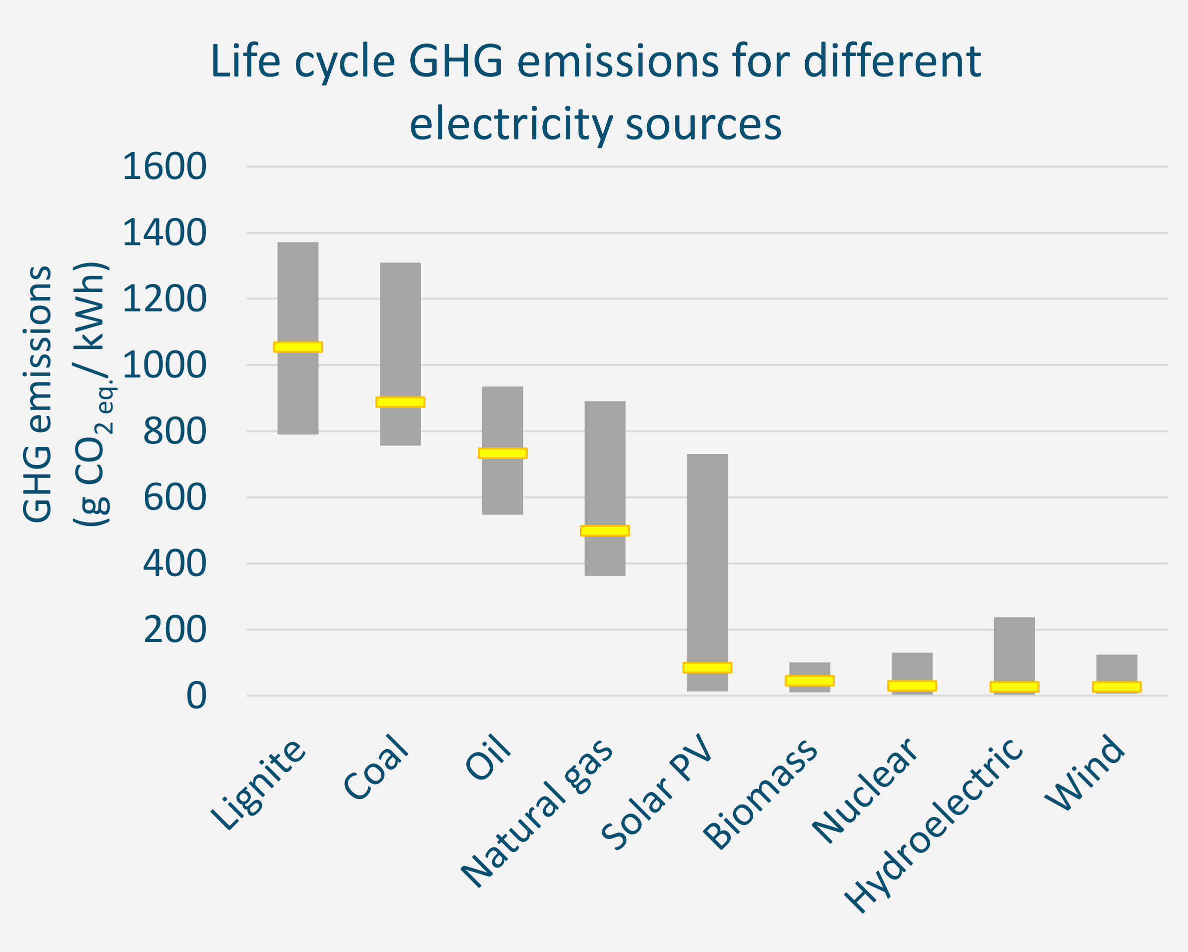
  - to marry low-carbon with affordable supply
  - to add flexibility to energy system
  - to reduce dependence on coal for power generation
  - to reduce dependence on liquid fuels for transport

- What governs the social licence to operate?



The business case: social licence

- Natural gas has lower CO_2 emissions than coal and oil, but higher than renewables (unabated)
- Air quality emissions from natural gas are substantially lower than from coal, oil and biomass
- But methane emissions are a risk to the social licence to operate
  - Environmental impact
  - **Lack of transparency decreasing trust**



Source: SGI. Note that natural gas includes both CCGT and OCGT in range, as well as range of methane emissions

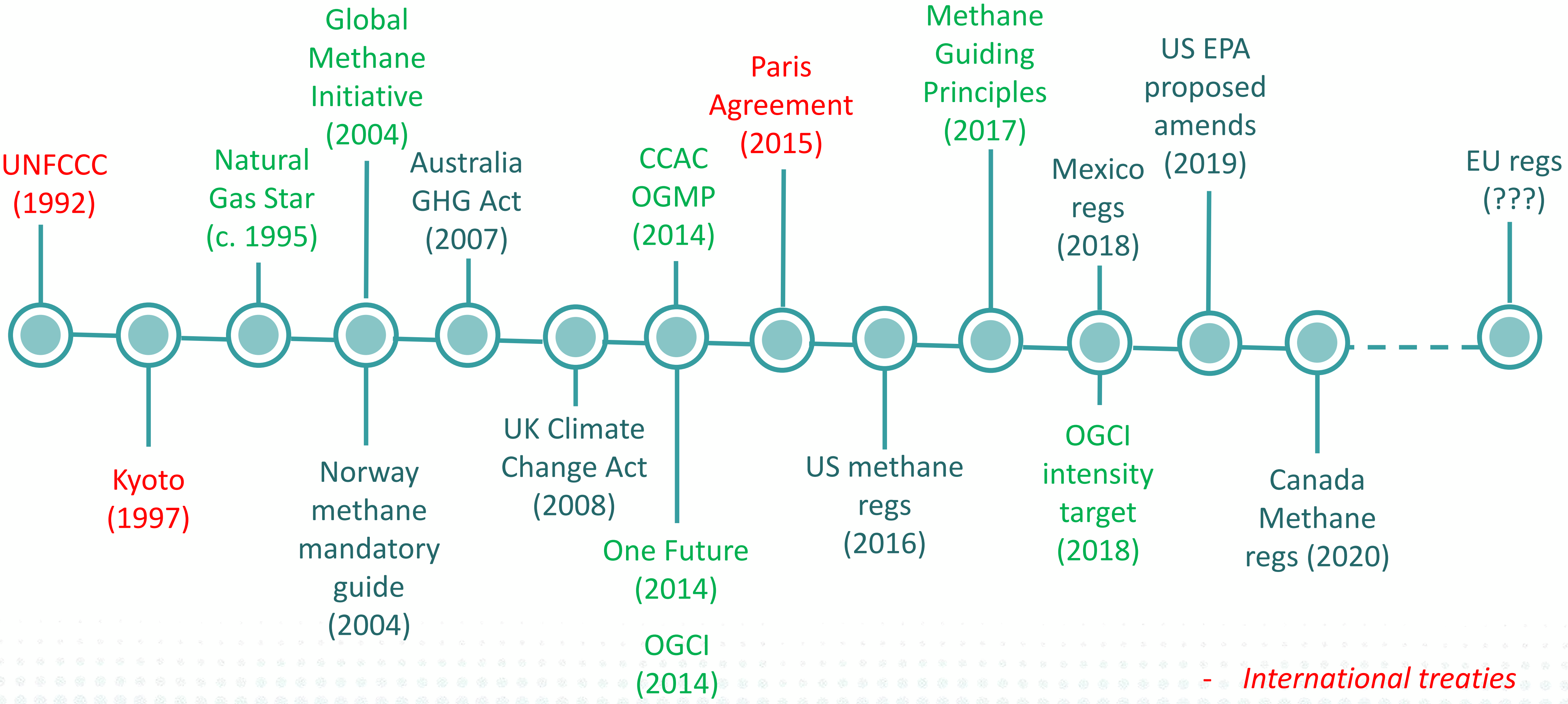
Methane reduction targets

- Strong voluntary commitments. Since 2017, many companies have announced methane reduction targets, including:
    - OGCI: 0.25% (ambition to 0.2%) of marketed gas by 2025 for all upstream oil and gas assets
    - Shell: 0.20% of marketed gas by 2025 across all Shell-operated assets
    - BP: 0.20% of marketed gas by 2025 for upstream BP-operated oil and gas assets
    - ONE Future: 1% of delivered gas by 2025 on average across member organisations (20 from production to distribution)

(*Targets differ in scope & implementation*)

- However, these targets do not yet cover the whole supply chain, or all regions
- Are these enough for a 1.5°C or 2°C world?

Action on methane: international treaties, voluntary initiatives and regulation



UNFCCC (1992)

Kyoto (1997)

Natural Gas Star (c. 1995)

Global Methane Initiative (2004)

Norway methane mandatory guide (2004)

Australia GHG Act (2007)

UK Climate Change Act (2008)

CCAC OGMP (2014)

One Future (2014)

OGCI (2014)

Paris Agreement (2015)

US methane regs (2016)

Methane Guiding Principles (2017)

Mexico regs (2018)

OGCI intensity target (2018)

US EPA proposed amends (2019)

Canada Methane regs (2020)

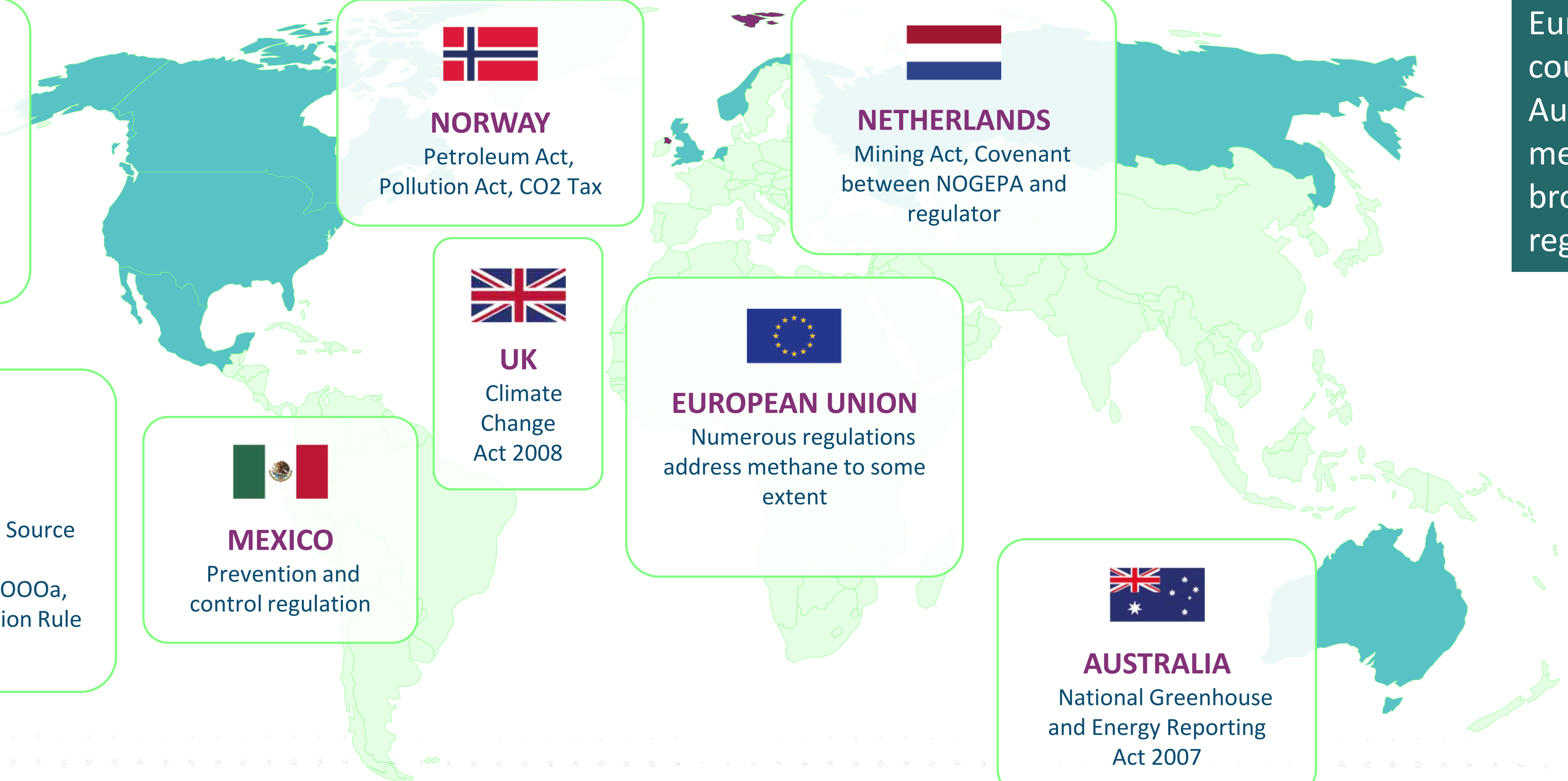
EU regs (???)

This is not an exhaustive list

- *International treaties*
- *Voluntary initiatives*
- *Regulation*

Policy coverage is limited but set to increase

Note: today, European countries and Australia cover methane under broader GHG regs



CANADA
Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (2020)

NORWAY
Petroleum Act, Pollution Act, CO2 Tax

NETHERLANDS
Mining Act, Covenant between NOGEPA and regulator

UK
Climate Change Act 2008

EUROPEAN UNION
Numerous regulations address methane to some extent

USA
Clean Air Act, 2016 New Source Performance Standards/OOOO and OOOOa, 2016 BLM Waste Prevention Rule and State rules

MEXICO
Prevention and control regulation

AUSTRALIA
National Greenhouse and Energy Reporting Act 2007

This is not an exhaustive list

Need for sound policy and regulation

Policy Objectives

Support climate goals

Establish confidence in gas

Give long-term certainty

Support for SDGs

Policy Principles

Incentivise early action for reducing methane emissions

Drive performance improvements

Facilitate proper enforcement

Support flexibility and innovation

Methane policies should…

- Apply to **both oil and gas** operations and across value chain segments.
- Be informed by **best available data and control techniques** and be designed to achieve verifiable emission reductions and incentivize early action.
- Apply to **New and Existing Facilities** and encourage high standards of design and technology that minimise methane emissions.
- Be **Cost-effective and flexible,** considering overall cost efficiency to industry and society, as well as societal and climate benefits of reducing emissions.
- **Encourage and support innovation**
- **Establish transparency**
- Embrace **continuous improvement**, learning from existing methane policies and driving more ambition over time.

Reducing methane emissions: the business case

1. Climate change
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Reducing methane emissions: the business case

1. Climate change
2. Safety
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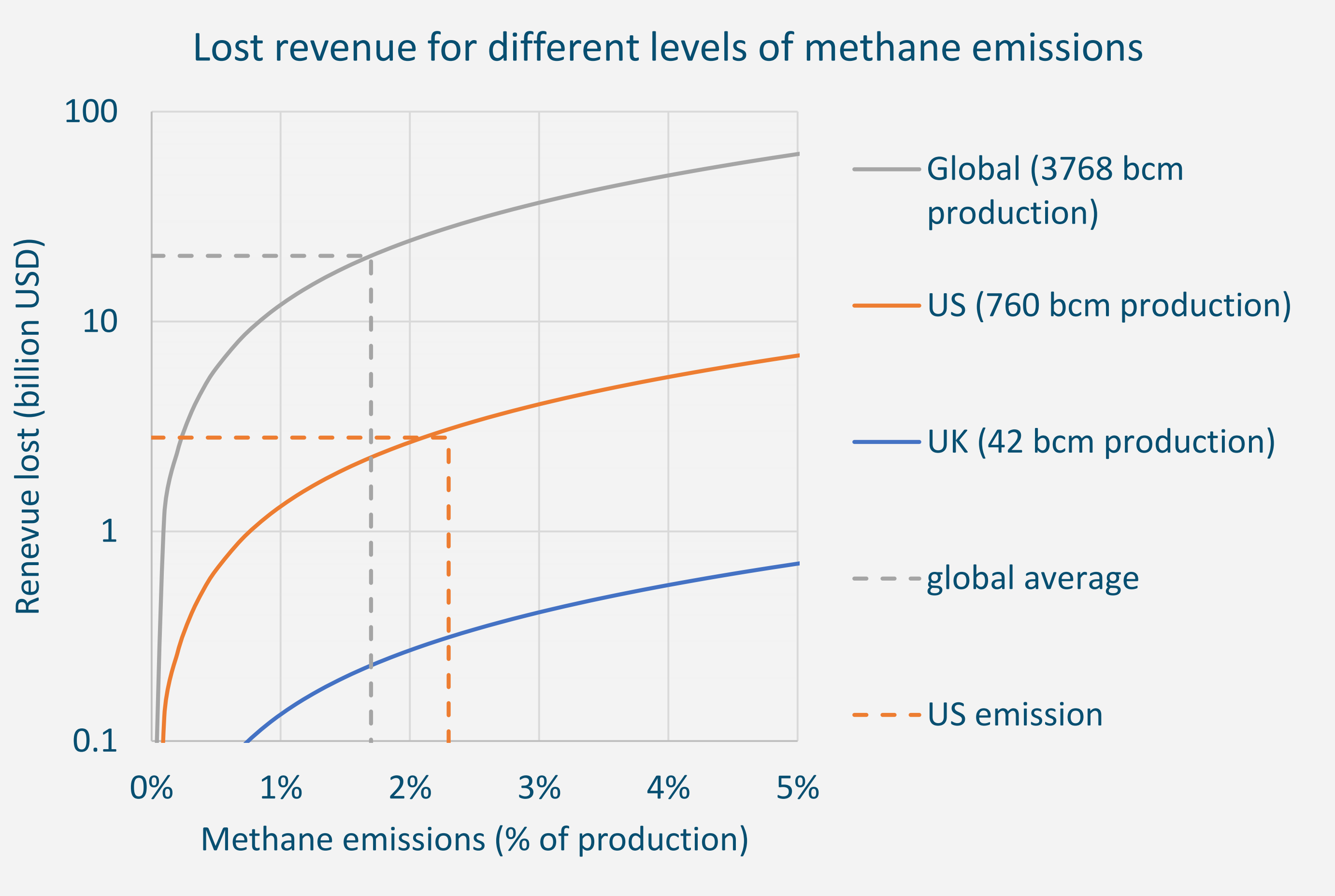
4. **Revenue**

The business case: lost revenue

- Lost revenue estimates for different levels of methane emissions

- For the US, 3 bn USD

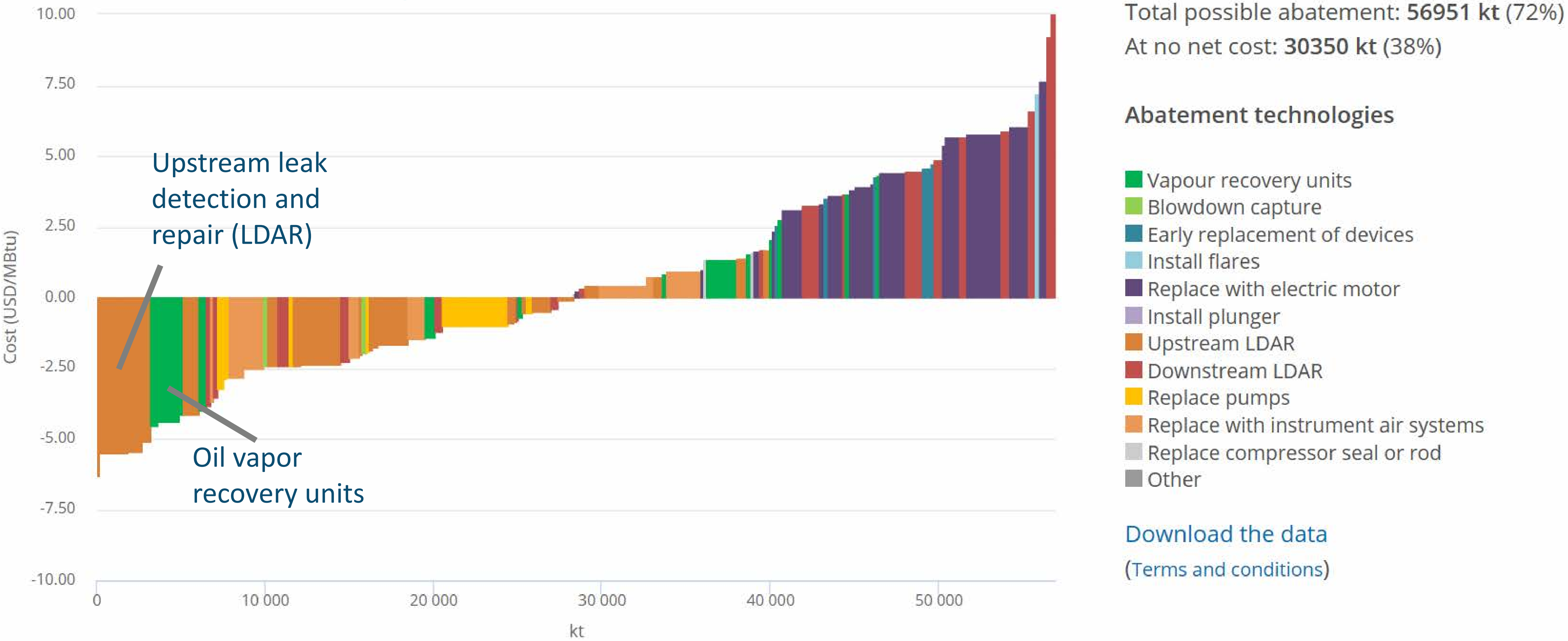
- Globally, 20 bn USD



Source: SGI 2017

The cost of methane emissions mitigation: world

IEA methane mitigation costs (2017)



Total possible abatement: **56951 kt** (72%)

At no net cost: **30350 kt** (38%)

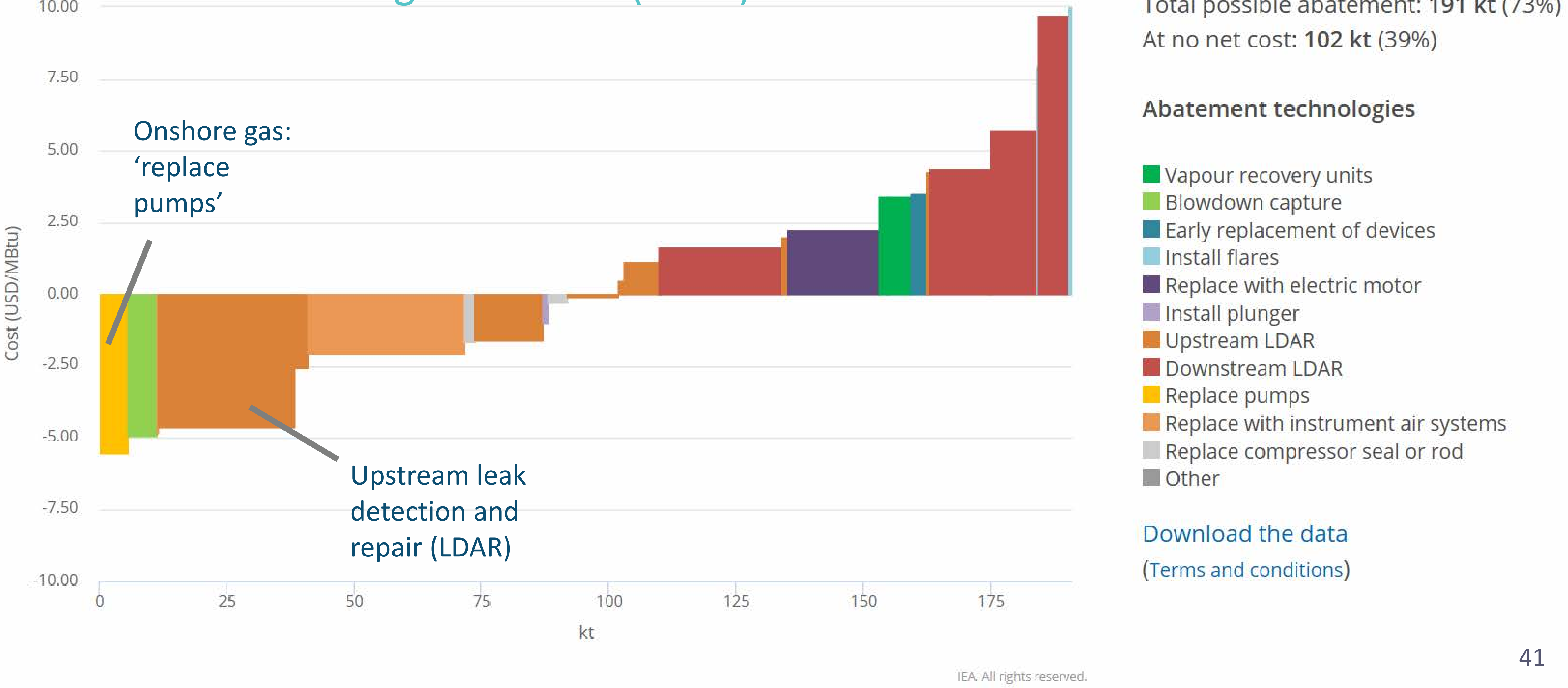
Upstream leak detection and repair (LDAR)

Oil vapor recovery units

Source: IEA, 2019

The cost of methane emissions mitigation: Netherlands

IEA methane mitigation costs (2017)



Total possible abatement: **191 kt** (73%)

At no net cost: **102 kt** (39%)

Onshore gas: 'replace pumps'

Upstream leak detection and repair (LDAR)

IEA. All rights reserved.

There is an economic opportunity

- The IEA estimate that ~50% of methane mitigation could be made at less than net-zero cost

- Some questions on accuracy of the data.
  - ‘Averaging’ across large groups of equipment/facilities hides much variation

- But the opportunity is substantial:
  - Reducing product loss equates to $3 billion from 2015 US supply chain alone

- What are the barriers?
  - Is net-zero enough incentive?
  - Are the emissions easily identifiable?
  - Is there available expertise to implement?

The business case: summary

1. Climate change

   Reducing methane emissions is critical to meet climate targets and is an opportunity to slow down global warming.

2. Safety

   Safety prioritisation has already helped to reduce methane emissions across industry, but can we engender this philosophy to further reduce methane emissions?

3. Social licence

   Methane management across the whole industry will help to maintain a social licence to operate and the continued role of gas in decarbonisation and improving air quality.

4. Revenue

   Methane emissions represent asset loss, where many emissions can be eliminated at zero cost or less, but barriers exist to investment in mitigation.

Reflection point

Every organisation is different - how would you make the case for methane emissions reductions in yours?

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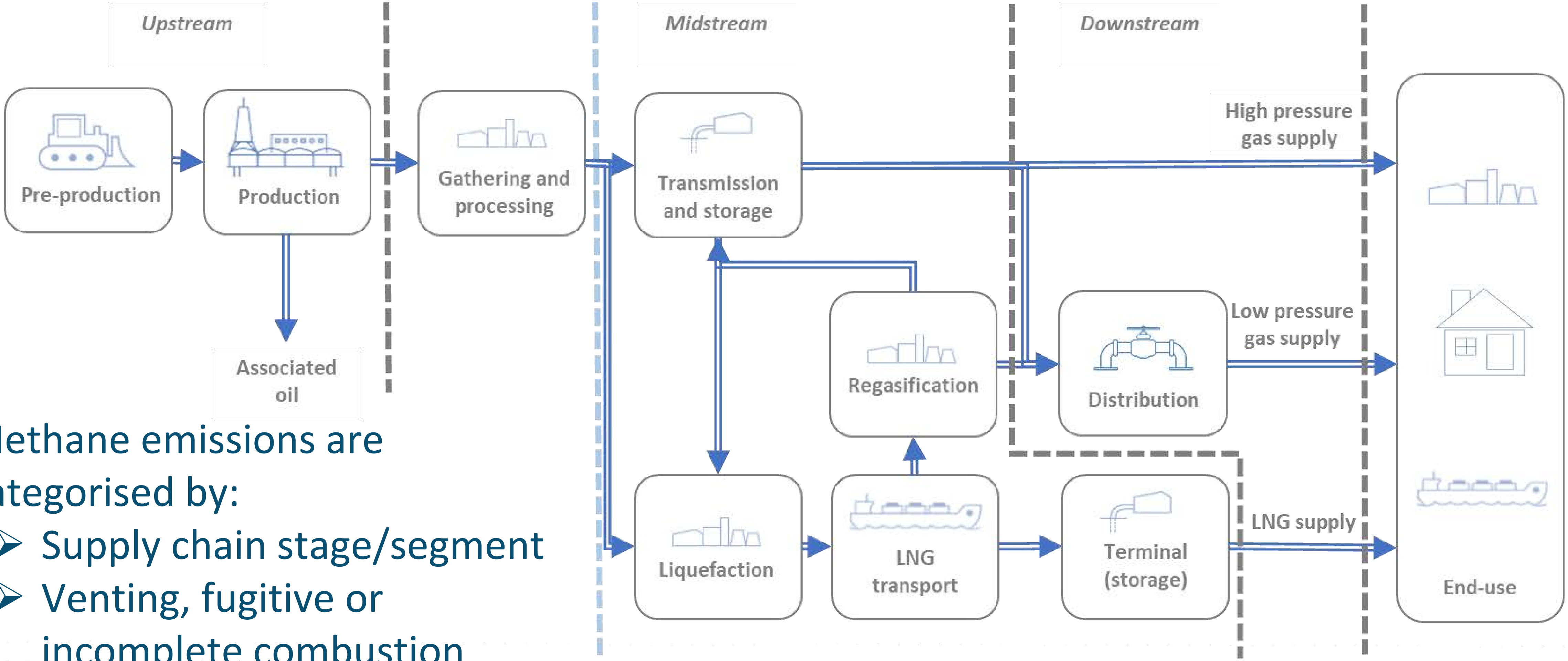
Reducing methane emissions: Understanding methane

Outreach programme

Understanding methane emissions

1. Sources of emissions from the oil and gas supply chain
2. The distribution: heavy tails and super-emitters
3. Estimation methods

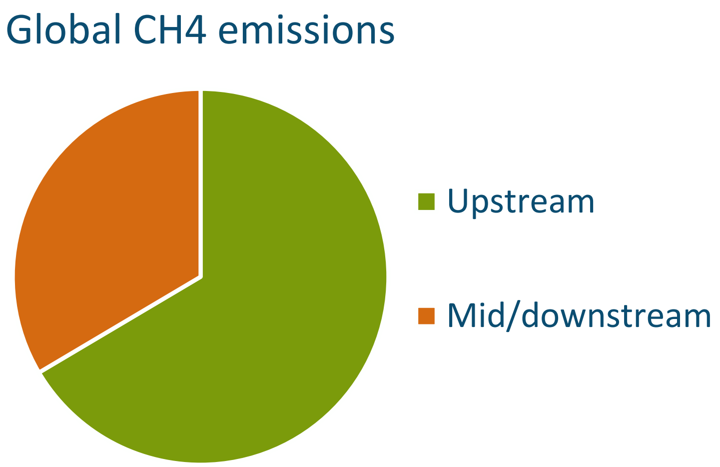
The natural gas supply chain

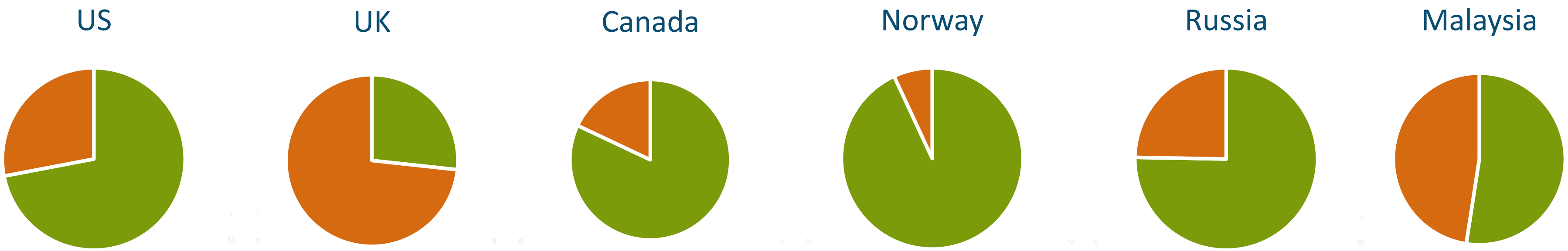


- Methane emissions are categorised by:
  - ➢ Supply chain stage/segment
  - ➢ Venting, fugitive or incomplete combustion

Sources of emissions

- Upstream emissions may dominate from gas supply chains, but there is high regional variability
- The quality of data is also varied across regions
- (Here mid/downstream is everything after processing)





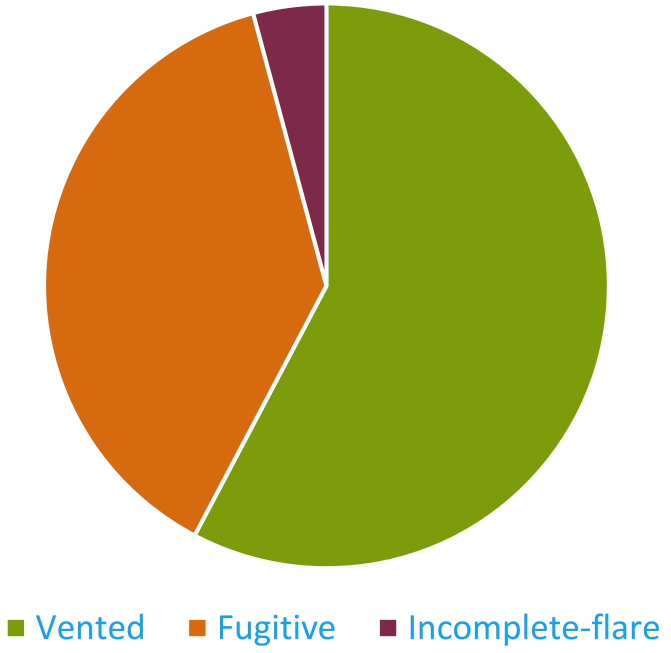
Source: International Energy Agency, www.iea.org/weo/methane/database

Emissions by type

Venting	Intentional release via a specified outlet (vent line)
Fugitives	Unintentional release from any component (e.g. seal or connector or corroded part)
Incomplete combustion	Uncombusted methane (slip) from flare or engine/turbine

Emissions by type

Global: oil and gas methane emission split between vents, fugitive and incomplete combustion



- All three emission categories are important
- There are regional variations, but particularly across the supply chain
- This data may underrepresent incomplete combustion emissions

Source: International Energy Agency, www.iea.org/weo/methane/database

Sources of emissions: upstream

Key emissions from process/ equipment:	Venting	Fugitives	Incomplete combustion
Well completions	✓		✓
Dehydrators	✓		
Gas-driven pneumatics	✓		
Liquid storage tanks	✓		
Compressor stations	✓	✓	✓
Liquids unloading	✓		✓
Gathering lines	✓		✓
Flaring			✓

Sources of emissions: upstream

Key emissions from process/ equipment:	Venting	Fugitives	Incomplete combustion
Well completions	✓		✓
Dehydrators	✓		
Gas-driven pneumatics	✓		
Liquid storage tanks	✓		
Compressor stations	✓	✓	✓
Liquids unloading	✓		✓
Gathering lines	✓		✓
Flaring			✓

Well type	Sample size	Well completion emissions (t CH4/ event)		
		Mean	Min	Max
Conventional	10	3.4	0.0	5.2
Unconventional: Reduced emissions completions (RECs)	76	2.1	0.0	17.4
Unconventional: Non-RECs	88	8.3	0.2	70.1

Source: Allen, D.T., et al., Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences of the United States of America, 2013. 110(44): p. 17768-17773.

Sources of emissions: midstream

Key emissions from process/ equipment:		Venting	Fugitives	Incomplete combustion
Compressor stations	Seals	✓		
	Venting	✓		
	Blowdowns	✓		✓
Metering and regulating stations	Fugitives		✓	
	Pneumatics	✓		
	Blowdowns	✓		
Pipelines	Fugitives		✓	
	Maintenance	✓		✓

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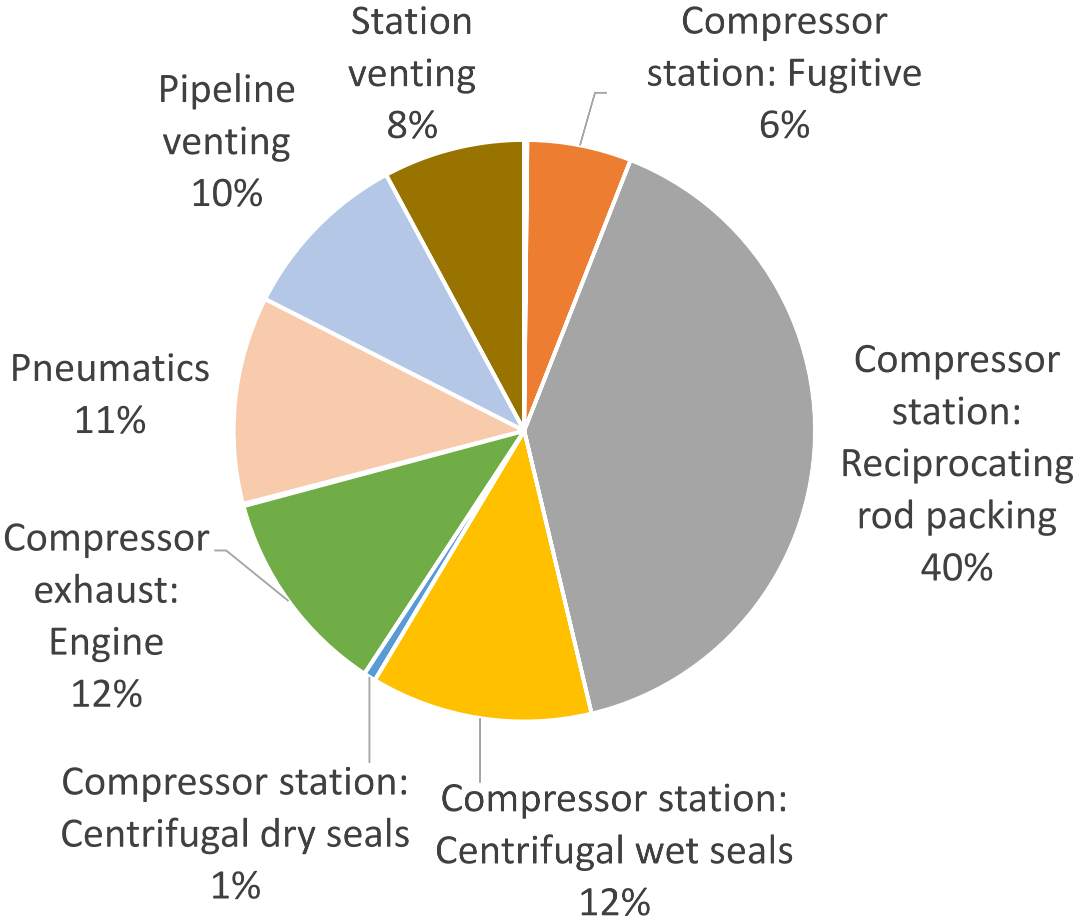
	Venting	✓		
	Blowdowns	✓		✓
Metering and regulating stations	Fugitives		✓	
	Pneumatics	✓		
	Blowdowns	✓		
Pipelines	Fugitives		✓	
	Maintenance	✓		✓

US gas transmission emissions (2014)



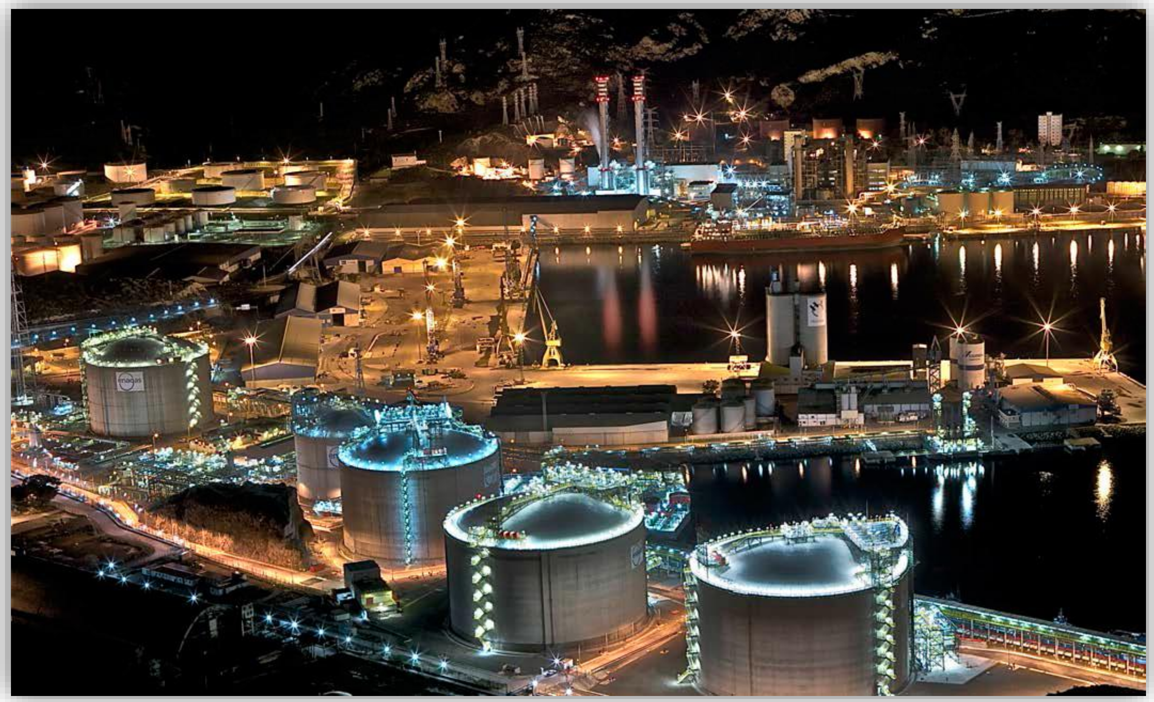
Source: Balcombe, P., et al., Methane and CO2 emissions from the natural gas supply chain: an evidence assessment, in White Paper Series, Sustainable Gas Institute, Editor. 2015, Imperial College London: www.sustainablegasinstitute.org/publications/white-paper-1

Sources of emissions: downstream

Key emissions from process/ equipment:		Venting	Fugitives	Incomplete combustion
Metering and regulating stations	Venting	✓		
	Fugitives		✓	
	Pneumatics	✓		
Valve stations	Venting	✓		
	Fugitives		✓	
Pipelines	Fugitives		✓	
	Maintenance	✓		

Sources of emissions: LNG

Key emissions from process/ equipment:		Venting	Fugitives	Incomplete combustion
Liquefaction	Venting	✓		
	Storage boil-off	✓		✓
	Loading	✓	✓	
Transport	Boil-off	✓		✓
	Engine slip			✓
	Cold venting	✓		
Regasification	Unloading	✓	✓	
	Storage boil-off	✓		✓
	Venting	✓		



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	Loading	✓	✓	
Transport	Boil-off	✓		✓
	Engine slip			✓
	Cold venting	✓		
Regasification	Unloading	✓	✓	
	Storage boil-off	✓		✓
	Venting	✓		

- It is typically assumed that LNG routes have low methane emissions: e.g. 0.01% (NGVA thinkstep 2017)
- However, there is a lack of data and transparency here, in particular LNG shipping
- Boil-off management, engine slip and cold venting may be a particular issue

Source: Schuller, O., et al., Greenhouse Gas Intensity of Natural Gas. 2017, Thinkstep AG: Natural & Bio Gas Vehicle Association (NGVA) Europe. p. 180

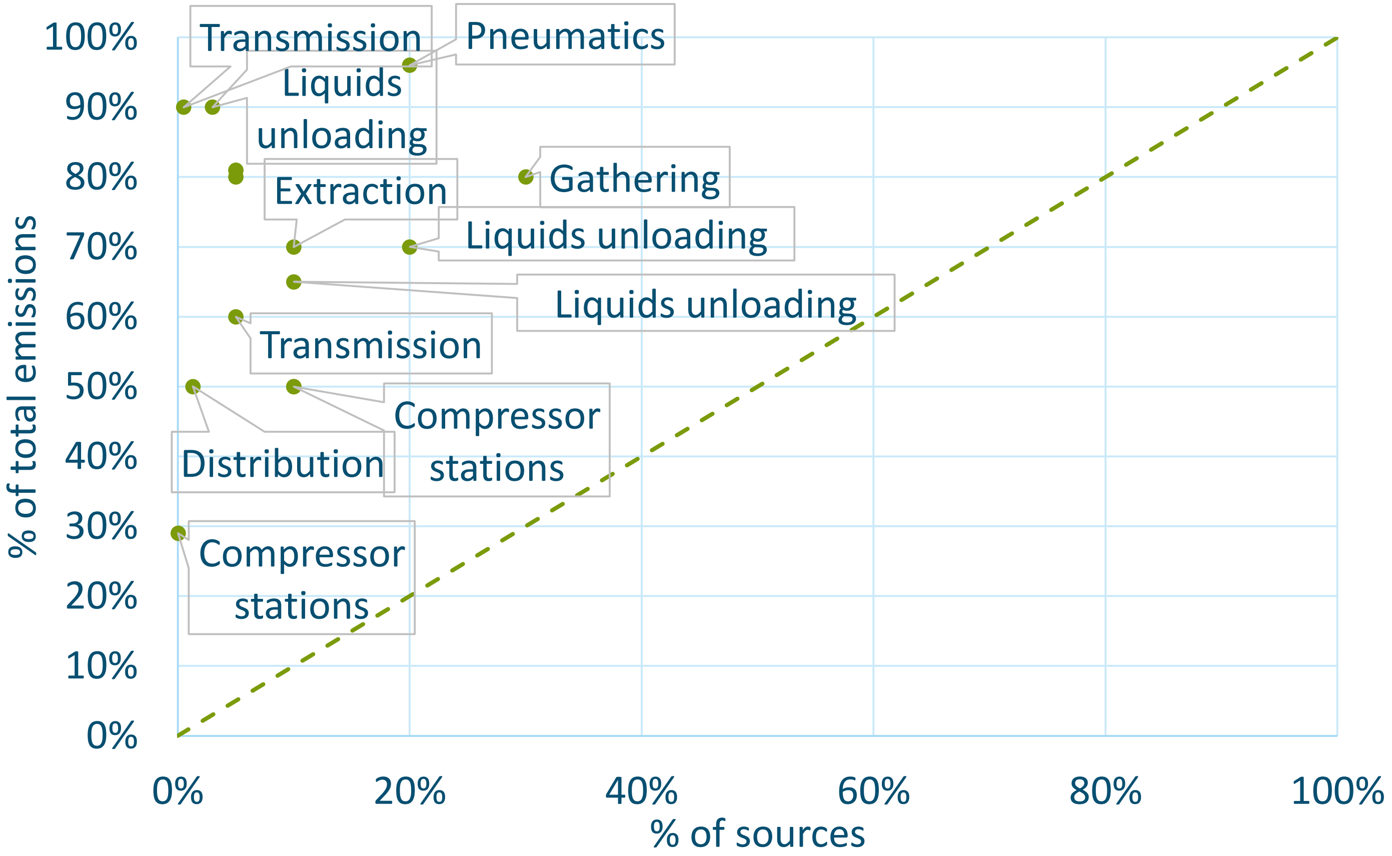
Understanding methane emissions

1. Sources of emissions from the oil and gas supply chain
2. **The distribution: heavy tails and super-emitters**
3. Estimation methods

The distribution of emissions

- The majority of emissions are low, but a select few disproportionately contribute to total emissions
- About 50% of emissions come from just 5% of the sources
- This has been seen all across the supply chain

Heavy tails detected during measurement campaigns



Source: SGI, data collected from various recent US onshore methane measurement campaigns

Where are the super emitters?

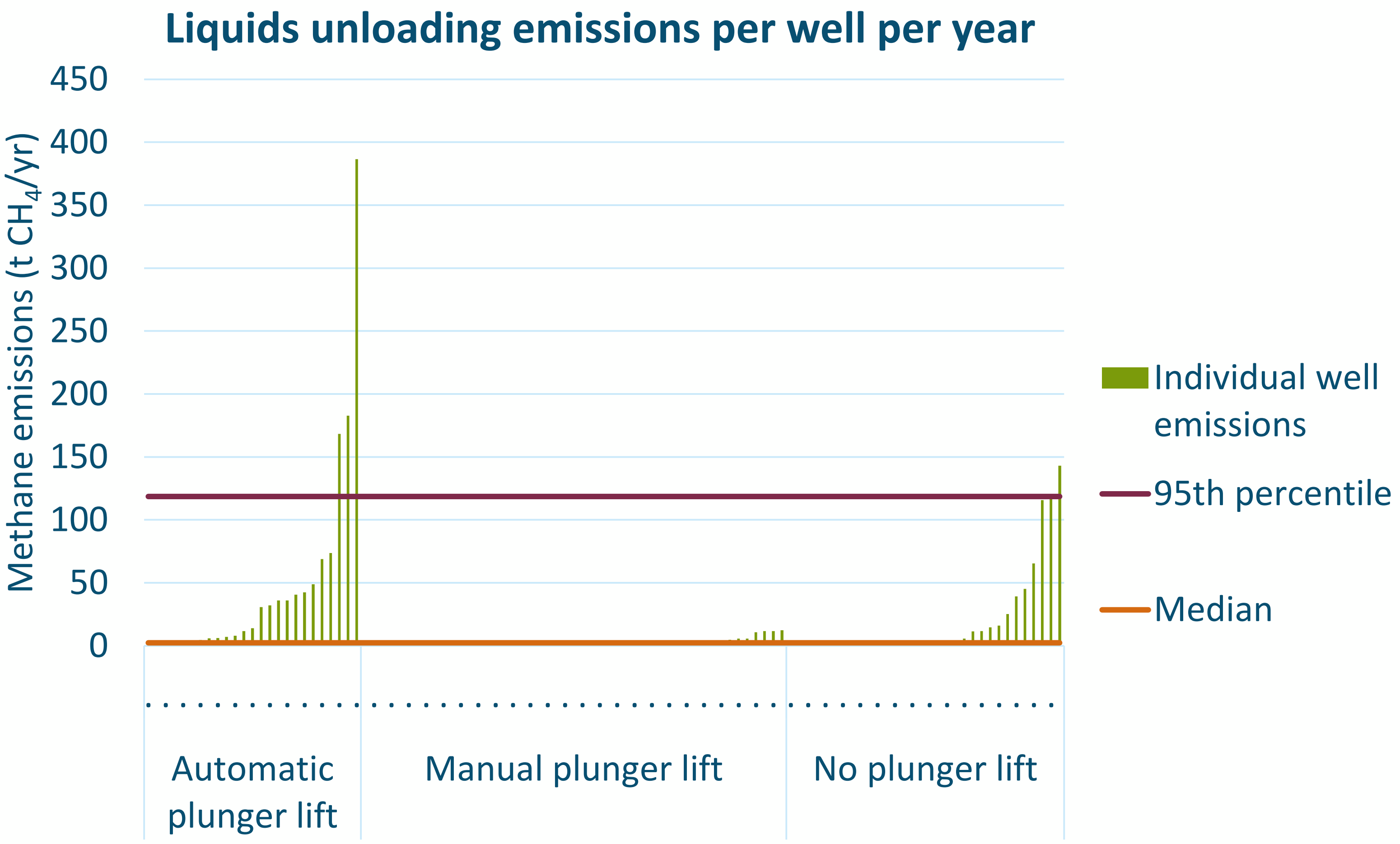
- Disproportionately large emitters have been identified everywhere they have been looked for, across all supply chain stages, regions, and processes

- Some key super emitters have been identified in these processes/equipment:
  - well completions
  - liquids unloading
  - pneumatics
  - liquid storage tanks
  - compressor stations
  - distribution pipeline

- One example: liquids unloading from Allen et al. 2015…

An example of the heavy tail

- Methane emissions from liquids unloading were measured at 107 wells across the United States in 2013
- 3 equipment types : automated plunger lifts, manual plunger lifts, or without a plunger
- Median emission rate is low ~ 2t CH_4/yr, but wide variation
- Top 5% of wells cause 51% of total methane emissions



Source: Allen, D.T., et al., Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Liquid Unloadings. Environmental Science & Technology, 2014. 49(1): p. 641-648.

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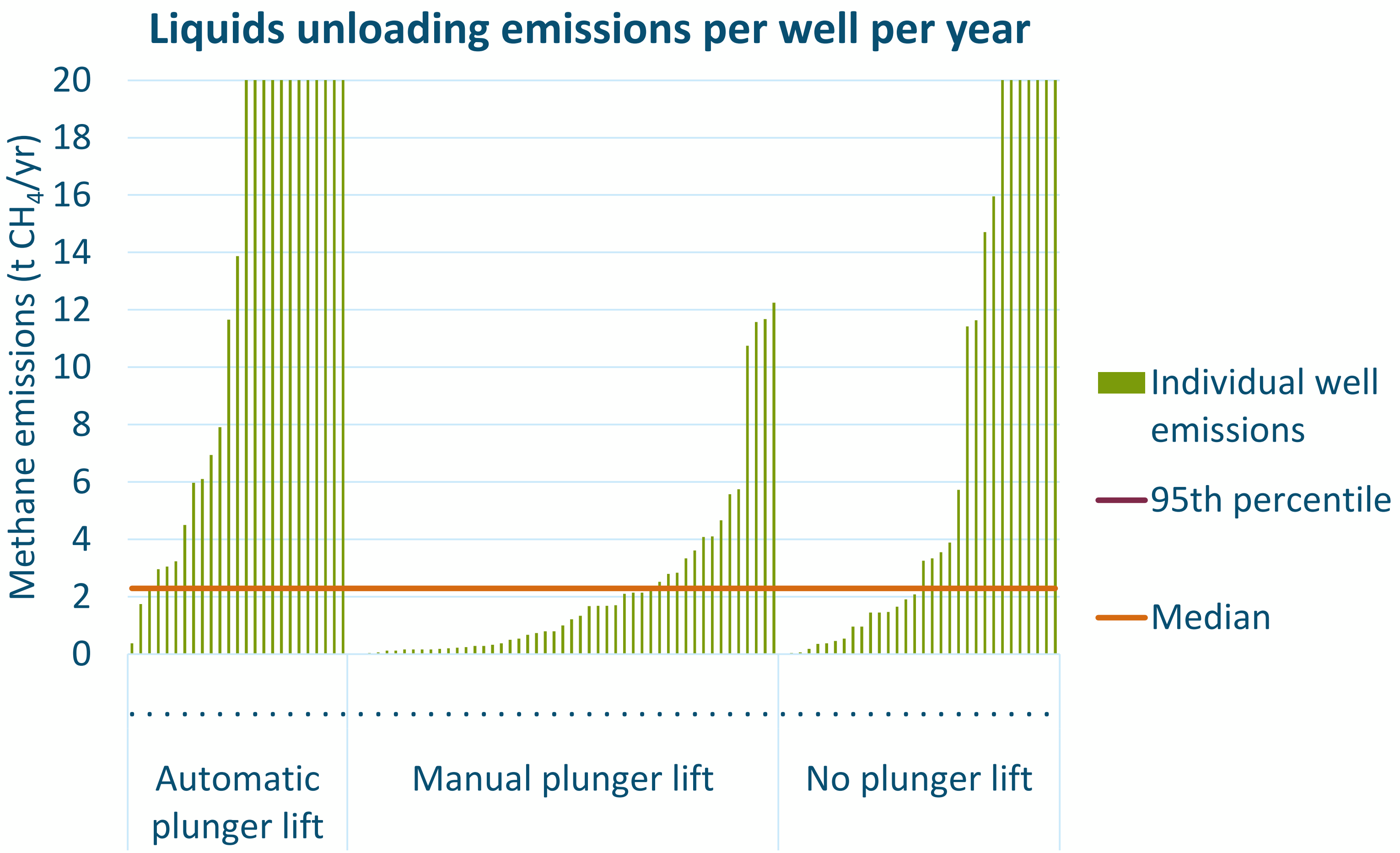
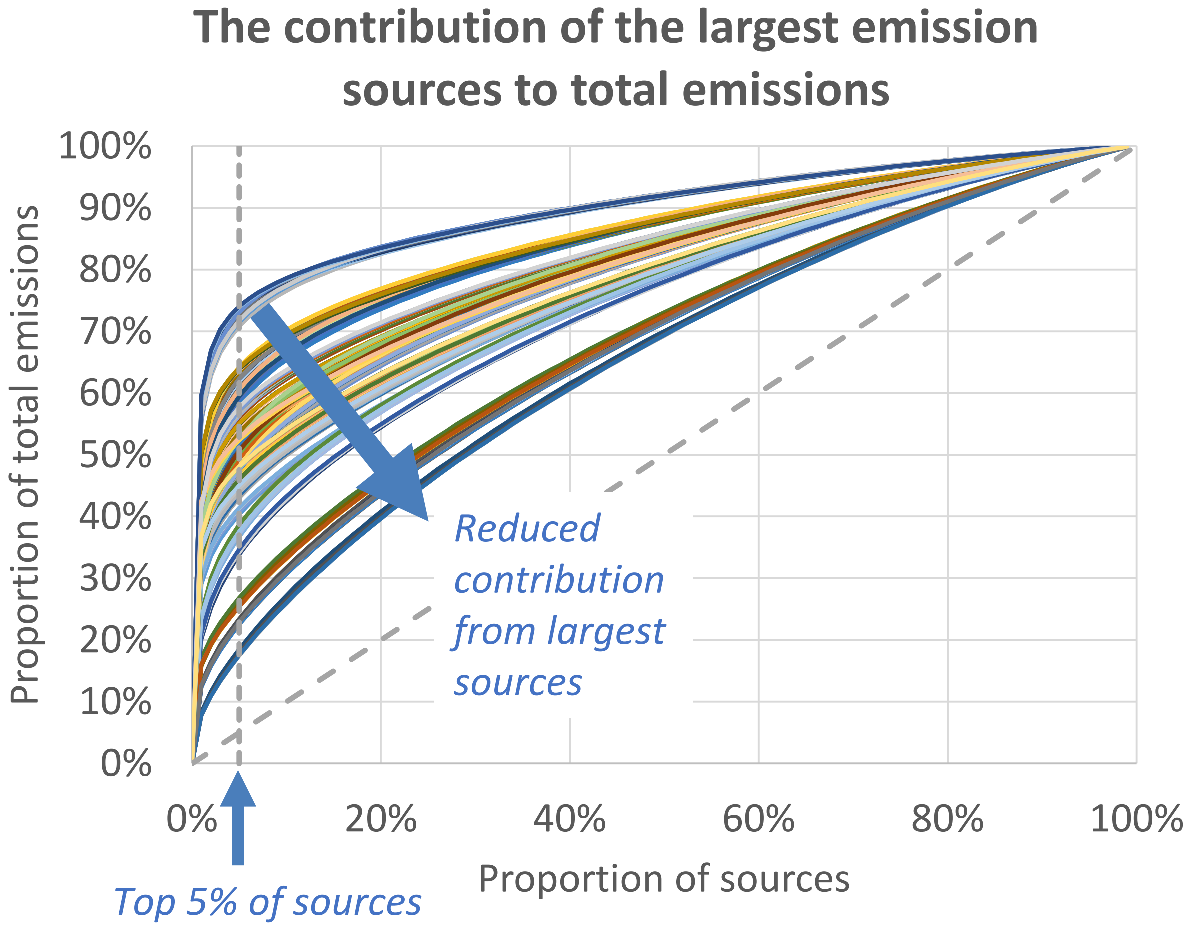


Source: Allen, D.T., et al., Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Liquid Unloadings. Environmental Science & Technology, 2014. 49(1): p. 641-648.

The heavy tail: 5% of sources contribution half of emissions



- Top 5% of sources contribute ~50% of total emissions (20% - 75%)
- Key opportunity to drastically reduce emissions by tackling the heavy tail
- But how?
  - Install emissions-minimising technology
  - Effective operation and maintenance
  - Quick detection and remediation of fugitives

Source: SGI

Understanding methane emissions

1. Sources of emissions from the oil and gas supply chain
2. The distribution: heavy tails and super-emitters
3. **Estimation methods**

How are methane emissions estimated/measured?

Three categories-

1. Emission factor. *Emissions = emission factor x number of equipment*
2. Process modelling/ engineering calculation
3. Direct measurement

How are methane emissions estimated/measured?

Venting

- Emission factor
- Process modelling: requires understanding of key process parameters
- Direct measurement (flow meter, concentration meter)

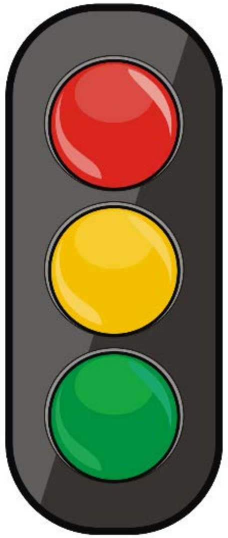
Fugitives

- Emission factor
- Direct measurement
- (or both…)

Incomplete combustion

- Estimated based on assumed combustion efficiency (e.g. 98%)
- Should be checked periodically to ensure efficiency is maintained

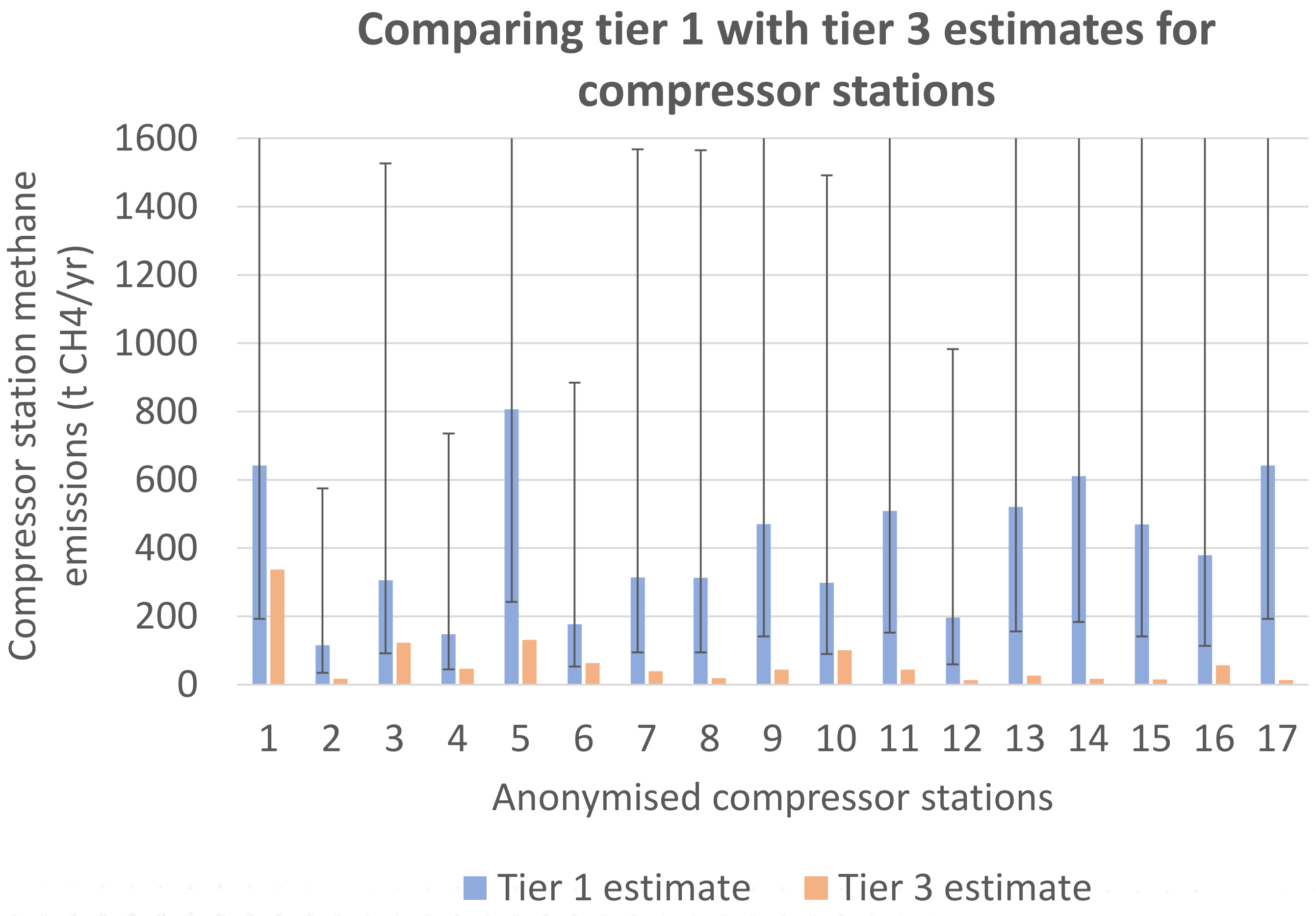
Intergovernmental Panel on Climate Change (IPCC) tiered fugitive emission factors



- Tier I- Non-region-specific emission factor, highest uncertainty
- Tier II- Region-specific emission factor, high uncertainty
- Tier III- Facility or asset-level-specific, lowest uncertainty

- Non-region specific emission factors carry uncertainties of +500%
- All methods require emission factors, but generic factors should be avoided
- Use asset-specific measurements to develop emission factors
- Tier 3 is very broad and there are many approaches to achieving this
- Update emission factors regularly to ensure accurate inventories

Case study: comparing Tier 1 and Tier 3 emission factors



- A study by the Sustainable Gas Institute estimates total methane emissions from compressor stations using tier 1 and tier 3 (LDAR and venting calculations) methods.

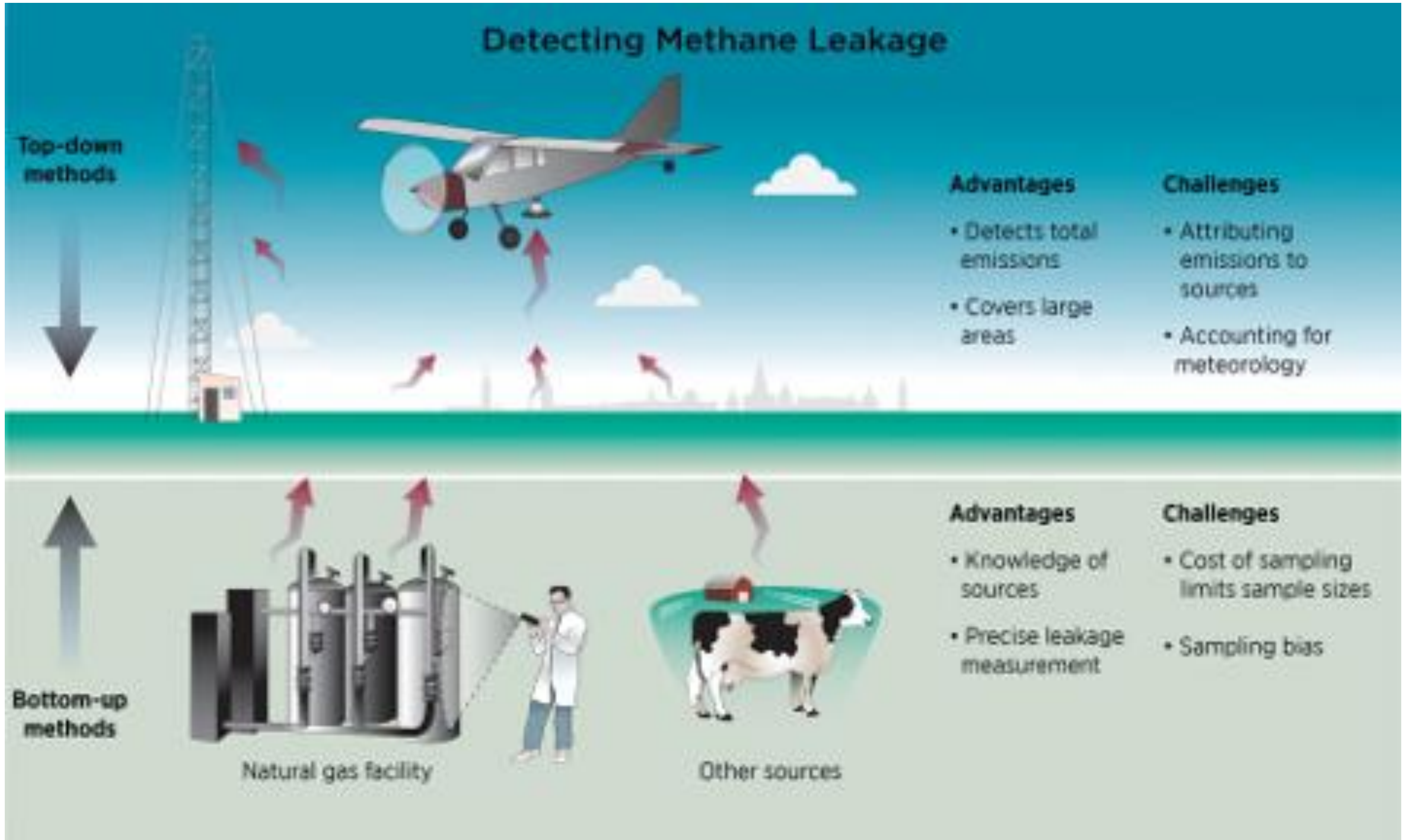
- On average, our estimate was 17% of the tier 1 estimate

- Tier 1 factors are not representative and should be avoided

Source: SGI

Direct measurement

- Bottom-up
  - Estimate emissions from point-sources, then extrapolate
  - Targets equipment
  - Measures emission rate or concentration
- Top-down
  - Estimate total emissions from a region, then allocate
  - Aerial surveys, satellite or ground-based surveys (e.g. lidar)



Estimation methods: top-down vs. bottom-up

Top-down:

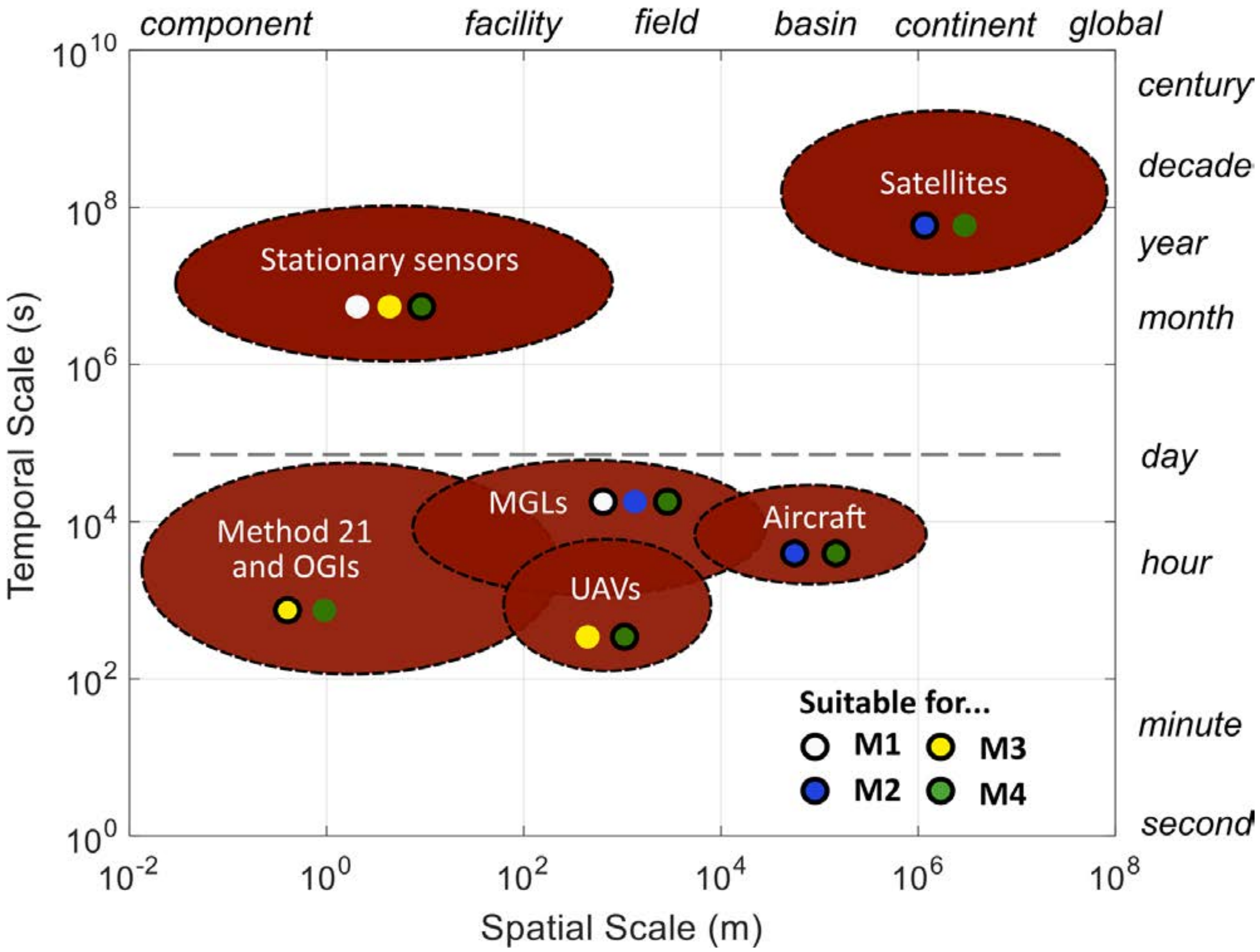
- Uncertainty in allocation of emissions
- Equipment expense

Bottom-up:

- High uncertainty in extrapolating
- Less able to ensure heavy tail is accounted for
- Labour-intensive

- ➢ Mixed-methods help improve both methods and reconcile differences
- ➢ Most methods are periodic, not continuous
- ➢ Future challenge: develop cost-effective frequent/continuous monitoring to quickly identify super-emitters

Different measurement technologies cover different spatial and timescales



Technologies:

- Hand-held: Method 21 and optical gas imaging (OGI)
- Stationary sensors
- Mobile ground labs (MGLs)
- Aircraft, unmanned aerial vehicles (UAVs) and satellites

Reason for detecting/measuring:

- M1: Improve emissions factors and inventories
- M2: Estimate regional emissions
- M3: To use for point-source assessment
- M4: Quick detection

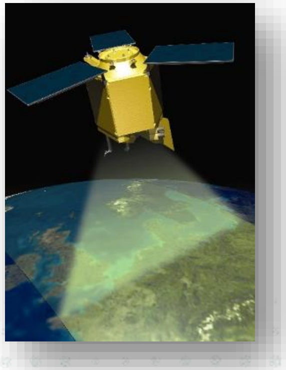
Source: Fox, T.A., et al., A review of close-range and screening technologies for mitigating fugitive methane emissions in upstream oil and gas. Environmental Research Letters, 2019. 14(5): p. 053002

Typical hand-held technologies used for LDAR

Technology	Description	Detection/ measurement	Quality	Suitability for quantification	Cost
Optical gas imaging (OGI)/ Infrared (IR) camera	Infrared absorption monitor	Mainly detection	Fast identification of point source	Low	USD $85,000 - $115,000
Organic vapour analyser/ flame ionisation detector (FID)	Estimates concentration of VOC by flame ionisation	Measurement (concentration)	Fast gauging of leak size, but uncertain quantification	Medium	~ USD $10,000
High flow sampler	High volume air suction with VOC concentration measurement	Measurement (emission rate)	Accurate quantification of leak rate	High	~ USD $20,000

Plus several others…

Technologies are developing fast…



Understanding methane: summary

1. Sources of methane

   Methane is emitted via various mechanisms across the supply chain and it is vital that organisations account for all potential sources

2. The distribution: heavy tails and super-emitters

   A small number of sources typically dominate total emissions, and there is an opportunity to substantially decrease emissions by faster detection and corrective action

3. Estimation methods

   We must rely less on non-asset-specific emission factors: more direct measurement of emissions is vital to reduce uncertainties and identify cost-effective reductions

What are the largest sources of methane emissions?

METHANE GUIDING PRINCIPLES

Activity

- On your own device, please go to www.socrative.com
- Go to login, then ‘student login’
- Type in the Room Name: MGPMASTERCLASS

How does this map on to your organisation?

Activity

- On your own device, please go to www.socrative.com
- Go to login, then 'student login'
- Type in the Room Name: MGPMASTERCLASS

Reflection point

Every organisation and asset is different. In your asset, do you know your top 3 sources?

How do you measure/estimate them and what are the challenges there?

METHANE
GUIDING
PRINCIPLES

Reducing methane emissions: Best Practices

Outreach programme

It is time to act

- The Outreach Programme until now has focused on background and understanding of methane emissions and why they occur
- From now, the focus shifts to **action** and **tools** to use to **direct effective methane reductions**
- Here we introduce the **Reducing Methane Emission Best Practice Guides**, supplementing with real-world **case studies** of best practice implementation, as well as some tools to help assess your **methane management plan** and **cost-effective mitigation options**

- Overview
- Best practices:
  1. Engineering design and construction
  2. Venting
  3. Flaring
  4. Pneumatic equipment
  5. Energy use
  6. Equipment leaks
  7. Operational repairs
  8. Continual improvement

Reducing methane emissions best practices: overview

What are the Reducing Methane Emissions Best Practices (RMEBPs)?

- Set of best practice guides which address methane emission reductions
- Cost models to assess cost-effectiveness of selected mitigation options
- Gap assessment tool to assess your organisations methane emissions management
- Available at: www.methaneguidingprinciples.org

Why produce the RMEBPs?

- To deliver guidance and tools for all supply chain asset-owners to help cost-effectively reduce methane emissions
- To provide a framework to continuously improve methane management

Who are they for?

- The whole supply chain
- Asset managers/ frontline management/

RMEBP source coverage

Best Practices Guide	SOURCES							
	Pneumatics/ controls	Tanks	Pipelines	Compressors / Engines	Wells	Equipment Leaks	Glycol Dehydrators	Maintenance Events
Engineering Design and Construction	✓							
Venting		✓		✓	✓		✓	✓
Flaring		✓	✓	✓	✓			✓
Pneumatic Equipment	✓							
Energy Use			✓	✓				
Equipment Leaks		✓	✓	✓	✓	✓		
Operational Repairs						✓		✓
Continual Improvement	✓							

Best practices:

1. Venting
2. Pneumatic equipment
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Best practices:

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RMEBP: Venting

- Venting causes 46 Mt of methane emissions per year (IEA Methane Tracker)
- Venting occurs across all supply chain segments and from a variety of activities.
- This guide focuses on a few common venting sources and strategies. These venting sources are cumulatively significant; they make up ~16% of the total methane emissions estimated from the US petroleum and natural gas systems (US EPA 2017).

RMEBP: Venting

Routine vs. non-routine venting

- Venting of gas occurs for safety reasons or where there is no infrastructure available for capture
  - ➢ Safety venting is vital (but may be minimised by design and operation)
  - ➢ But routine venting could be all-but eliminated…

RMEBP: Venting

Emission Source	Description of Equipment	Mitigation Strategy	Effectiveness
1. Storage Tanks: Flash Gas	Flash gas at tanks with no vapor recovery units (uncontrolled tanks)	a) Add Vapor Recovery Units (VRU)	95%
		b) Eliminate Tanks at production sites	100%
2. Storage Tanks: Loading /Unloading Emissions	Tank loading and unloading, and tank gauging emissions	a) Add automatic gauging systems	100%
		b) Implement a system to balance or exchange vapors between the tanks and tank vehicles	Variable
3. Storage Tanks: Vapor blowthrough from upstream vessels	Vapor blowthrough to a tank	a) Add tank pressure monitors	Variable
		b) Routine monitoring	Variable
4. Compressors: Reciprocating Rod Packing	Rod packing on reciprocating compressors	a) Conduct regular monitoring	Variable
		b) Regular replacement of rod packing	50-65%
		c) Route to control device	95%
5. Compressors: Centrifugal Wet Seals	Wet seals on centrifugal compressors	a) Conduct regular monitoring of vented emissions sources	Variable
		b) Route to control device	95%
		c) Convert compressor wet seals to dry seals	Variable

RMEBP: Venting

Emission Source	Description of Equipment	Mitigation Strategy	Effectiveness
6. Compressors: Gas Starters	Starter motors	a) Convert to electric starters	100%
		b) Switch starters to compressed air (EPA Gas Star)	100%
		c) Route starter discharge to vapor recovery or flare	95%
7. Glycol Dehydrators: Regenerator vent stack	Regenerator vents residual methane	a) Replace a gas assist lean glycol pump with an electric lean glycol pump	100% of pump added emissions
		b) Install a flash tank separator, recover gas, and optimize glycol circulation rates	90%
		c) Replace with “near-zero emissions” dehydrator system	100%
8. Well Completions	Flowback of liquids, solids, and gas from the wellbore after drilling and fracturing	a) Implement reduced emission (green) completion system	~90%
9. Gas Well Liquids Unloading	Removal of accumulated liquids in a low pressure gas well	a) Manual liquids unloading: minimize time	Unknown
		b) Altering the well and well downhole operation so that periodic unloadings are not needed	100%
		c) Automated liquids unloading	Unknown

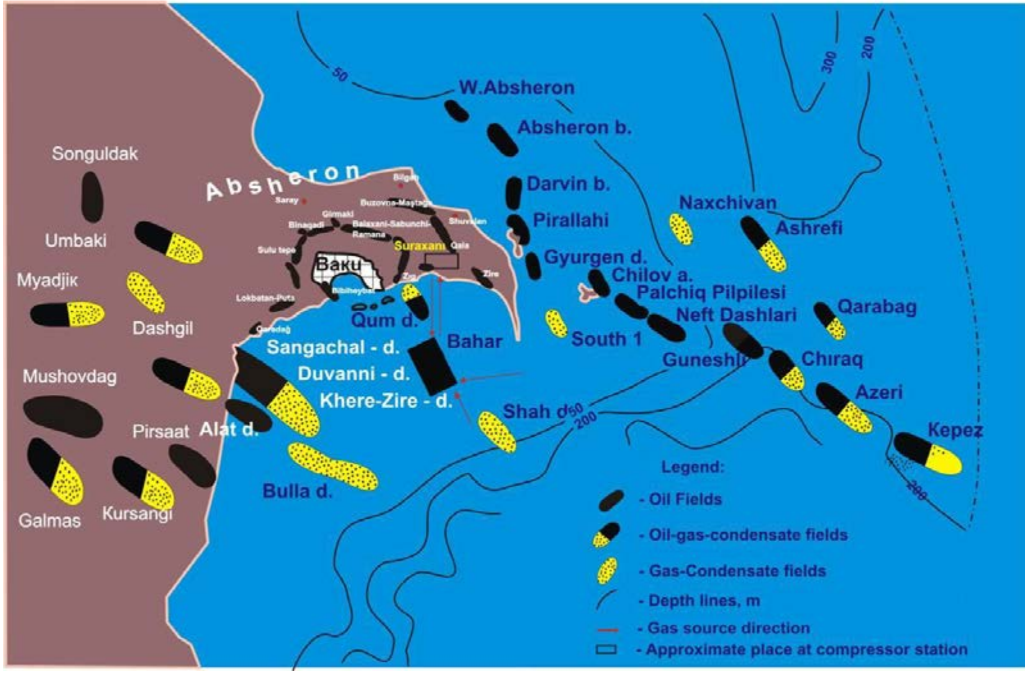
RMEBP: Venting

Best practices for reducing methane emissions from venting:
• Assemble an inventory of emissions from vented sources
• Avoid or reduce venting from major potential emissions sources, including:
– Hydrocarbon liquid storage tanks
– Compressor seals and starters
– Glycol dehydrators
– Gas well liquids unloading operations
– Well completion operations for hydraulically fractured wells
• If avoidance is not possible, prioritize vapor recovery or flaring over direct venting
• Monitor vents and evaluate for further improvements/controls

Case Study. Socar: Utilisation of Associated Gas in Gunashli Oil Field

Case Study. Socar: Utilisation of Associated Gas in Gunashli Oil Field

Best Practice: Venting, Engineering Design and Construction



The Issue

- The Gunashli oil field started producing oil in 1980, in the central part of the Azeri sector of the Caspian Sea, 110 km from Baku Bay.
- Despite the existence of high pressure gas gathering system, there was nothing for low pressure associated gas resulting in 310m m^3 gas vented to atmosphere annually.

The approach

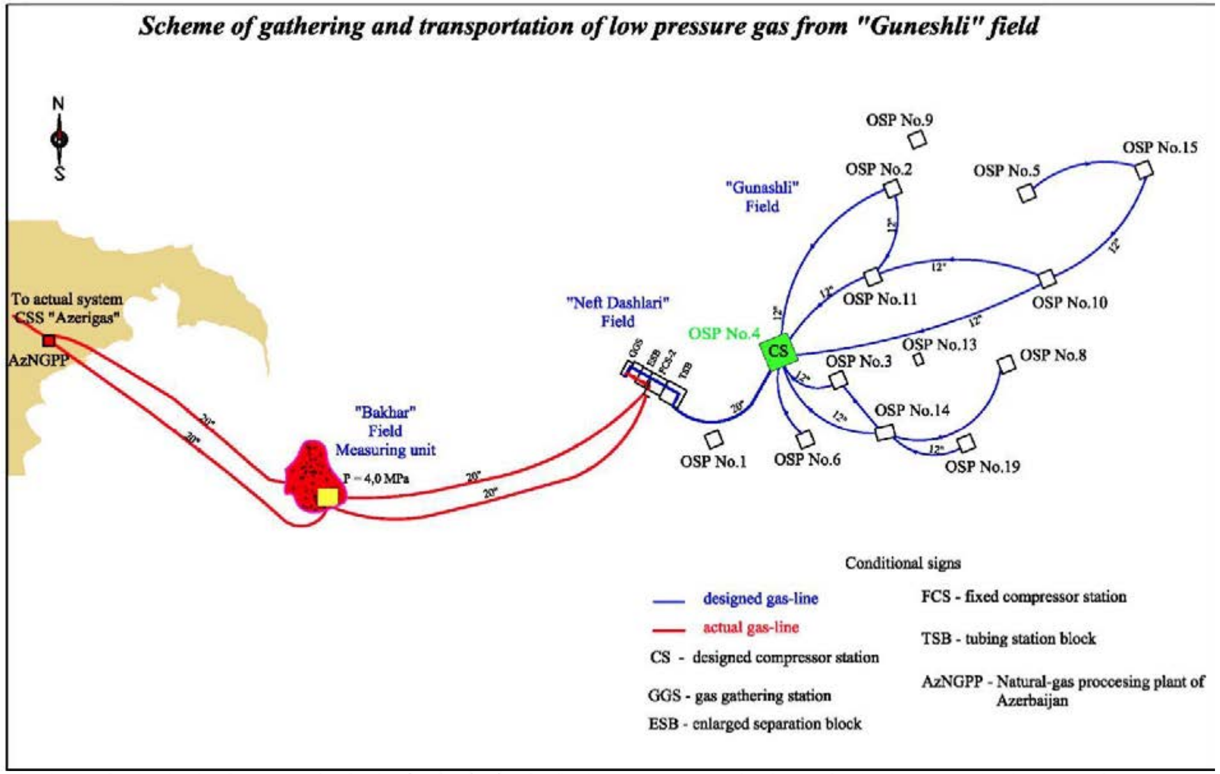
- In 2007, construction of a collection pipeline system to connect 10 offshore platforms with a 325 mm underwater pipeline
- Construction of 13.4 MW compressor station
- Construction of 508 mm pipeline to transport pressurized gas to existing natural gas line

Case Study. Socar: Utilisation of Associated Gas in Gunashli Oil Field

Best Practice: Venting, Engineering Design and Construction

The Result

- 310m m^3 gas recovered per year
- 4.2m $tCO_{2eq.}$ emissions avoided
- Capital cost of 130m USD and operating costs of 8m USD/yr



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RMEBP: Pneumatic equipment

- Gas-driven pneumatic devices are typically used where electrical power is not available.

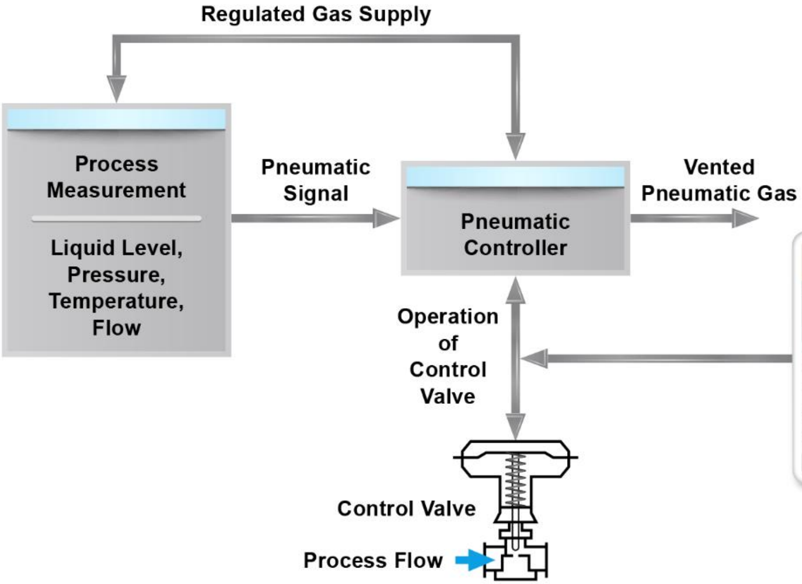
- The two main types:
  - Pneumatic controllers control levels, temperatures and pressures. The gas used to drive the controller is continuously or intermittently vented.
  - Pneumatic pumps are used to inject chemicals into wells and pipelines and for glycol circulation for water separation. The natural gas may be vented as the pump operates.

- Pneumatic devices is one of the largest sources of methane emissions in the United States.

RMEBP: Pneumatic equipment

The United States Environmental Protection Agency (US EPA) classifies the different designs of pneumatic controllers as:

- **Intermittent-vent controllers** are 'snap-action' devices that vent only when a specific condition is met. Intermittent controllers are the most common type of controller used in the oil and gas industry.
- **Continuous-vent controllers** use gas pressure to sense the conditions of an operating process. The gas flows to the valve controller continuously and then vents (bleeds) to the atmosphere (that is, is released into the atmosphere). These can be classed as either **high bleed** or **low bleed**.
- **Zero-bleed controllers** divert vented gas to the gas being produced from the well, rather than into the atmosphere.



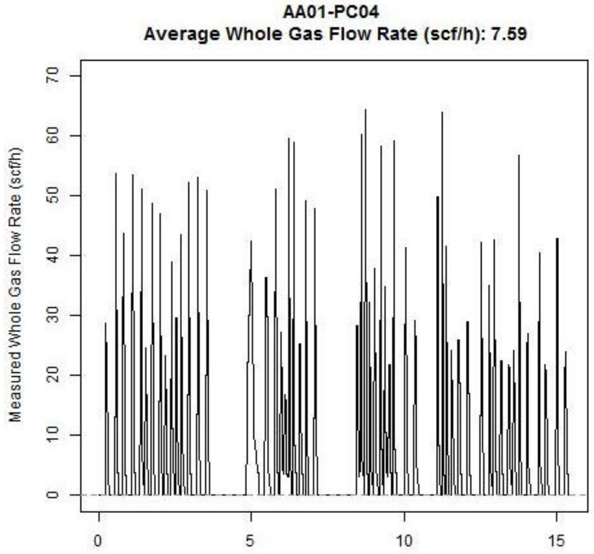
RMEBP: Pneumatic equipment

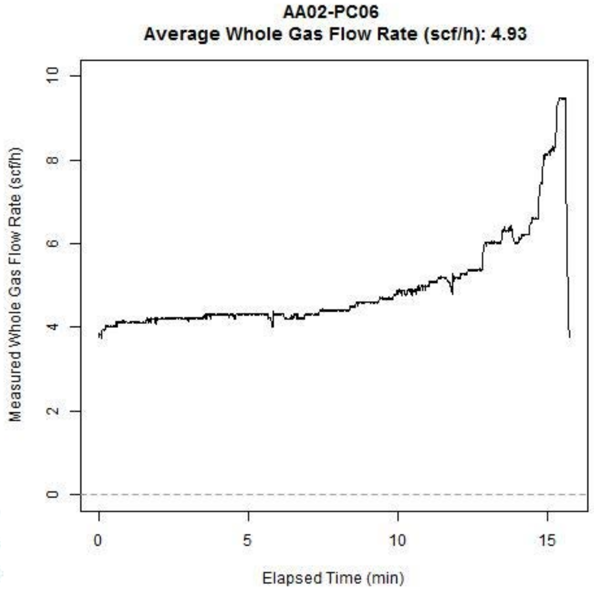
- A small percentage of controllers are responsible for most emissions. For example, at production sites in the US, 95% of the emissions from pneumatic controllers arose from less than 20% of the pneumatic controllers.

- Some controllers that are producing higher-than-expected emissions may be not working properly.

- Emission rates from intermittent-vent controllers depend on how often the mechanism is triggered to release gas.

- Controllers can switch between relatively low emission rates and relatively high emission rates, but what causes this is not well understood.


AA01-PC04
Average Whole Gas Flow Rate (scf/h): 7.59


AA02-PC06
Average Whole Gas Flow Rate (scf/h): 4.93

RMEBP: Pneumatic equipment

Mitigation strategy	Description
1. Replace high-bleed devices with low-bleed or zero-bleed devices	1a Replace pneumatic devices with electrical or solar-powered devices.
	1b Replace pneumatic controllers with mechanical controllers.
	1c Replace high-bleed devices with intermittent-vent or low-bleed devices.
2. Use compressed air rather than natural gas to drive pneumatic devices	Use compressed air generated on-site to drive devices.
3. Carry out regular inspections and repair or replace items where necessary	A small proportion of controllers are responsible for the majority of emissions. If controllers with high emissions due to faults can be identified, they can be repaired or replaced.

RMEBP: Pneumatic equipment

Best practice for reducing methane emissions from pneumatic devices
• Keep an accurate inventory of pneumatic devices that are driven by the natural gas produced from wells.
• Replace pneumatic devices with electrical or mechanical devices where practical.
• If pneumatic devices have to be used, choose ones that use compressed air rather than natural gas.
• When using devices driven by natural gas is the most feasible option, replace high-emission devices with lower-emission alternatives.
• Include any pneumatic devices driven by natural gas in a formal inspection and maintenance program and record the emissions in an annual inventory.

Case Study. Snam: Converting gas pneumatics to instrument air

Case Study. Snam: Converting gas pneumatics to instrument air

Best Practice: Pneumatic equipment

The Issue

- Gas-driven pneumatic systems are used across the natural gas industries for process control, including pressure, temperature, liquid level, and flow rate regulation.
- All vent gas by design (high bleed, low bleed, intermittent, continuous)

The approach

- Instrument air systems substitute compressed air for the pressurized natural gas, eliminating methane emissions and providing additional safety benefits.
- Devices were replaced at many compressor and regulating & reducing stations to instrument air driven
- During 2014-15, Snam replaced ~450 high-bleed old positioners in its R&R stations with a low-emission model
- In new R&R stations, Snam installed boilers with electric control, used fewer regulating lines but of greater diameter, and installed electrically actuated control valves

Case Study. Snam: Converting gas pneumatics to instrument air

Best Practice: Pneumatic equipment

The Result

- 200,000 m^3 gas saving per compressor station per year
- Across R&R plants, 4,000,000 m^3 gas saving per year
- As a result of the pneumatic equipment replacement initiatives, the Snam pneumatic emission reduction from 2013 to 2018 was about 33%, ~6,000,000 m^3 of natural gas saved per year.

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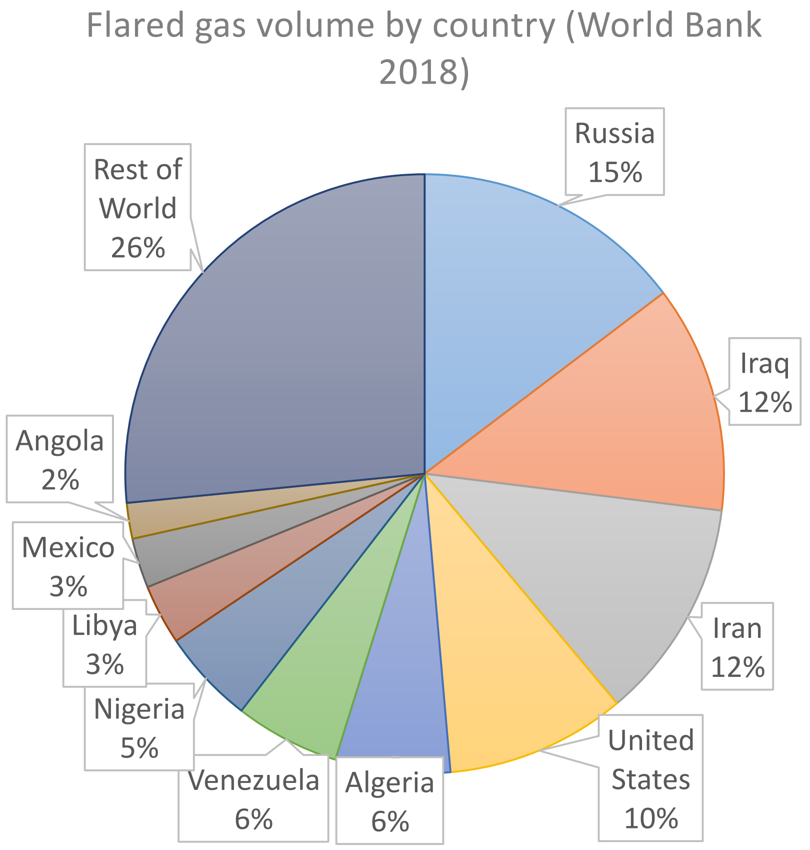
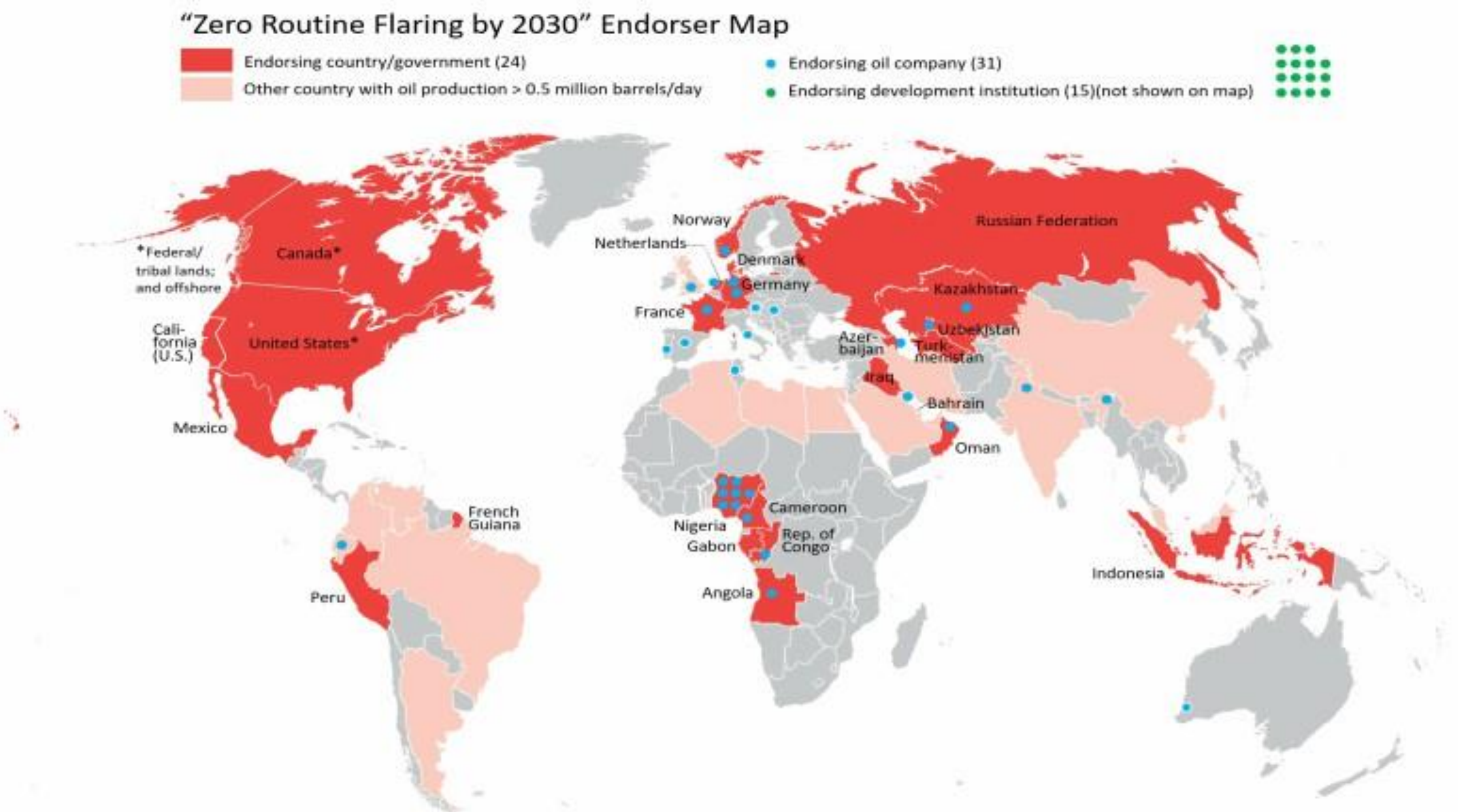
RMEBP: Flaring

- Open flaring burns approximately 145 bcm of gas per year (World Bank 2019).
- If this was converted to electricity (750bn kWh), it would be enough to cover all of Africa's electricity demand
- Methane emissions from this are ~2 Mt, or 2% of methane emissions from global oil and gas production.
- But flow rates of flared gas can vary widely between locations. In Alberta, approximately 10% of sites accounted for half the gas flared, whereas in the United States, less than 5% of 20,000 flares accounted for half of the total volume of gas flared.



RMEBP: Flaring

- In 2015, the World Bank introduced the ‘Zero Routine Flaring by 2030’ initiative
- Commits industry and governments to eliminate routine flaring on new (and reduce existing) assets, as well a reporting progress.
- Endorsed by many nations and oil and gas companies



RMEBP: Flaring

Flaring is needed for…

- safety reasons during activities such as well-completion, maintenance, and emergency shutdowns.
- when more gas than can be used is produced, e.g. lack of infrastructure, over-supplies and pressure imbalances, equipment shut-downs.
- if gas is produced from oil wells before gas-gathering lines are available, flaring may be used.
- a routine emission control, to control emissions that might otherwise be vented and released into the atmosphere

RMEBP: Flaring

Mitigation strategy	Description
1 Prevent the need for flaring	Add a second separator when designing wells
2 Recover flared gases and sell them as natural gas or natural gas liquid	a Add vapor-recovery units on tanks
	b Reduce flaring during well-testing and completion
	c Compress natural gas and transport it by road
	d Recover natural gas liquids
3 Store gases that would otherwise be flared	Store gases by injecting them into oil or gas reservoirs
4 Find alternative uses for flared gases	Use waste gases to generate electricity
5 Improve the efficiency of flaring	a Improve combustion in manned steam- or air-assisted flares
	b Improve combustion in small flares at unmanned sites

RMEBP: Flaring

Best practice for reducing methane emissions from flaring:

- Keep an accurate inventory of flaring activities
- Prevent flaring by designing systems that do not vent gases
- Recover gases that are currently being flared, so they can be sold as natural gas or natural gas liquid products
- Store gases (through injecting into gas or oil reservoirs) that cannot be recovered and immediately sold
- For gases that cannot be sold as natural gas or natural gas liquid, find alternative uses such as generating electricity
- For gases that must be flared, make sure the combustion of those gases is efficient
- Track flaring and venting activities in an annual inventory

Case Study.

BP: Angola LNG flare reduction

Case Study.
BP: Angola LNG flare reduction

Best Practice: Flaring; Engineering Design and Construction

The Issue

- Associated oil production resulted in flaring of 65 mmscfd
- LNG facility enabled capture of otherwise flared gas
- Challenge to eliminate the flare without impacting oil production

The Approach

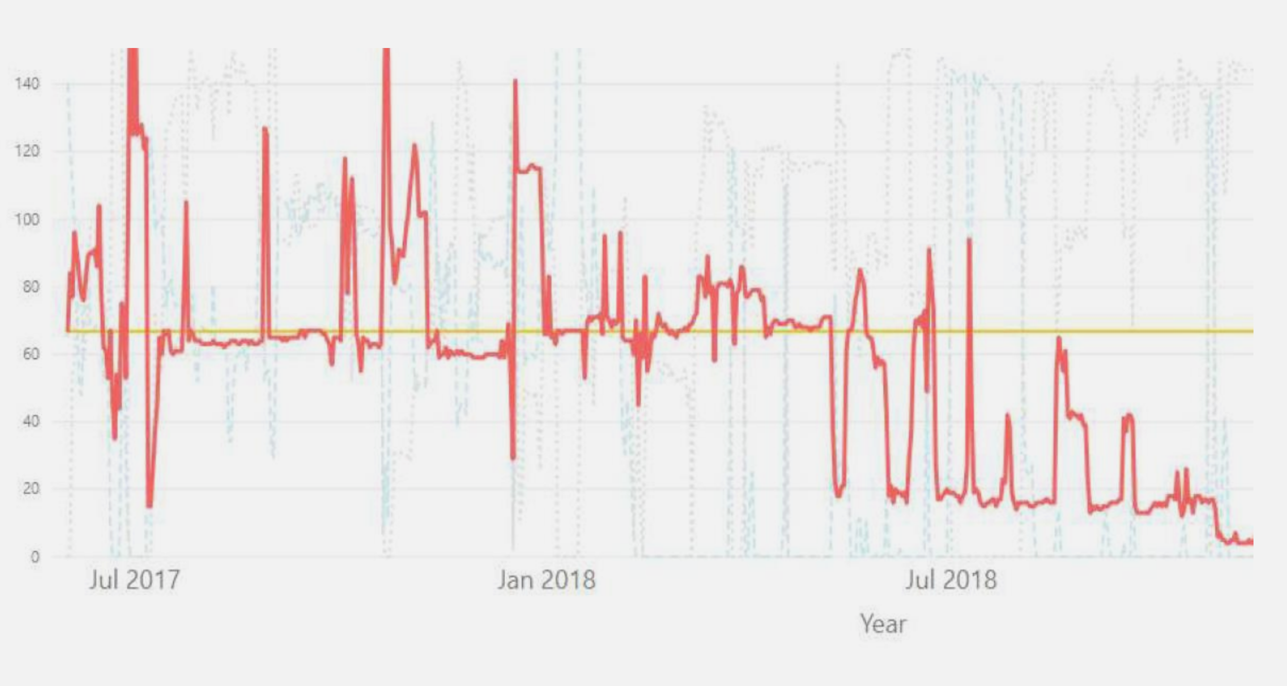
- Four low flare field trials were completed
- over a 2 ½ year period to identify the most suitable mechanism
- Conversion of gas to water well injection
- Re-optimisation of well and production settings
- Improved stability across wider operation envelope for multi-stage compression system

Case Study.
BP: Angola LNG flare reduction

Best Practice: Flaring; Engineering Design and Construction

The Result

- Total average flare reduced from 72.5 to 16.5 mmscfd
- Increased gas export, small increase in oil production, and reduced flaring has created several hundred million dollars of value.
- Enhanced BP reputation in country; increased oil production during a period of decline; more gas flow to under-utilised ALNG plant; reduction of flaring aligning with national environmental aims.



Best practices:

1. Venting
2. Pneumatic equipment
3. Flaring
4. Equipment leaks
5. Operational repairs
6. Energy use
7. Engineering design and construction
8. Continual improvement

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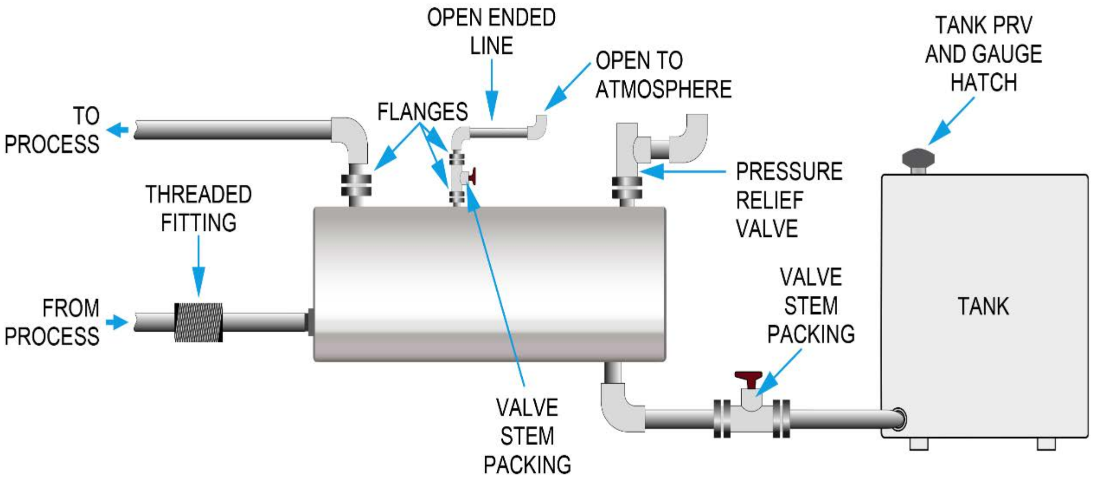
RMEBP: Equipment leaks

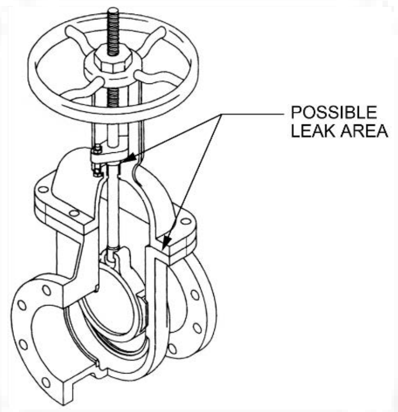
- Fugitive emissions are estimated to contribute ~ 30 Mt CH4 per year (IEA Methane Tracker)
- A fugitive equipment leak is an unintentional loss of process fluid, which could be past a seal, threaded or mechanical connection, valve seat, or flaw on equipment.
- Most sites have thousands of individual components: only a small percentage may leak but this may represents a significant emission source.



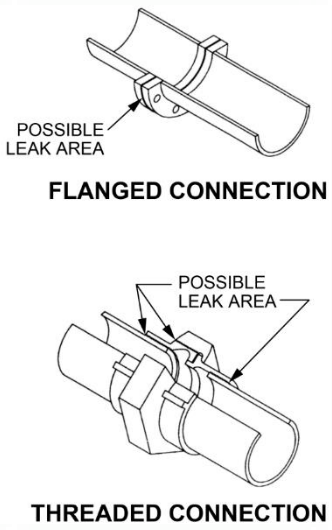
- In the United States, annual equipment leak emissions of methane are estimated to be 16% of all methane emissions from Petroleum and Natural Gas Systems. Similar results are seen in other jurisdictions, such as Canada.

RMEBP: Equipment leaks

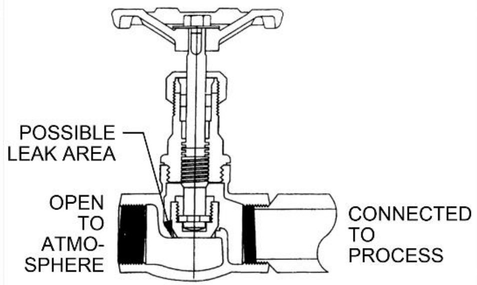
Sources:



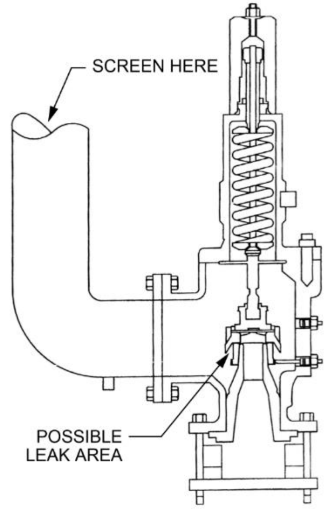
Valves



Connectors



Open-ended lines



PRVs

PRVs/gauge hatches

Pipes

RMEBP: Equipment leaks

- First mitigation: effective equipment design.
- Second mitigation: Leak Detection and Repair (LDAR) programs
  - Procedure must be comprehensive with total coverage (close range)
  - Select effective technology for detection/estimation
  - Record leaks (tag numbers and leak size)
  - Repair in-situ where possible, and prioritise repairs where not
- The frequency of surveys varies (from monthly to multiple years).
- Smart LDAR/ Directed Inspection and Maintenance (DI&M): analyse for common failures/causes and optimise inspection frequencies
- Alternative LDAR programs include different leak detection techniques including large-scale surveys (e.g. satellite, aerial) or mixed method surveys, or continuous monitoring programs.

RMEBP: Equipment leaks

Mitigation strategy	Description
1. Conduct periodic leak detection and repair programs for all facilities above ground	a. Upstream production sites and midstream sites commonly use OGI cameras, such as the specially designed, cooled Infrared cameras (examples are the FLIR GF320 or the OpGal EyeCGas cameras), to detect natural-gas leaks. OGI cameras are used in a walking survey where the user scans all views of the equipment.
	b. Other scanning detection, using devices such as the tunable diode laser absorption system (TDLAS), which measure gas concentration along all scanned paths. An example is the Heath RMLD device.
	c. Flame ionization detectors (FIDs) or similar devices are used for RM21 surveys or other similar approaches. While this may be the most sensitive and reliable leak-detection method, it is also the most complex and costly. It takes longer to scan a facility, so it is usually not the method used for oil and gas facilities. However, it is used if it is required by regulation.
2. Conduct periodic leak detection and repair programs for all underground pipelines	a. Leak detection is usually performed by a walking survey with a highly sensitive wand detector. Leaks have to have travelled from the point of emission on the buried pipe up to the surface in order to be detected.
	b. Leak detection can also be carried out from motorized vehicles on the ground. Aerial surveys can be used for long pipelines, such as transmission lines. However, the effectiveness of aerial surveys has not been fully proven for detecting leaks. Aerial surveys are mainly safety-related surveys, but as technologies and methods improve, they may become effective for detecting leaks.

RMEBP: Equipment leaks

Mitigation strategy	Description
3. Follow a directed inspection and maintenance (DI&M) program	With this approach, risk-management decisions are used to focus detection and repair only on certain equipment or components, or detection is carried out on all equipment and components, but only more significant leaks are prioritized for repair. A focused program requires extensive information from full detection and repair activities carried out in the past, using that information to determine where to focus efforts.
4. Follow an alternative detection and repair program, such as a comprehensive monitoring program	Research programs are testing both surveys and continuous monitoring as alternatives to existing detection and repair methods. Some of these alternatives are called 'comprehensive monitoring programs'. One such research program, based at Colorado State University, is a 'Pathway to Equivalency' initiative, which includes a wide-ranging set of stakeholders and research teams in the USA and Canada (Fox et al, 2019). The initiative involves: • testing potential solutions in field laboratories; • modeling mitigation strategies using simulation tools; • trials to test potential solution in field conditions; and working with stakeholders to encourage them to accept qualifying alternative detection and repair programs.
5. Replace components that persistently leak	This step can be done at the design stage by reducing the number of components and connections, or replacing components that commonly leak.

RMEBP: Equipment leaks

Best Practice Checklist:

Best practice for reducing methane emissions from fugitive leaks
• Keep an accurate inventory of emissions from equipment leaks
• Conduct periodic leak detection and repair (LDAR) on all facilities above ground, to identify and repair leaks
• Conduct periodic LDAR on all pipelines below ground, to identify and repair leaks
• Use ‘focused’ or ‘alternative’ programs such as: o directed inspection and maintenance (DI&M), which is a focused program; and o comprehensive monitoring programs, which are alternative programs, some of which are still being developed
• Replace or remove the need for components that persistently leak

Case Study. Equinor: Hammerfest LNG leak detection improvements

Case Study. Equinor: Hammerfest LNG leak detection improvements

METHANE GUIDING PRINCIPLES

Best Practice: Operational Repairs; Equipment Leaks

The Issue

- Hammerfest LNG liquefaction, 7.6 bcm/yr capacity
- CH_4 emissions ~3,000 t/yr, fugitives and cold-vents ~80% of total
- Uses differential absorption lidar (DIAL) to estimate total emissions (but not pin-pointing)

The Approach

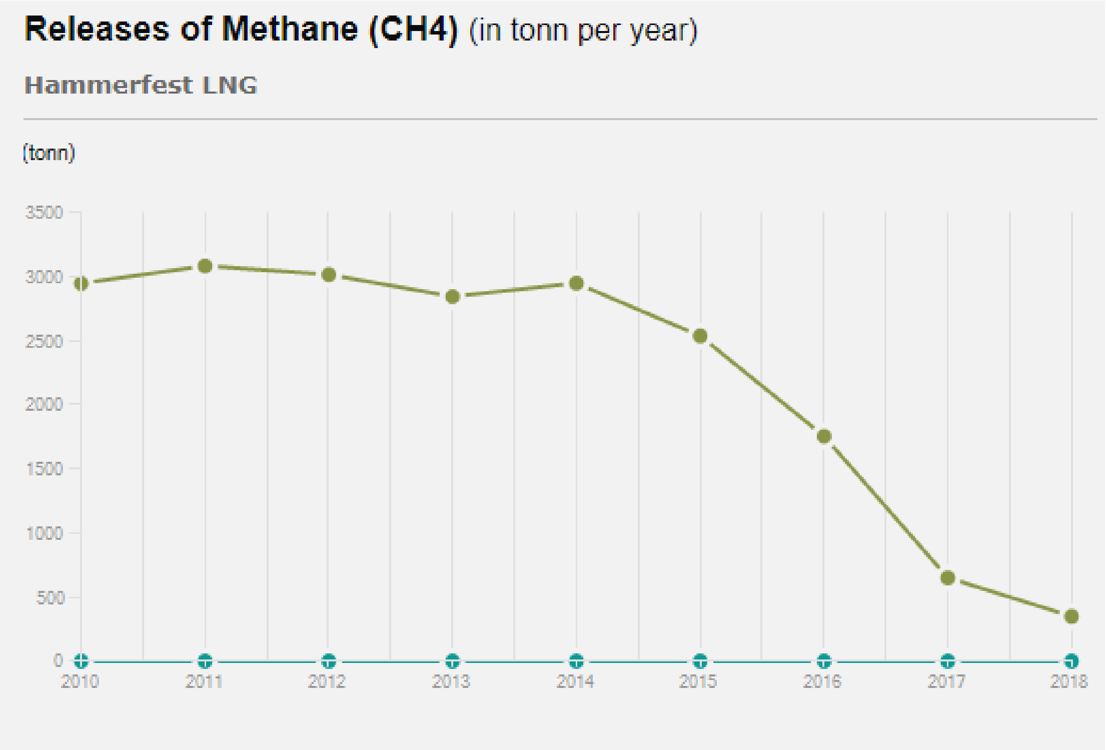
- In 2016, optical gas imaging (OGI) leak detection began
- “OGI leak/no leak” method defined as a Best Available Technology by the Industry Emission Directive
- Enables pinpointing and quick repair of identified leaks

Case Study. Equinor: Hammerfest LNG leak detection improvements

Best Practice: Operational Repair; Equipment Leaks

The Result

- In the first campaign 173 leaking sources identified (e.g. process valves, connectors).
- All leaks reported in the company’s CMMS and corrective action taken.
- Total methane emissions reduced >80%
- In-house availability of technology has led to cultural shift for operators, seeing otherwise invisible leaks has raised focus on early warnings
- The technology is now a preferred tool to manage day-to-day operational risks in the plant.



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RMEBP: Operational repairs

- Operational repairs cover:
  - repairs to leaks discovered during LDAR programs;
  - and minimizing emissions from routine maintenance and repairs.
- Maintenance and repair often requires equipment to be depressurized before maintenance service, where methane may be vented.
- Implementing LDAR programs reduces product losses, increases safety, and can help facilities avoid enforcement actions and fees.

RMEBP: Operational repairs

Best practice leak detection and repair programs include the following elements:

1. Carry out repairs as soon as reasonably practical.
    - Confirm when repairs have been successful.
    - Where repairs are unavoidably delayed, they should be tracked and a date set for the repair.
2. Keep accurate records of leaks and repairs.
3. Analyze records of leaks and take action when necessary.
4. Avoid leaks and the need for repairs where possible.
5. Minimize emissions arising from making repairs.

RMEBP: Operational repairs

To avoid emissions arising from traditional maintenance and repairs.

- Make new connections to pipelines using hot taps, and so avoid the need to depressurize the pipeline.
- Use non-intrusive inspection, such as inline inspection tools, to avoid larger blowdowns for inspections.
- Look for opportunities to co-ordinate operational repairs and routine maintenance and repairs to minimize the number of blowdowns.

To minimize emissions arising from traditional maintenance and repairs.

- Plan for venting-reduction steps such as ‘pressure pumpdowns’ when large vessels and pipelines need to be isolated and depressurized.
- Minimize the volume that has to be handled. For some long pipelines, this could be careful selection of where to isolate the line, or adding stops to isolate a smaller section of line.
- Reduce emissions from pigging by recapturing the released gas using a vapor-recovery unit.
- If venting cannot be avoided, consider flaring to reduce the emissions impact.

RMEBP: Operational repairs

	Operational Repairs Checklist:
Equipment Leaks	Keep accurate inventories that include estimates of emissions from leaking equipment, calculated using a method that includes the duration of any leaks that were discovered
	Have a leak detection and repair program on all facilities
	Make repairs as soon as practical after each leak-detection survey
	Keep accurate and up-to-date records of leaks found and repairs carried out
	Regularly analyse records of leaks and repairs and take action where necessary
Maintenance and Repairs	Perform pumpdowns of pipelines and large vessels
	Minimize the volume of gas that has to be depressurized by using hot taps and line stops
	Reduce emissions from pigging by using a vapor-recovery unit to capture the gas that is released
	Avoid emissions by using non-intrusive inspection approaches, such as inline inspection tools
	Avoid emissions by using hot taps to make new connections to pipelines
	Reduce the number of blowdowns by coordinating operational repairs
	Where depressurizing means that makes releasing gas to the atmosphere necessary, consider flaring to reduce the emissions impact

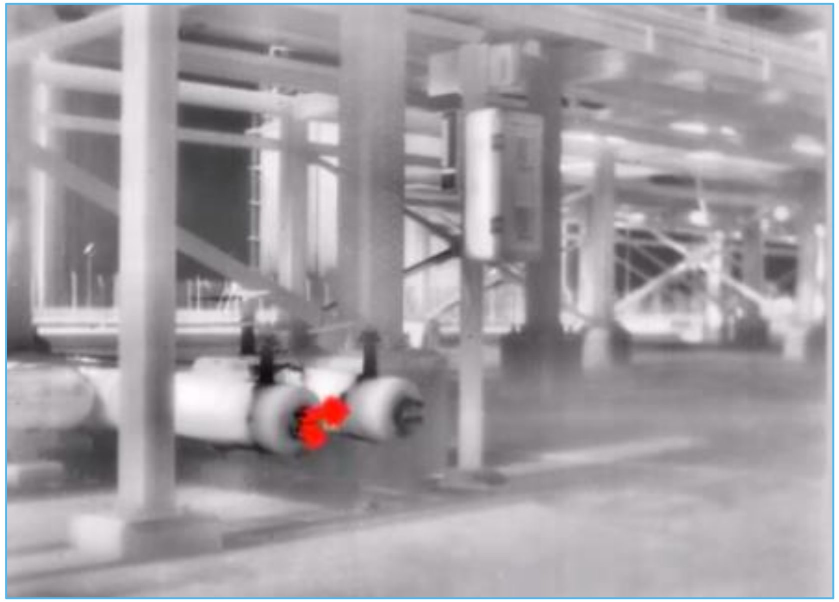
Case study. Enagás: Fugitive emissions reduction, LDAR campaigns

Case study. Enagás: Fugitive emissions reduction, LDAR campaigns

Best Practice: Equipment leaks; Operational repairs

The Issue

- Enagás has 12,000 km pipelines, 19 compressor stations, 493 regulation and metering stations, 3 underground storage facilities and 4 LNG regasification plants.
- CH4 emissions account for approximately 1/3 of the carbon footprint of Enagás; being 60% due to fugitive methane emissions.



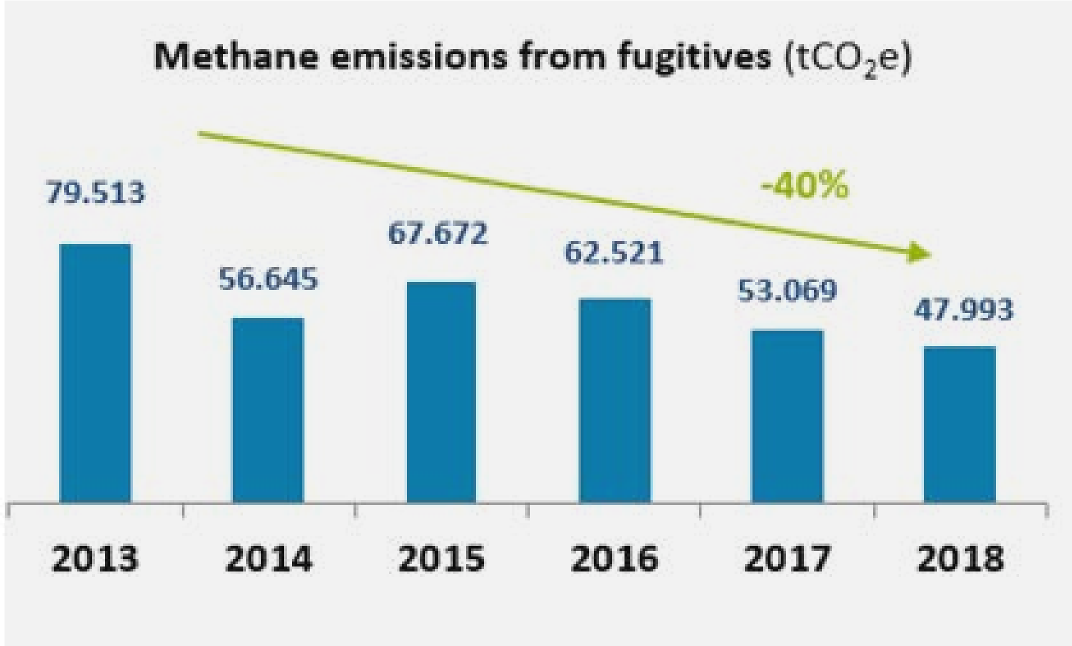
The approach

- In 2013, first LDAR campaign was carried out, using infrared camera combined with flame ionised detector
- Between 2013 and 2015, all LNG terminals monitored, all underground gas storages and a representative sample of the transmission gas infrastructure.

Case study. Enagás: Fugitive emissions reduction, LDAR campaigns

METHANE GUIDING PRINCIPLES

The Result



- Since 2013, emissions reduced by over 40%
- Key lessons learnt for continual improvement
- There is still great uncertainty associated with quantifying equipment and emission factors, and there is no standardised methodology.
- Valves are the most difficult to repair and the main leaking components in LNG terminals (58% of detected emissions) and underground storages. Connectors are also likely to leak in compressor stations (49%).
- The age of the installation is also an influencing variable.
- The frequency of the campaigns is key in reducing fugitive emission, especially in installations where there is a large variation of temperature.
- A training course in leak detection is developed and to monitor all data obtained in the campaigns, the company is developing an IT platform.

Compressor station cost model…

Best practices:

1. Venting
2. Pneumatic equipment
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8. Continual improvement

Best practices:

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7. Engineering design and construction
8. Continual improvement

RMEBP: Energy use

- Natural gas is used as a fuel throughout the oil and gas supply chains, for compression, electrical power generation, heating, dehydration, and acid gas removal.
- Devices using gas as fuel may operate at 98+% combustion efficiency, so some methane is emitted.
- Methane slip is generally estimated, rather than measured.
- Reducing fuel use can lower methane emissions in multiple ways
- However, there is also the possibility that reducing energy use may increase emissions in other parts of the value chain (e.g. electrification).
- Methane emission reduction practices that reduce energy use, may lower energy costs.

RMEBP: Energy use

Mitigation strategy	Description
1. Prevent fuel use by using electrical or other types of power	a Install electrical compressors
	b Replace natural gas used in compressor starters with electrical starters or pneumatic starter using air or nitrogen
2. Reduce fuel use by improving energy efficiency	Efficient energy use in gathering lines
3. Improve fuel combustion efficiency	a Replace compressor cylinder unloaders
	b Install automated air/fuel ratio controls

RMEBP: Energy use

Best practice for reducing methane emissions from energy use in oil and gas operations
• Keep an accurate inventory of where natural gas is used as fuel
• Use electricity or pneumatic power from compressed air or nitrogen
• Improve the energy efficiency of operations and equipment
• If natural gas needs to be used as a fuel, improve the efficiency of combustion engines
• Track progress in reducing the use of natural gas as fuel

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RMEBP: Engineering design and construction

- Methane emissions can be minimized by design. The design phase provides the best opportunity to identify methane reductions.

- The following design strategies should be considered in this order of priority:
  1. Eliminate sources of methane
  2. Reduce the amount of methane emitted and the amount of fuel used
  3. Control remaining sources of methane

RMEBP: Engineering design and construction

General design principles to reduce methane emissions:

1. Use electric, mechanical and compressed-air equipment where possible
2. Centralize facilities
3. Use pipelines to transport oil and natural gas from facilities
4. Recover methane for beneficial use
5. Use alternative low-emission and low-maintenance equipment

RMEBP: Engineering design and construction

Engineering and design strategies to reduce methane

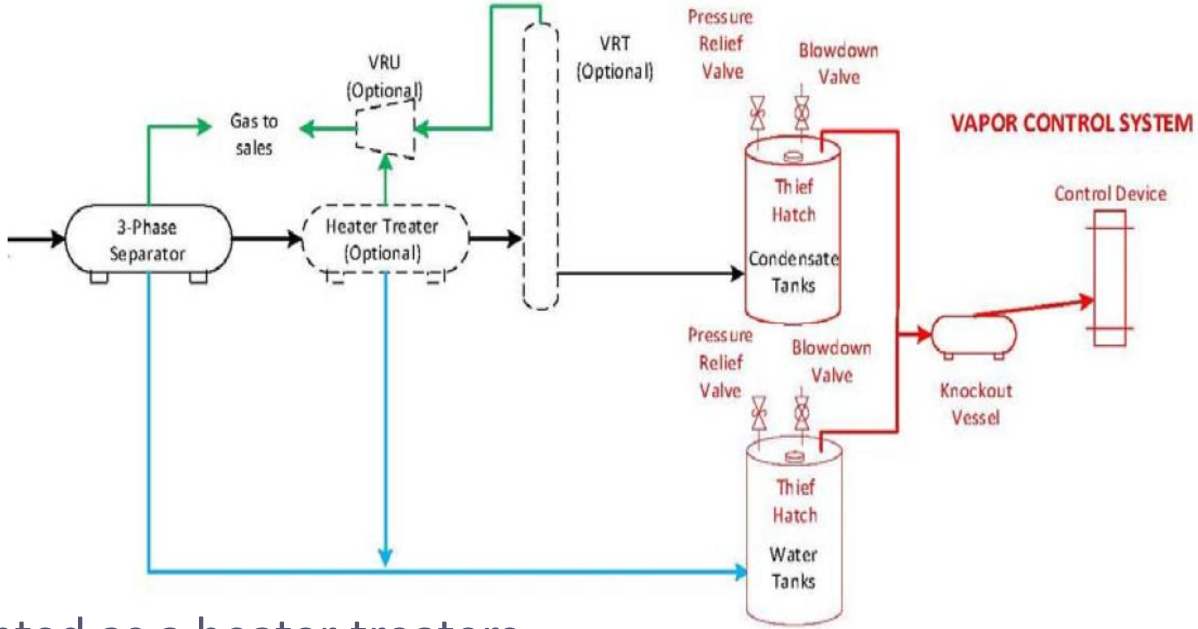
Engineering and design strategy	Eliminates sources of methane emissions	Reduces venting, leaks or energy use	Controls methane	Design Strategy Category
1 Siting of utilities and centralization	X	X		1, 2, and 3
2 Modular design	X	X		5
3 Eliminating fugitive components		X		5
4 Location of fire-gate valves and isolation valves		X		4
5 Secondary and tertiary separation		X		4
6 Tankless design	X	X		3 and 5
7 Storage tank design		X	X	5
8 Using electric compressors	X	X	X	1
9 Pig ramps and jumper lines		X		4 and 5
10 Using methanol to prevent hydrates	X	X		5
11 Amine unit flash tank		X		4
12 Acid gas control device		X	X	5

Design categories: 1) Use electric, mechanical and compressed-air equipment; 2) Centralize facilities; 3) Use pipelines to transport oil and natural gas; 4) Recover methane for beneficial use; 5) Use alternative low-emission and low-maintenance equipment

RMEBP: Engineering design and construction

Engineering and design strategy 5: Secondary and tertiary separation

- Oil and condensate separation usually occurs at greater than 100 psig (700 kPa).
- At storage tanks ‘flash gas’ is often released, which is typically vented or flared.
- Secondary and tertiary separation can be used to recover the flash gas and minimize flashing.



- E.g. secondary and tertiary separators represented as a heater treaters, and vapor-recovery towers (VRT) at a production facility.

RMEBP: Engineering design and construction

Best Practice Checklist:

Activity
• Include methane reduction in standard design practice
• Use electric, mechanical and compressed-air equipment where feasible
• Centralize facilities
• Use pipelines to transport oil and natural gas from facilities
• Recover methane where feasible
• Control methane where recovery is not feasible
• Use alternative low-maintenance equipment and processes

Case Study.

QP: Jetty Boil-off Gas Recovery Project

Case Study.
QP: Jetty Boil-off Gas Recovery Project

Best Practice: Flaring; Engineering Design and Construction

The Issue

- Qatar's LNG production capacity is expected to increase to 110 MTA by 2024
- During LNG loading, boils off occurs as it comes in contact with the warmer ship tank.
- Previously it was flared, but the Qatar Ministry of Environment mandated the minimization of flaring

The Approach

- A Central Compression Area is connected to all 6 LNG berths in the area through a 60-inch collection header
- BOG is pressurised to 48 bar and distributed to be used as fuel gas
- Technical challenge with transport distance (5 km), low pressures and temperatures

Case Study.
QP: Jetty Boil-off Gas Recovery Project

Best Practice: Flaring; Engineering Design and Construction

The Result

- Commissioned in October 2014, it recovers more than 90% of BOG.
- Recovers approximately 0.6 million tons of flared gas per year, producing 750 megawatts.
- Total project cost nearly USD 800 Million.
- CO2 emission reductions of approximately 1.6 million tonnes per annum.

It recovers more than 90% Of gas that was flared at the six berths of jetties in Ras Laffan Port	Cost USD 800 Million
This saves 600,000 Tons of LNG per annum	Recovers the loss of approximately 0.6 million Tons of flared gas per annum
Which is enough Natural gas to power 300,000 homes	This equates to saving of 1.5 million tons of CO_2 per year

Gap assessment tool

What is it for

- A simple excel tool asking you to rate your asset/organisation's performance on methane emissions management and continual improvement
- A resource for asset managers to baseline methane management achievement and identify improvement areas
- A diagnostic tool to provide preliminary insights against current best practices
- Uses the continual improvement plan-do-check-act categorisation

Where to find it

- MGP webpage: www.methaneguidingprinciples.org/

Here's what it looks like…

METHANE
GUIDING
PRINCIPLES

Gap assessment tool

Activity

- To demonstrate the types of questions and opportunities for improvement, let’s conduct a survey here…

- On your own device, please go to www.socrative.com
- Go to login, then ‘student login’
- Type in the Room Name: MGPMASTERCLASS

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RMEBP: Continual improvement

- Methods to reduce methane emissions (mitigation) drive discrete reductions, but continual improvement of methane management is needed to maintain a company-wide culture of methane excellence.
- Continual improvement of methane management can lead to recognition for methane excellence and help improve the reputation and long-term acceptance of the asset, the organization and the oil and gas industry as a whole.
- The most important factor to achieving methane excellence is commitment from everyone – ranging from senior leadership to frontline employees.

RMEBP: Continual improvement

Improve methane mitigation capabilities

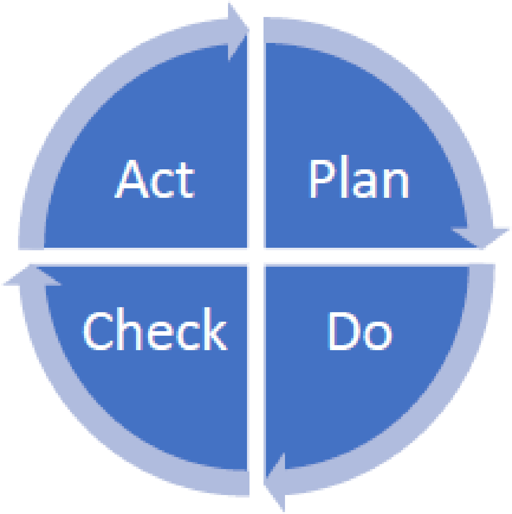
- Improve methane monitoring and response practices to prevent, detect and repair leaks
- Learn from existing operations to reduce methane through engineering and design
- Create an end-to-end process for reducing emissions

Learn from methane-emissions data, patterns and trends

- With emissions monitoring output, assess trends and patterns in emissions
- Remediation successes and repeat failures
- Root cause analysis

Set strong methane-reduction targets

- Include all methane emissions from both gas and oil production
- Address emissions from both operated and non-operated assets
- Rigorous emissions measurements and analysis inform targets and validate reduction levels



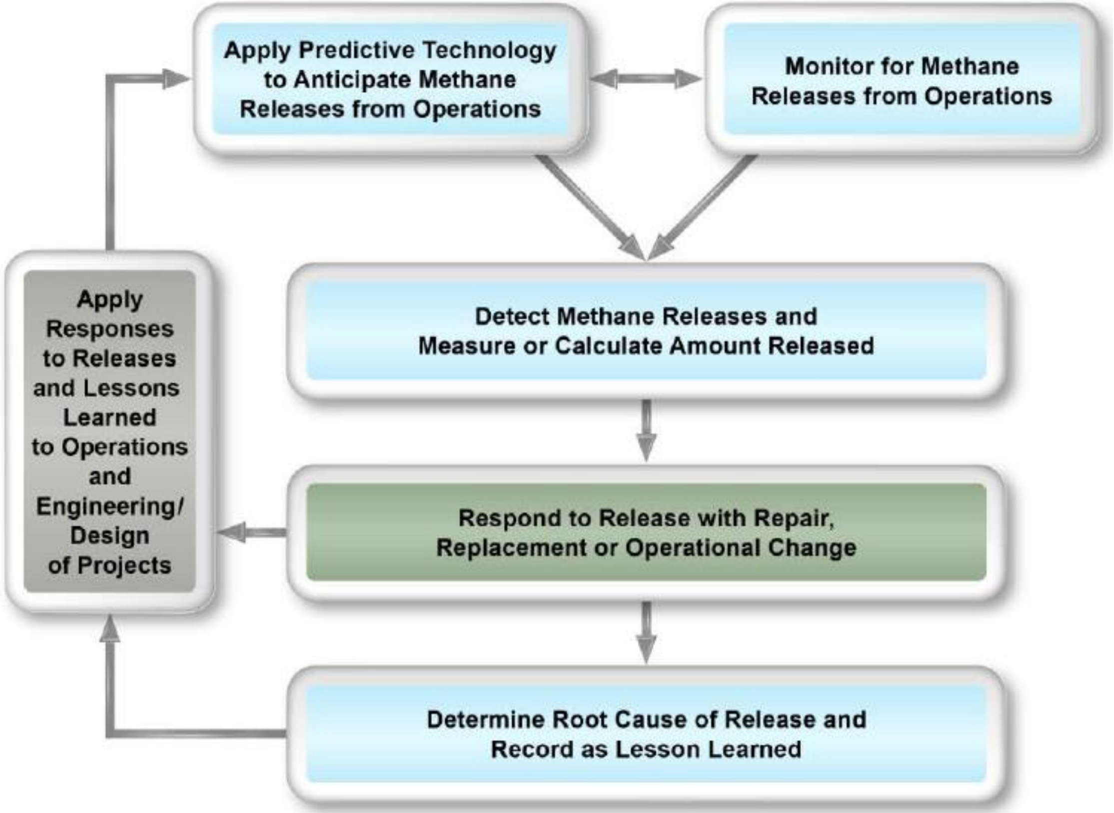
RMEBP: Continual improvement

Report mitigation strategies used and the results

- Transparency critical for building internal and external confidence
- Asset and company level
- Consider reporting units (CO_{2e}, CH_4, $)
- Third party validation

Integrate mitigation strategies into company culture

- Incorporate into existing management system
- Establish learning opportunities and encourage experience sharing
- Promote excellence and innovation



RMEBP: Continual improvement

Best Practice Checklist:

Best practice for continual improvement of methane management
• Use a management process such as the 'plan-do-check-act' cycle (the PDCA cycle)
• Improve methane leak detection and practices to prevent and repair leaks
• Apply methane mitigation strategies at the project engineering and design stage
• Learn from methane-emissions data, patterns and trends
• Set strong methane-reduction targets
• Report the results of mitigation activities.
• Build methane management into company culture

Case Study. TOTAL: Methane Emission Measurement Testing Facility

Case Study. TOTAL: Methane Emission Measurement Testing Facility

Best Practice: Equipment leaks; Continual improvement

The Issue

- There is a need for precise methane emissions measurements
- But many equipment appear every year to detect/ quantify methane emissions. How to select the right equipment?

The approach

- In 2015, a test facility was created to accelerate development of sensors and measurement for methane.
- Able to reproduce leaks in real conditions: tanks, valves, flare, well head, with mass flowmeters to reproduce leaks 0.1 to 300g/sec.
- Ground and airborne sensors or satellite measurements can be tested.
- A 2000 m^2 platform with its own control room.

Case Study. TOTAL: Methane Emission Measurement Testing Facility

Best Practice: Equipment leaks; Continual improvement

The Result

- Two large measurement campaigns took place in 2018, allowing more than 20 technologies to be tested, going from very low TRL to commercially available tools.

- Measurement technologies as well as modelling tools are developed to lead to real time follow up of gas plume.

- The platform has a virtual twin to allow us to develop data driven applications to monitor and control leaks, on a human-centred approach.

Case Study. National Grid: Continuous monitoring of emissions

Case Study. National Grid: Continuous monitoring of emissions

Best Practice: Equipment Leaks; Continual Improvement

The Issue

- Compressor station leaks covered by periodic LDAR, meaning small leaks may last long time (until the next LDAR)
- Develop cost-effective method to monitor and quantify fugitive emissions

The Approach

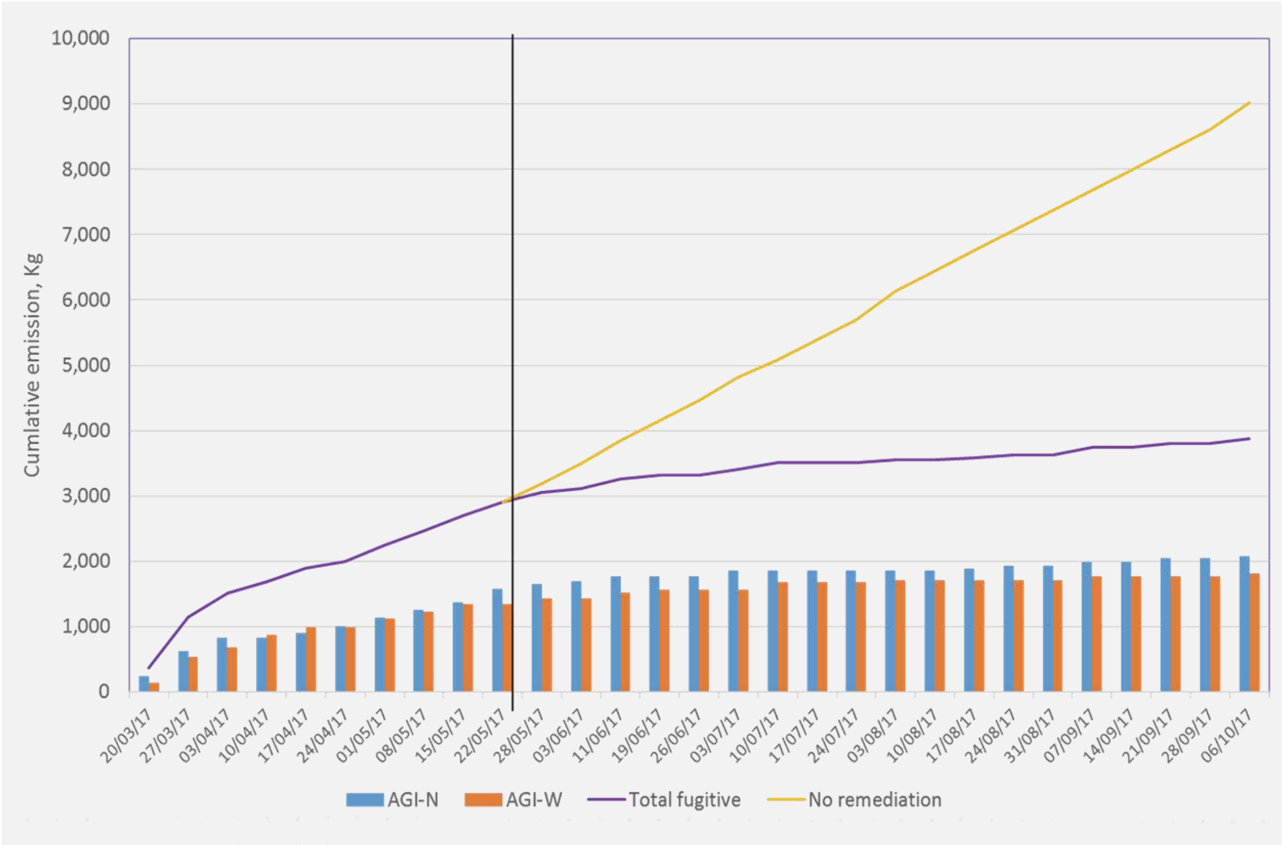
- Install multiplexed, highly accurate and sensitive gas analyser at several locations on boundary fence of compressor station.
- Combine with wind speed, direction and temperature data to identify location and determine emission rate

Case Study. National Grid: Continuous monitoring of emissions

Best Practice: Equipment Leaks; Continual Improvement

The Result

- Two outputs –probability map showing where emissions originate from and emission rate quantification.
- The system monitors continuously providing updated emission rates and leak detection once an hour.
- Uncertainty reduced to ~25%
- Being rolled out across more assets



Reducing Methane Emission Best Practices: summary

1. Engineering design and construction
2. Venting
3. Flaring
4. Pneumatic equipment
5. Energy use
6. Equipment leaks
7. Operational repairs
8. Continual improvement

METHANE
GUIDING
PRINCIPLES

Reducing methane emissions: Summary

Outreach programme

The business case: summary

1. Climate change

   Reducing methane emissions is critical to meet climate targets and is an opportunity to slow down global warming.

2. Safety

   Safety prioritisation has already helped to reduce methane emissions across industry, but can we engender this philosophy to further reduce methane emissions?

3. Social licence

   Methane management across the whole industry will help to maintain a social licence to operate and the continued role of gas in decarbonisation and improving air quality.

4. Revenue

   Methane emissions represent asset loss, where many emissions can be eliminated at zero cost or less, but barriers exist to investment in mitigation.

Understanding methane: summary

1. Sources of methane

   Methane is emitted via various mechanisms across the supply chain and it is vital that organisations account for all potential sources

2. The distribution: heavy tails and super-emitters

   A small number of sources typically dominate total emissions, and there is an opportunity to substantially decrease emissions by faster detection and corrective action

3. Estimation methods

   We must rely less on non-asset-specific emission factors: more direct measurement of emissions is vital to reduce uncertainties and identify cost-effective reductions

Reducing Methane Emission Best Practices: summary

1. Engineering design and construction
2. Venting
3. Flaring
4. Pneumatic equipment
5. Energy use
6. Equipment leaks
7. Operational repairs
8. Continual improvement

METHANE
GUIDING
PRINCIPLES

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