‘KNOWN UNKNOWNS’ – THE CHALLENGE OF FUGITIVE EMISSIONS IN ENERGY SYSTEMS

By David Bamford

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EXECUTIVE SUMMARY

Recently we have reviewed flaring and venting from the UK's onshore oil sites, methane emissions from U.K. oil & gas facilities as a whole, fugitive emissions from the UK and EU gas pipeline systems, leakage and odours from landfills in the UK and EU, potential for fugitive emissions from Anaerobic Digesters.

There is one consistency between the reporting from these quite different UK and EU facilities - it is that currently there is little in the way of actual measurements; instead companies seem to rely on 'proxy measurements' (eg this year is 5% less than last year), or 'engineering protocols' (eg pipeline of this diameter, flowing this much gas, at this pressure, will leak this % of the gas), or 'guesstimates'. When actual measurements are made elsewhere, mainly in the USA, with satellites or aircraft that image larger/super events, the amounts observed are oftentimes significantly more than companies report and/or regulators' estimates.

What does this all mean?

The World Bank and the IEA focus on the climate change impacts of the continued global increases in the amount of methane that is simply burnt (ie flared) or vented or leaked. We suggest that there are two other aspects that merit attention:

First of all, investors should be concerned that a valuable source of energy that they have invested in is simply being Wasted. Climate Trace, whose estimates should be regarded as tentative volumes, state total global methane emissions as 394MT in 2021 and 402MT in 2022. Good material to talk about at COP28 but how does this lead to action?

Think Global, Act Local - for example "if the United Kingdom's 12,500 dairy farms captured their slurry lagoon methane.....this would significantly reduce Britain's total methane emissions, helping to achieve the country's Global Methane Pledge, and produce fuel worth £406 million per year. The carbon savings would be worth £191m if traded."(1)

Secondly, the problems of air pollution have traction with individuals and communities as there are well known health risks from odours, leaks, venting, and combustion (2)(3).

In the UK and EU, Regulators, despite having clear, existing, restrictions to apply, seem to accept these situations without serious enforcement, effectively allowing companies - oil & gas producers, gas grid/pipeline and landfill operators - to 'mark their own homework'.

Elsewhere, in Africa and the Caribbean for example, regulation needs appropriate development, especially in the light of the EU's - and possibly the UK's - plans for a Carbon Border Adjustment Mechanism to be applied to incoming goods, effectively a Carbon Tax, probably based initially on methane intensity. The oil & gas, agriculture and manufacturing sectors will need to develop methane emissions mitigations and eliminate flaring.

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SECTION 1

THE UK'S FLARING AND EMISSIONS PERFORMANCE

The UK's North Sea Transition Authority (NSTA) has recently published its review of 2023 flaring and emissions performance(1) together with a helpful 'dashboard'(2) which offers details, with some very useful cross-plots.

In this report, we will dig into this review and its supporting data but first it's informative to review some global analyses produced by the IEA, the World Bank, MethaneSat and Stanford University.
The IEA's Global Methane Tracker(3) states that 'Methane emissions from the energy sector remained near a record high in 2023':

'We estimate that the production and use of fossil fuels resulted in close to 120 million tonnes (Mt) of methane emissions in 2023, while a further 10 Mt came from bioenergy – largely stemming from the traditional use of biomass. Emissions have remained around this level since 2019, when they reached a record high. Since fossil fuel supply has continued to expand since then, this indicates that the average methane intensity of production globally has declined marginally during this period."

he World Bank's 2024 Global Gas Flaring Report(4) states that:

'Global gas flaring volumes rose by about 7% to 148 bcm in 2023 from 139 bcm in 2022. Oil production remained relatively stable, resulting in an increase in the global average flaring intensity. The total increase of 9 bcm in gas flaring resulted in an additional 23 million tonnes of CO2e emissions.

The top nine flaring countries continue to account for 75% of all flaring but only 46% of global oil production. The gas flared in 2023 could have been used to improve energy access in some of the world's most energy-poor regions. If utilized, it could have generated enough electricity to double the amount currently provided in Sub-Saharan Africa."

The reports can be summarised thus:

1 Global volumes of flared and emitted methane are going up not down, as some would claim.

2 Large amounts of energy are being wasted, p&@@ed up against a wall so to speak!

This is in spite of the significant amounts of money being invested in ever higher resolution satellite systems, the plethora of sensors, certification etc; the burgeoning regulations in the EU and the USA.

The impression is that regulations are simply not being enforced, companies are allowed simply to "mark their own homework" and problems emerge whenever some serious measurement is done(5) – MethaneSat report that "oil and natural gas producers across the U.S. are emitting methane into the atmosphere at over four times the rates estimated by the Environmental Protection Agency for those same areas based on industry-reported data. The results also show that operators are exceeding their own widely touted emissions goals eightfold."

Likewise, Stanford(6) report similar results and in particular note that:
" *The new emission and cost estimates are roughly three times the level predicted by the U.S. government. The results are based on approximately 1 million aerial measurements of U.S. wells, pipelines, storage, and transmission facilities in six of the nation's most productive regions, including the Permian and Forth Worth in Texas and New Mexico; California's San Joaquin basin; Colorado's Denver-Julesburg basin; Pennsylvania's section of the Appalachian basin; and Utah's Uinta basin."*

and

"*Total estimated leaked emissions range from just less than one percent to as much as 9.6% of total volume, with an average of 3% across the surveyed regions. The federal government estimates that methane emissions from oil and gas facilities nationwide average roughly 1% of gas production."*

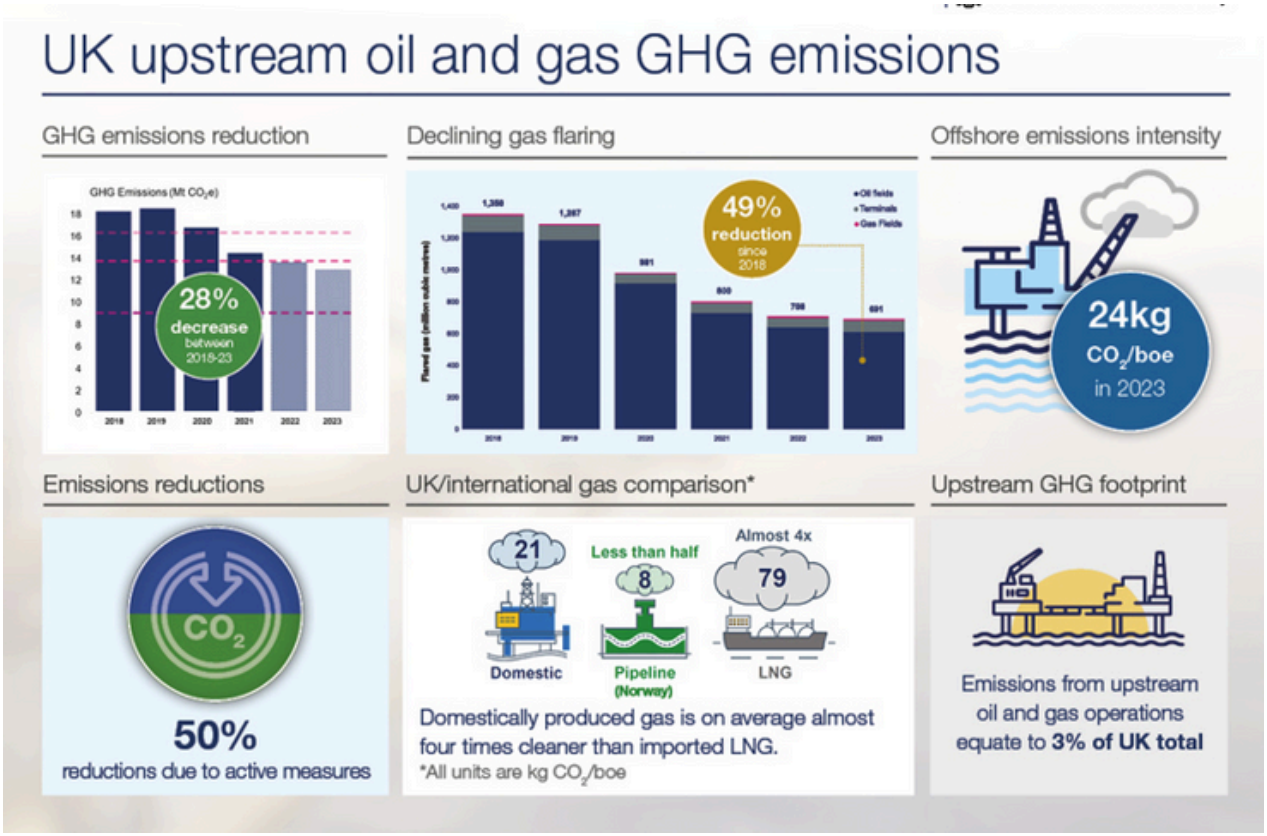
To summarise:

1 Globally, flaring and emissions volumes are going up and not down.

2 Actual emissions measurements, typically involving a combination of satellite, airborne and ground station sensors, aided by "walkers" are oftentimes significantly higher than:

a) assessments reported by companies.
b) estimates and predictions made by regulators/governments.

With this in mind, let's review NSTA's findings for 2023, well summarised in this graphic.



Posing a number of questions, but not asking why the UK's flaring and emissions resemble ski slopes when global flaring and emissions are increasing:

1. The words 'measurement' and 'verification' are hard to find in the NSTA report, as opposed to 'estimate' and 'prediction'. Is most of the data the result of 'proxy measurements' (eg 5% less than last year) or 'engineering protocols' (eg gas at this pressure will leak 1% of the flowing volume) or simply 'guesstimates'?

2. Should we anticipate that as and when actual verified measurements become available, they will report emissions (and flaring) significantly higher than current NSTA reporting?

3. The data is grouped in terms of regions, sub-regions and field complexes. Why is there no reporting by company which is surely the information that investors would find the most useful?

4. Comparisons with alternative sources of gas such as LNG and Norwegian pipelines are important. What is the source of the 4x statement re LNG?

NSTA publicises when it has fined companies for not complying with regulations(7), for not doing their 'homework'. Surely it would welcome independent verification of companies' reported flaring and emission measurements, independent 'marking of homework'?

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3) https://www.iea.org/reports/global-methane-tracker-2024/key-findings
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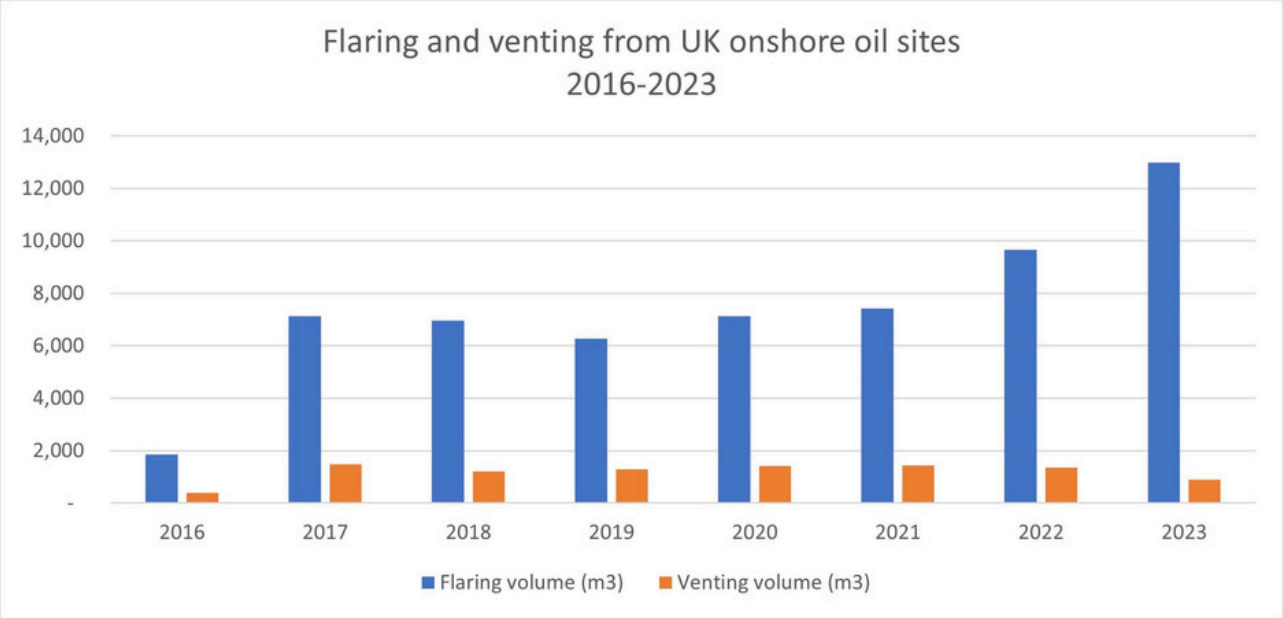
SECTION 2

HISTORIC FLARING AND VENTING OF METHANE ONSHORE UK



What can be said about flaring and venting by onshore UK oil & gas companies? Based on our review, there are four key takeaways:

1. As shown in the NSTA's graphic, summarising what companies report, the recent history of flaring and methane emissions onshore UK is a microcosm of the global pattern - either flatlining or going up!

2. Much more methane is wasted in flaring than in emissions.

3. Most UK onshore fields are flaring, some intermittently, some continuously.

4. Satellite data, going back ~10 years, offers onshore companies 'no hiding place' on flaring; the Regulator doesn't seem to be using it!

'Light is the best disinfectant'

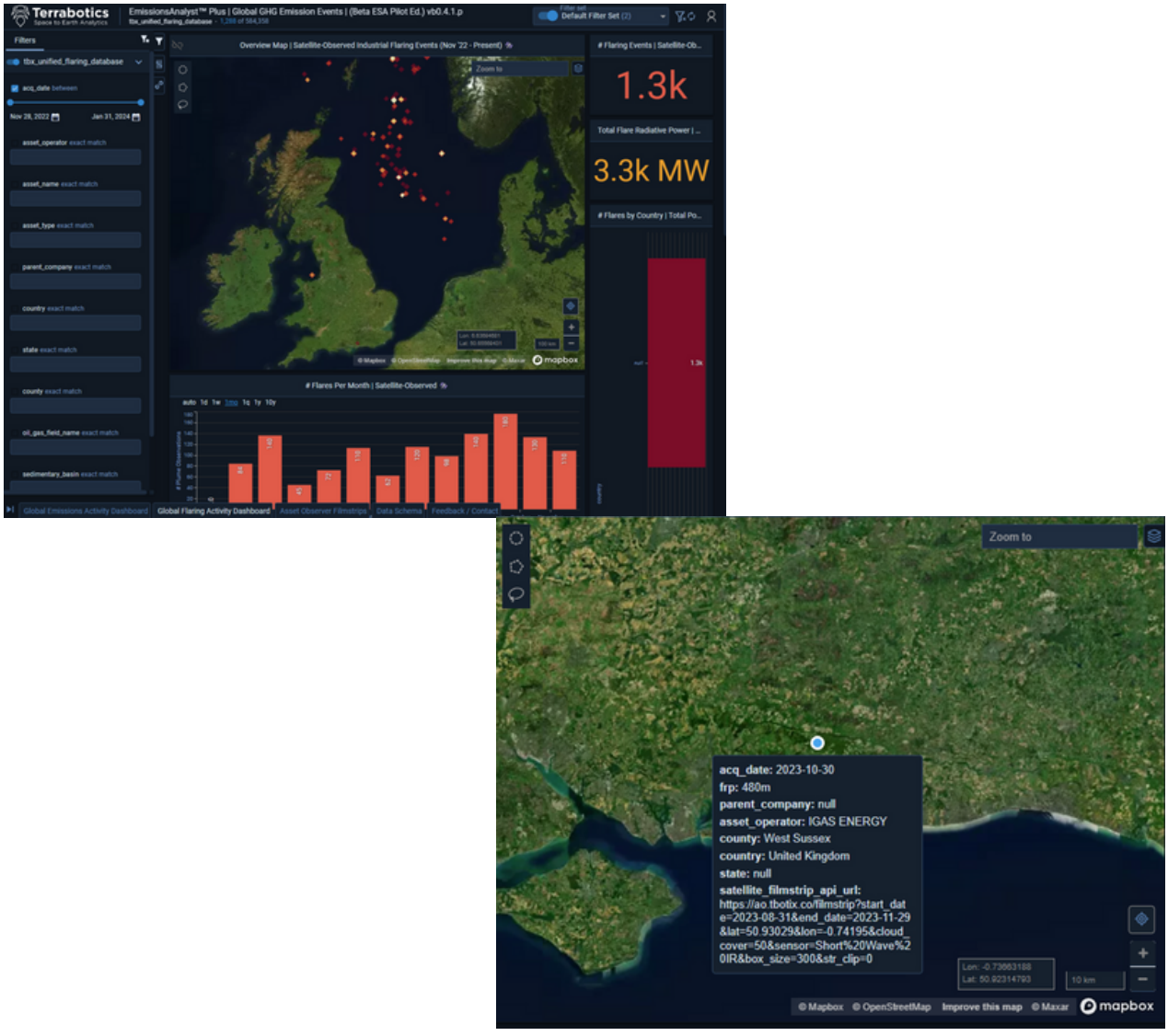
During 2021 – 2024 intrepid investigators from the Clean Air Task Force (CATF) have visited many onshore UK oil & gas facilities utilising handheld Flir sensors to evidence methane emissions. The results of their recordings are summarised in these two articles:

- Weald oil fields still emitting methane
- Investigation: "Significant" methane emissions recorded at UK onshore oil sites

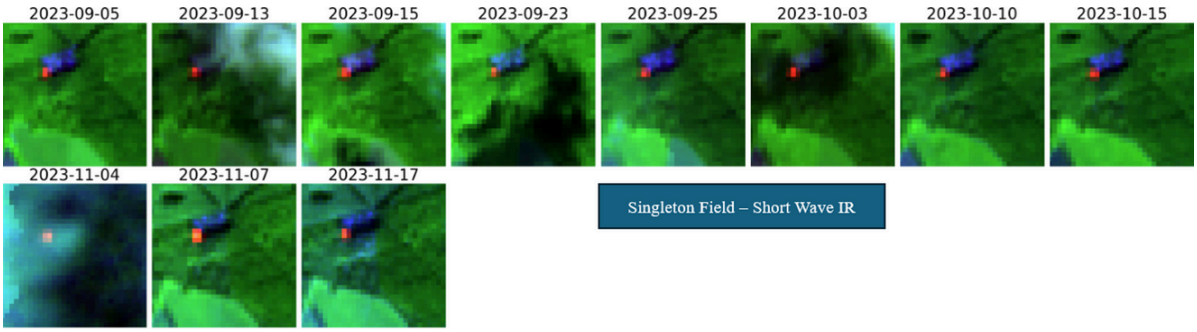
And we can namecheck a few fields – Singleton, Kimmeridge, Horndean, Stockbridge (Larkwhistle Farm) – in the Weald and Wessex basins where there seems to have been no significant change over the 3 years covered by CATF's surveillance.

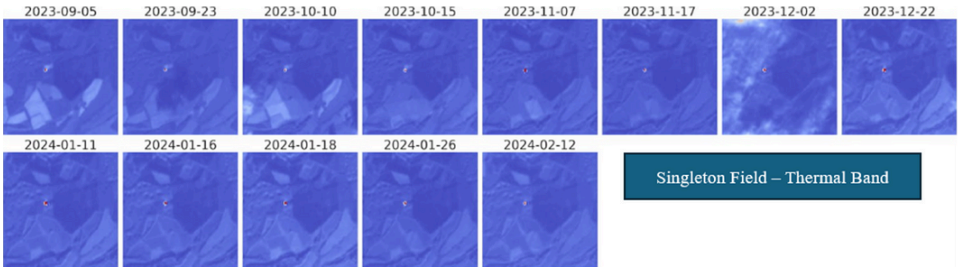
As our opening graphic shows, volumetrically much more methane is wasted in flaring than in emissions and, unfortunately, satellite imagery reveals that most onshore U.K. fields are flaring, some intermittently, some continuously.

This first image shows that whereas there are many significant flares to be seen offshore in the UKCS, there is only one immediately visible onshore - see the small red dot just NW of Southampton/the Solent - and it turns out this is the aforementioned Singleton field in the Weald basin.

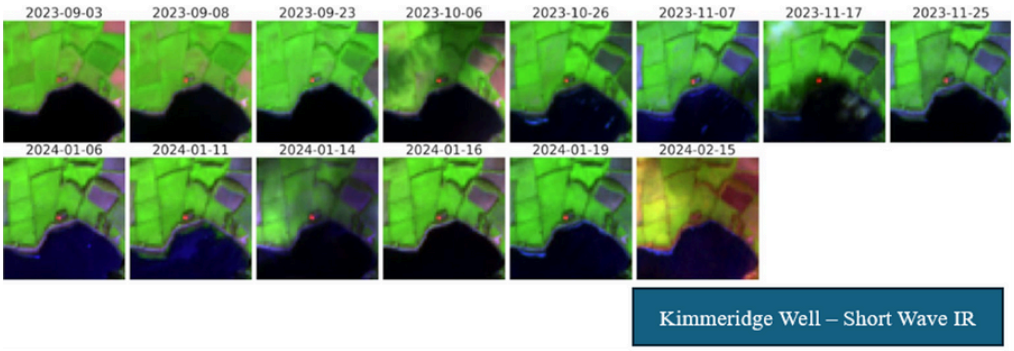


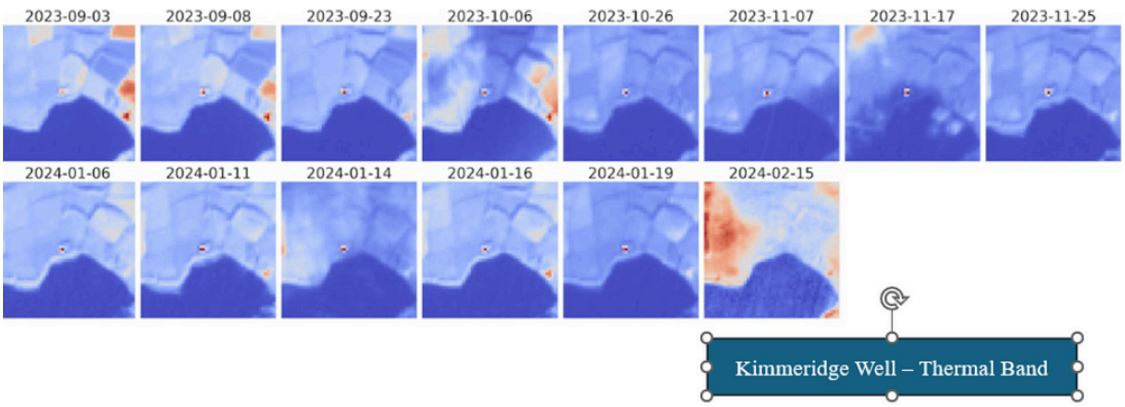
One of the advantages of satellite data is that we can go back several years if we wish: the next image looks at Singleton over just a few months, using both Short Wave Infrared and Thermal Band images - a reasonable interpretation of these images is that flaring has, at least recently, been continuous at this site.



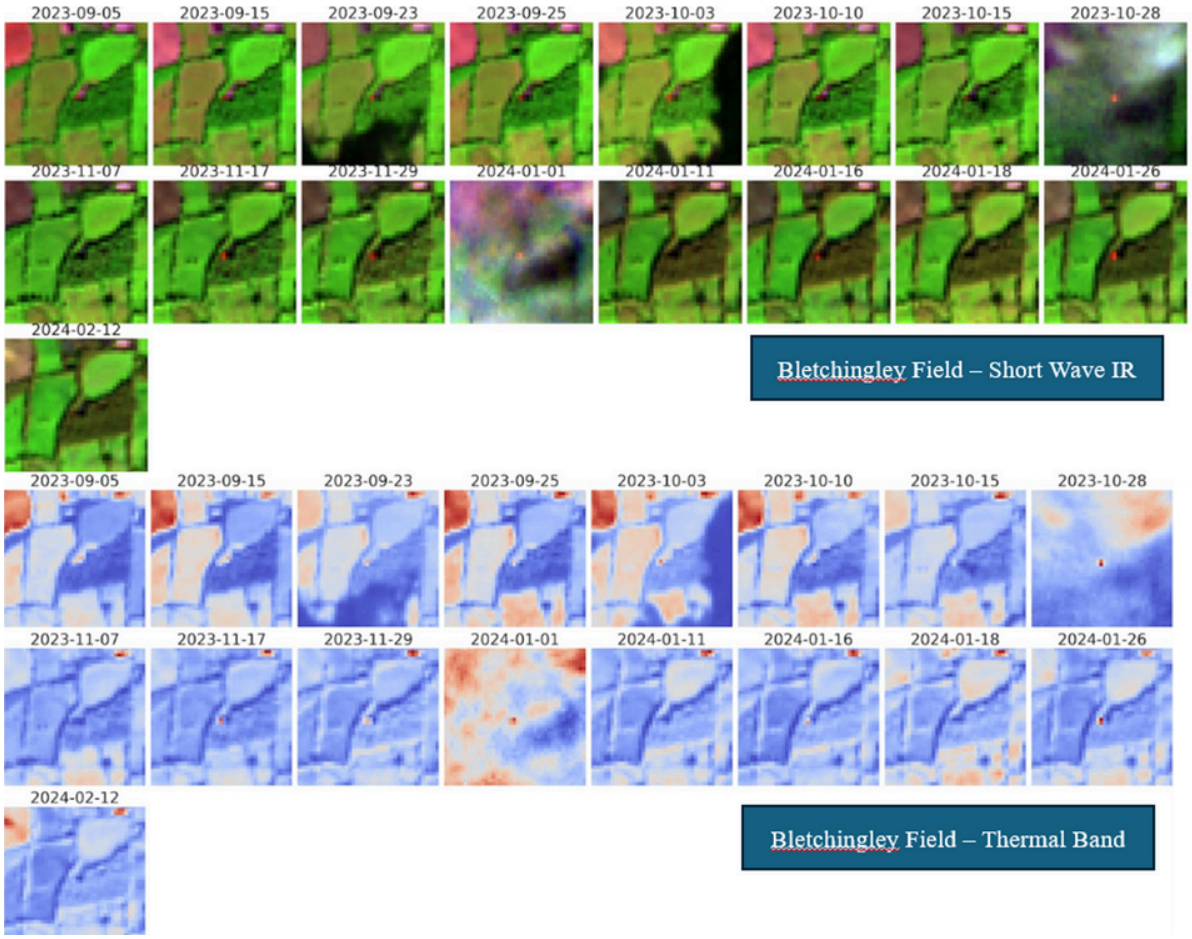


Likewise at the famous Kimmeridge 1 well, in the Wessex basin, this pair of images again demonstrates that, at least recently, flaring has been continuous at this site.





For our final investigation, we head up to the NE corner of the Weald basin, to the Bletchingley field and again we can reasonably interpret these images as indicating that flaring has been occurring at this site, possibly intermittently.



It is worth noting that satellite data covering around the last 10 years can easily be accessed and so the regulator could use it to offer onshore companies 'no hiding place' on flaring.

Their own graphic seems to suggest that they haven't been doing so.....

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(https://climatetrace.org
Weald oil fields still emitting methane
Investigation: "Significant" methane emissions recorded at UK onshore oil sites

SECTION 3

FUGITIVE EMISSIONS FROM THE EU AND UK GAS GRIDS

Our new report leaves little doubt that there are significant volumes of methane emissions from the U.K. and EU gas grids that as yet go largely unmonitored, unmeasured and unreported, both by asset and by operator. Key takeaways are:

1. At least in part, this is due to the limited metrology that is deployed - "walkers" carrying 'sniffers' and optical gas imagers - in contrast to the continually improving satellite sensors targeting 'super emitters' emergent in the USA and Canada, independent inspection to the fore.

2. Cross-Atlantic transfer of these satellite technologies is needed but into an integrated system which includes sensors carried by UAVs, in fixed stations, plus those carried by "walkers".

3. However, a further, major, issue is that the regulatory approaches of the EU Commission and the U.K. Government have allowed operators to police their own emissions, to write their own reports, "mark their own homework".

4. This situation has many parallels with that in the U.K's water industry, highlighted by The Times' Clean It Up campaign(0), from which this quote:

> "Light, it is said, is the best disinfectant. Independent inspection of potentially polluting industries and their impact on the environment should be a given. A company that knows it is liable to periodic monitoring by an outside body should become a cleaner company or face penalties."

Indeed so!

Context

This was an interesting article(1) by Bloomberg (BNEF) summarising their use of satellites to study methane emissions in the Permian Basin.

It sits alongside MethaneSat's report(2) that "oil and natural gas producers across the U.S. are emitting methane into the atmosphere at over four times the rates estimated by the Environmental Protection Agency for those same areas based on industry-reported data. The results also show that operators are exceeding their own widely touted emissions goals eightfold."

However, what I caught my eye in Bloomberg's report was "Compressor stations account for majority of observed releases" and this set me thinking about gas distribution systems, gas grids.

A schematic EU 'Gas Grid'

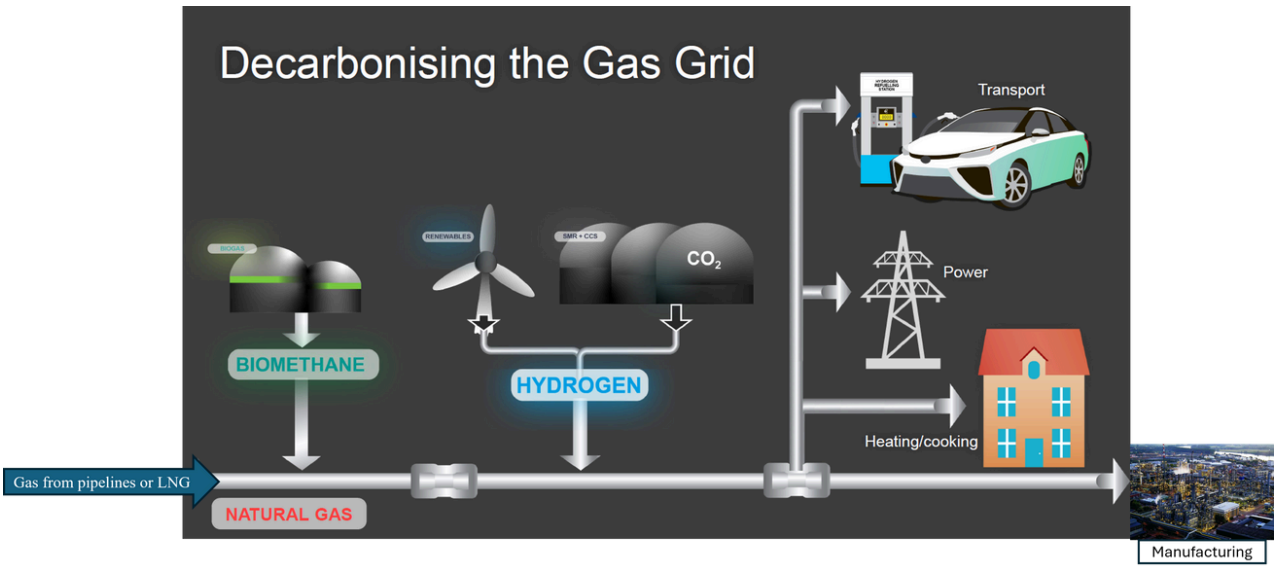
This graphic is a detailed summary of a recently concluded EMPIR project "Decarbonising the Gas Grid", co-funded by the EU's Horizon 2020 research and innovation programme and the EMPIR Participating States - www.decarbgrid.eu.

This is a verbatim description of the intent:

> "This project will be the first large scale project of its kind that will tackle four measurement challenges that the gas industry need to solve before they can decarbonise the gas grid through introduction of biomethane, hydrogen-enriched natural gas, 100 % hydrogen, and carbon capture and storage (CCS). The project will cover the priority challenges within flow metering, gas composition, physical properties and safety (including monitoring of gas leaks)."

Given the sources of funding, I don't think it's unreasonable to assume that the EU Commission will be guided by this work and its recommendations in defining and agreeing its (slowly emergent) emissions legislation, which aims to reduce carbon emissions from its domestic industries.

The question I'm addressing here is what would this mean for individual companies? Below is a slightly modified version of the 'gas grids' graphic which appears above:



I predict two outcomes

1. Every company that sits at a key point in this grid - put simply, every company that sits at one of the arrowheads - will need to provide verified measurements (metrology) on the historic and current flow rates, composition, physical properties and fugitive emissions of the gas they are inputting to the grid.

2. Every company that utilises this gas in some way - to generate power, as feedstock for the chemical industry, to manufacture fertiliser etc etc - will need to be able to look back along its supply chain (in addition to doing its own verified metrology) and account for the carbon emissions therein. Companies supplying gas to the grid - especially via pipeline or LNG - will also need to 'carbon account' along their supply chain.

A particularly difficult aspect to 'carbon account' for will be the leaks and venting from the gas grid itself – as we will see in a moment, there will be 'known unknowns' in both the EU and the UK.

To be clear, this is our guess at the consequences of as yet fully developed EU regulatory plans.

However, as we reviewed(3) in the case of the U.K, politically ambitious plans might have unintended consequences such as EU industries offshoring to countries with less demanding regulatory environments and doing this despite the EU introducing a Carbon Border Adjustment Mechanism – CBAM(4) - to protect domestic industries.

A sub-text here is whether the new U.K. government, seemingly keen to normalise relationships with the EU, adopts similar regulations?

EU realities!

In reality, the EU's Gas Grid - at least until March 2022 - looked like this:

Do compressor stations in this system leak?

Here's a Terrabotics satellite image of methane emissions in Russia, what we might call the 'upstream' part of the EU's system:

I think we can agree that the layout of these emissions 'plumes' is similar to the layout of the actual pipelines, and it's most probable that compression stations are key contributors.

Moving 'downstream' into the EU itself, the folk at the Clean Air Task Force visited many, many gas sites within the EU collecting videos with handheld Flir thermal imagers - you can see them all here(5) - but here's a selection you can view for yourselves from Slovakia, the Czech Republic and (above all) Germany:

GERMANY

- Breitbrunn Compressor Station
- Bunte Compressor Station
- Folmhusen Compressor Station
- Mallnow Compressor Station
- Olbernhau Compressor Station
- Ruckersdorf Compressor Station
- Sidenberg Ost Compressor Station
- Rothenstadt Compressor Station
- Waidhaus Compressor Station
- Visbek K45 Compressor Station
- Voigtei Compressor Station
- Walsrode Compressor and Gas Drying Station

SLOVAKIA

- Kapusany Compressor Station
- Ivankapro Nitre Compressor Station

CZECHIA

- Breclav Gas Compressor Station
- PZP Damborice Gas Compressor Station

Proper metrology on the EU Gas Grid would no doubt reveal the same issues as noted in the USA: measured methane emissions way above what operators report and compression stations in the Gas Grid being a, possibly the, major contributor.

What about the UK?

Earlier we noted(3) that in the case of the U.K, politically ambitious plans might have had unintended consequences such as industries offshoring to countries with less demanding regulatory environments.

Britain's journey towards net zero is a narrative rich with milestones and declarations of environmental leadership. Official figures suggest an impressive halving of greenhouse gas emissions from 800 million tonnes in 1990 to 417 million tonnes in 2022. Such statistics position the UK as a global frontrunner in emission reduction, a narrative strongly endorsed by political leaders.

However, this celebrated decline masks a critical oversight—the "elephant in the room" of Britain's climate strategy: the country's consumption emissions. While the UK's territorial emissions have indeed fallen, this success story overlooks the carbon footprint of all goods imported into Britain, from cars and clothes to food, alongside the emissions from international shipping and aviation.

Research led by Professor John Barrett at Leeds University reveals that the UK's consumption-based emissions present a starkly different picture. As Britain's industries have dwindled, our reliance on imports has surged, significantly inflating our overseas carbon footprint. In 1990, these emissions were under 200 million tonnes of CO2 annually, but today they oscillate between 350 and 400 million tonnes—a figure that threatens to surpass the UK's domestic emissions.

The reality is that Britain's net reduction in emissions, when accounting for imports, is far from the 50% reduction often cited. Instead, the true figure, adjusting for exports, suggests a carbon footprint closer to 750 to 800 million tonnes. This adjustment paints a less rosy picture of Britain's climate achievements, challenging the narrative of a nation leading the charge towards net zero.

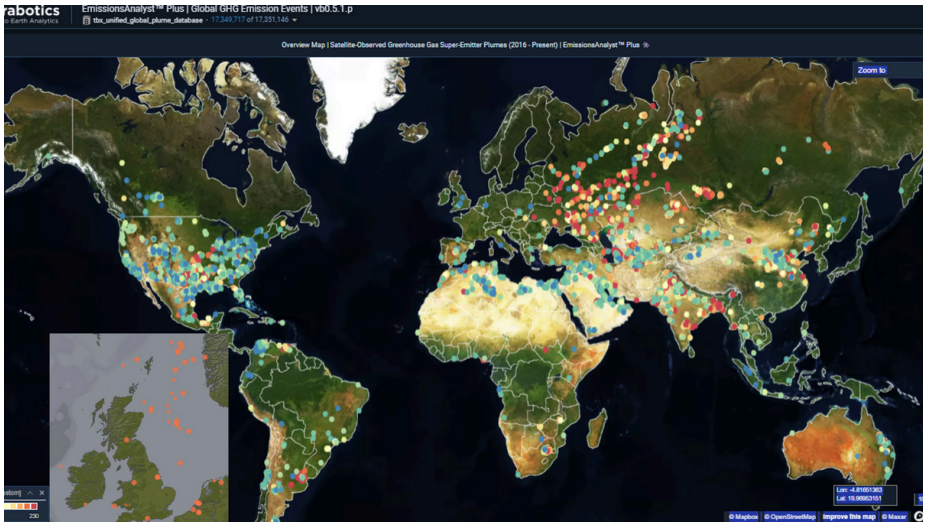
Thus, one flip side of the U.K's much vaunted plummeting emissions is that they are at least in part caused by such offshoring.

A second is that most of what is reported is in fact estimated - not measured - and that the reports in any case disappear into the high level statistics maintained first by BEIS, now DESNZ - with by-asset details unavailable, as somebody said, digging them out, is like trying to find a duck that has been swallowed by a crocodile!

Turning to the U.K.'s Gas Grid - see below - this makes it nigh on impossible to understand methane, or indeed any other, emissions at the level of a gas terminal or compressor station.

What can we observe from satellites - ‘top down’ if you will?

Below is a Terrabotics image of methane ‘plumes’ observed from 2016 until recently, displaying images from GHGSat, Carbon Mapper and SORN. What is immediately apparent is that there are no more than 2 or 3 observations in the U.K. compared with the many many in the USA, Russia, SE Asia…..



Another source of information is Climate Trace data – ‘bottom up’ this is a combination of reported/estimated emissions; their image for 2022 for methane emissions in the U.K., Ireland, Norway, Belgium and the Netherlands is shown in the lower left of the above display. Offshore installations show up and refineries too but of the U.K. Gas Grid itself, the terminals eg Bacton and St Fergus that receive gas from offshore, the LNG terminals at Milford Haven and on the Isle of Grain, the Interconnectors from Bacton to Belgium and the Netherlands and from Moffat/Beatock to Northern Ireland and Ireland - absolutely no sign at all.

So either, and miraculously, these facilities don’t leak at all or data is not collected and/or is not reported.

Well, let’s back up a little and reveal that of the emissions shown above, just one of the U.K. ‘plumes’ relates to leakage from an underground pipeline, in Gloucestershire, observed by GHGSat in April-May 2023 - here’s an image:

In addition, the CATF folk that worked around Germany, Slovakia, the Czech Republic - see above - visited the U.K. during their fieldwork.

Here are some of the sites they observed, you can see their Flir images if you click on the text:

- Blyborough to Cottam Gas Pipeline
- Bacton Gas Terminal
- Kirton Lindsay Loc No 7
- Kings Lynn Compressor Station
- Hatton Compressor Station
- Cambridge Compressor Station
- Chelmsford Compressor Station

What does this mean?

Manifestly, the UK Government's and the EU Commission's strategies for monitoring and measuring methane emissions and reporting the results – for metrology – are not working. As in this UK Environment Agency document(6), the strategies are based on 'sniffers' and Optical Gas Imagers; these are 'dated' technologies which are being supplemented and replaced in the USA by increasingly high resolution satellites, supported by accurate cameras such as QLM's quantum LiDAR(7) – perhaps one will soon be flying on UAVs.

As the Bloomberg article(1) notes: "The BNEF analysis is one of the first to attribute hundreds of individual methane observations from satellites to individual assets and operators."

It won't be the last……..

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SECTION 4

LEAKAGE AND ODOURS FROM LANDFILLS

Landfills are an eyesore, attractive only to seagulls, and – as we document in our new report – unpleasant (at least) for our environment. Key takeaways are:

1. Landfills are a significant source of air pollution - **locally** because of odours from leachates, **globally** because of emissions of methane.

2. As with the Gas Grid, 'Known unknowns' – fugitive emissions from the EU and U.K. gas grids, the regulatory approaches of the EU Commission and the UK Government have allowed operators to "mark their own homework". As a result, the **Known Unknowns** are the true volumes of methane emissions and the extent of local 'odour' problems.

3. The technologies to measure, verify and report such pollution are well known, reliable and available.

4. 'Green' technologies to replace the use of landfills are also well known, reliable and available.

What is the problem?

Whilst climate change may seem somewhat distant from peoples' daily experiences, air pollution and water pollution – the latter highlighted by The Times' Clean It Up campaign (0), from which this quote:

> *"Light, it is said, is the best disinfectant. Independent inspection of potentially polluting industries and their impact on the environment should be a given. A company that knows it is liable to periodic monitoring by an outside body should become a cleaner company or face penalties."*
>
> - are not.

One of the more comprehensive reports(1) on air pollution emanated from the Share Action Group earlier this year; their list of harmful air pollutants affecting human health included particulate matter, ozone, sulphur oxides, nitrogen oxides, VOCs (volatile organic compounds) and carbon monoxide, sourced from a wide range of activities – transportation, mining, oil & gas production, power generation, manufacturing, agriculture.

My only surprise is that they did not mention Landfills as these are bad for the environment in at least two ways:

Locally they are a source of leachate: this is a liquid formed when landfill waste breaks down and water filters through the waste - it is very toxic because landfill waste contains a vast quantity of harmful substances. Leachate can pollute waterways, land, and groundwater, and brings **local** air pollution, usually reported in the form of 'bad odours' (predominantly from hydrogen sulphide) (2)(3)(4)(5)(6).

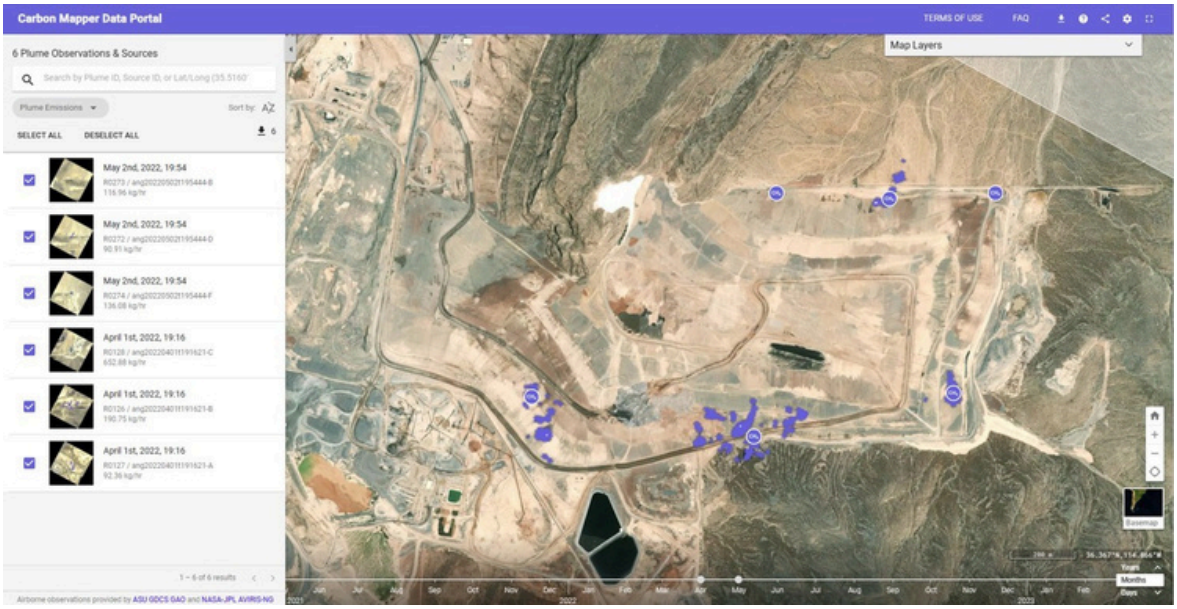
Landfills are a major **global** source of methane because organic waste such as food, garden waste etc goes into them; when a landfill is 'capped' with a membrane and/or a thin layer of clay, this organic waste enters an anaerobic state and generates methane. Such methane is a **global** problem and a mitigation is to use this methane to generate electricity by gathering it for gas engines - this is the 'methane transformation to energy' as much discussed by companies extolling their 'green' credentials. As an example the landfill at Bletchley UK was said - early in 2023 - by the operator FCC Environment Ltd to have ~300 gas wells and to generate 8.5MW of electricity, enough to power 7600 homes.

'Methane transformation to energy' sounds like a great idea to stop emissions from landfills escaping into the atmosphere - the only problem is, it is only partly effective.

Here is Climate Trace's CH4 from Landfills map for 2022; you can see they count a total of over 53 million tonnes from 10314 sources:

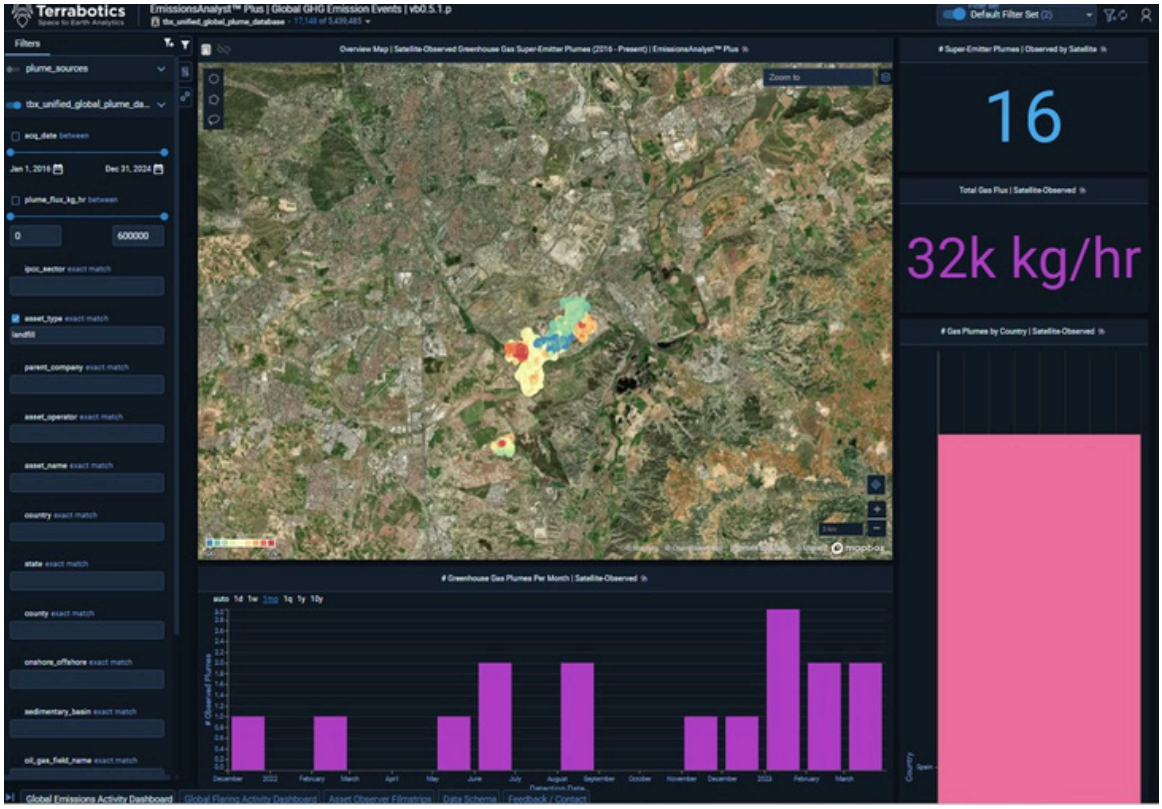
If we look at Terrabotic's display of landfill 'plumes' - remember these are basically 'spot' observations of 'plumes' that are big enough to be seen by satellites or aircraft - there are nearly 1000 in the data base:

Let's look at one site in particular, the Apex Regional Landfill in Nevada as imaged by Carbon Mapper in 2022:



The site is clearly leaking from points around the edges of the ‘capping’ and also through any imperfections in the ‘capping’ such as fissures; in reality the landfill, full of methane, is just a shallow petroleum accumulation - petroleum geoscientists are thoroughly familiar with the concepts of micro-seepage (vertically by diffusion) and macro-seepage (somewhat laterally through faults and fissures). It leaks.

Finally let’s have a look at Spain which shows up with 3 identifiable landfill locations in the above Terrabotics image. The best studied site is just outside Madrid, sort of in its SW suburbs:

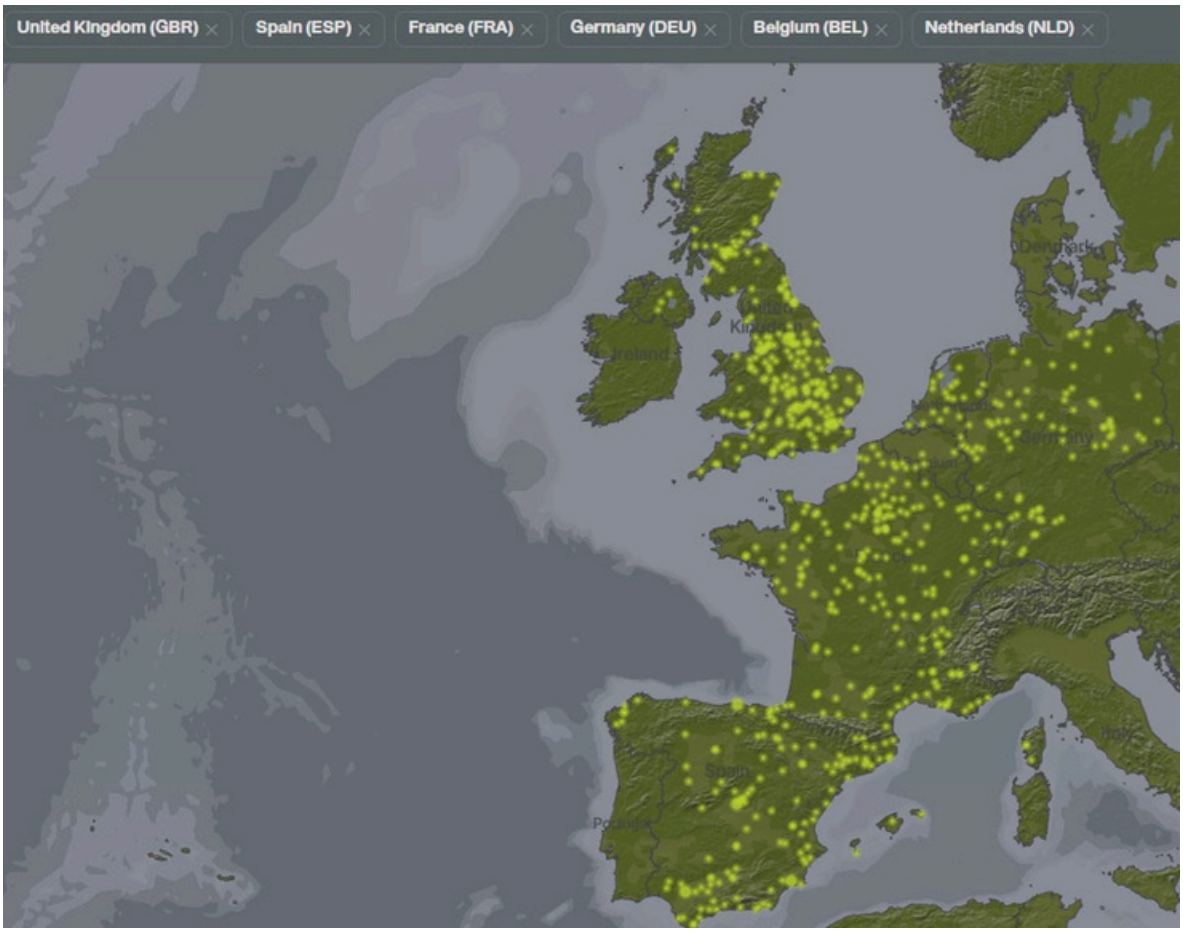


You can see that 16 ‘spot’ observations have been made, by GHGSat; typical volumes are of several tonnes of methane emissions/hour, 4.3k kg per hour for one ‘plume’.

What does this add up to?

That continuing to dump non-recyclable waste including food, garden waste etc into landfills and attempting to mitigate the environmental impact by partially combusting the methane is only partly successful.

Whilst some landfills are what are known as Super Emitters - for example the one just outside Madrid, see above - there are many that emit relatively small amounts - but a few tonnes here and a few tonnes there soon add up to significant volumes - see the many Spanish sites in this Climate Trace image for example:



and also those in the UK, France, Belgium, Netherlands, Germany……

This range or diversity of 'targets' tells us about the metrology that is needed to measure, verify and report such emissions. Yes, the Super Emitters can be imaged by satellites but the many, many smaller leaks need low flying aircraft ie UAVs working in coordination with fixed stations.
Meanwhile, I'm glad I don't live in the SW of Madrid!

Finally, on a more serious note, how are the EU and U.K. Regulators dealing with this?
The impression is, as with the UK's rivers, the focus on the air we all breathe is 'light touch' to the point of invisibility. The actual volume of methane emissions, and the extent of local air pollution from 'odours', are thus **Known Unknown**s.

And yet there are worthwhile alternatives to landfills: available via two 'green' U.K. technologies, namely:

Energy from Waste:
This is the high temperature (>1000deg C) combustion of non-recyclable waste, excluding organic materials, to generate electricity which can be used locally or fed into the grid.

and

Anaerobic Digesters:
These involve separately collecting organic waste, especially food, and subjecting it to anaerobic conditions, producing methane rapidly - said methane resource is then sent to a gas engine to produce electricity (it's also possible to feed the methane into the gas grid).
These technologies work and are reliable – they are **Known Knowns!**

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SECTION 5

FUGITIVE EMISSIONS FROM ANAEROBIC DIGESTERS

Anaerobic Digesters (ADs) are seen as a relatively new, 'green', renewable energy source (of methane) which we review in our latest report. Key takeaways are:

1. ADs produce biogas, typically containing ~60% methane which has to be separated from the other gases, mainly carbon dioxide.

2. In principle this methane can be fed into the UK and EU gas grids alongside LNG and pipeline gas. However, the 'greenest' use will be for local power generation.

3. This methane will be subject to the same UK or EU fugitive emissions regulations as non-renewable methane with a likely focus on 'methane intensity' (emissions volume/produced volume).

4. AD facilities present rather straightforward targets for the measurement, verification and reporting of fugitive emissions using a combination of sensors deployed on UAVs and as fixed stations.

Background on anaerobic digesters

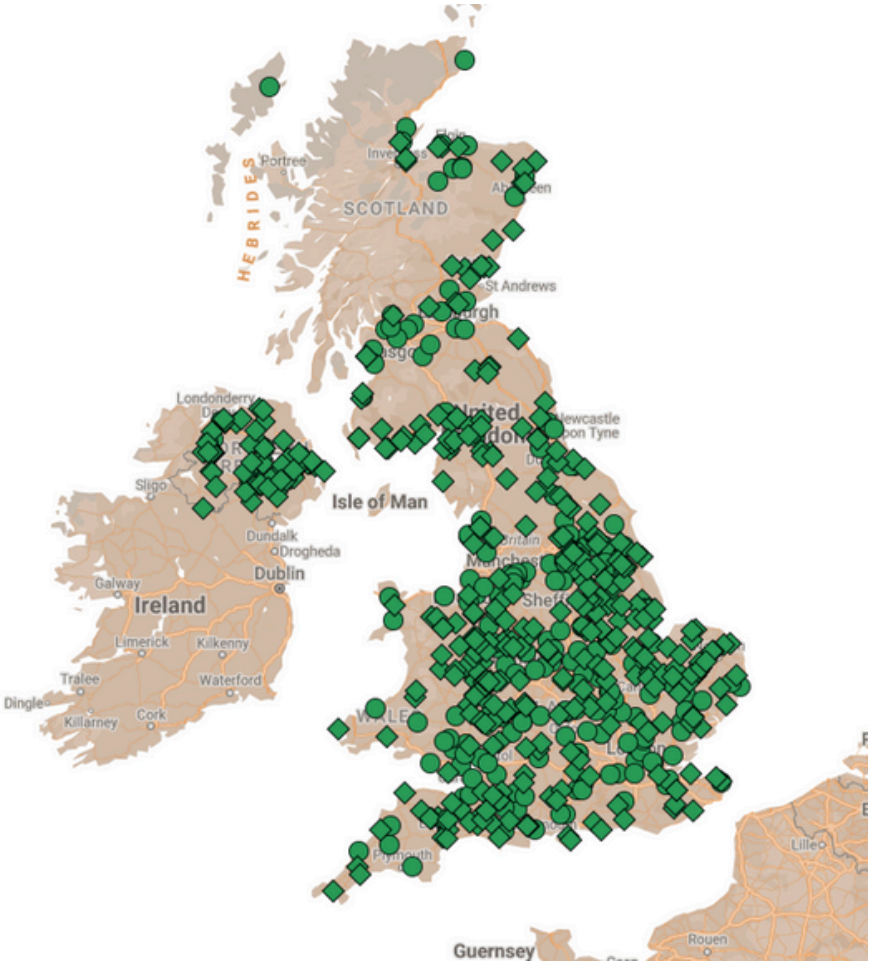
This image summarises something we are increasingly used to in the UK - as householders putting our food waste into a small bin and it being used down the road to fuel an Anaerobic Digester like the one shown (this is in fact the Severn Trent Green Power facility at Benson a mile or so away from our house):

Similar looking facilities sit atop ‘slurry pits’ out in farms up and down the countryside.

As always, we rely completely on what our government has to say(1):

“Certain types of organic waste and purpose-grown crops can be used to produce bioenergy through the process of anaerobic digestion. Anaerobic digestion (AD) is a natural process in which plant and animal materials are converted into useful products by micro-organisms in the absence of air. The process releases biogas, (mainly a mixture of around 60% methane and 40% carbon dioxide) which can be used directly to provide heat, power or transport fuel. Biogas can also be purified by removal of the carbon dioxide to produce biomethane, which can be fed directly into the public natural gas grid in the same way as natural gas, or used as a vehicle fuel. The types of materials suitable for AD include food waste, slurry and manure, crops and crop residues.” Do read on - though you might find it tells more than you need to know!

The Biogas-Info website(2) includes a very useful map and summary for the very large number of Anaerobic Digesters (ADs) that operate in the U.K:



and notes that facilities can be filtered by the following categories:

- **Agricultural** – plants that use predominantly agricultural feedstock such as manures, slurries, crops and crop residues. These are shown by diamonds on the map,
- **Waste** - plants that use predominantly municipal, commercial and industrial waste streams as feedstock. These are shown by circles on the map.

Each is then further categorised by the end-use of the biogas:

- **Heat and/or power** – an anaerobic digester generating biogas which is burned on-site to generate heat, power or both.
- **Biomethane to grid** – an anaerobic digester generating and upgrading biogas, to derive biomethane for injection into the national gas grid.

As summarised in our earlier article(3) on the EU and UK Gas Grids, these facilities will likely be subject to the same regulations as for example LNG flowing through the grid, namely:

1. Every company that operates an AD to generate gas will need to provide verified measurements (metrology) on the historic and current flow rates, composition, physical properties and fugitive emissions of the gas they are inputting to the grid.

2. Every company that utilises this gas in some way - to generate power, as feedstock for the chemical industry, to manufacture fertiliser etc etc - will need to be able to look back along its supply chain (in addition to doing its own verified metrology) and account for the carbon emissions therein. Companies supplying gas to the grid - especially via pipeline or LNG - will also need to 'carbon account' along their supply chain.

A particularly difficult aspect to 'carbon account' for will be the leaks and venting from the gas grid itself(3) - there will be 'known unknowns' in both the EU and the UK.

What does this mean?

Some preliminary thoughts:

1. Biogas is not just combustible methane; there's a 'removal of carbon dioxide' issue.

2. The way ADs are covered suggests that fugitive emissions will be much less of an issue than for landfills(4) where the weak capping process may result in relatively high 'methane intensities'.

3. This latter advantage may be negated if the biomethane is just fed – after significant compression - into the leaky(3) U.K. (or EU) gas grids for transport over long distances. Local power generation may be the best option.

Is there any data that indicates the scale of emissions from ADs in the UK or EU?

Interestingly, Climate Trace(5) does not show any data and, unsurprisingly, the individual small emissions are not visible from publicly available satellites.

It should be noted however that in their paper 'Using remote sensing to detect, validate, and quantify methane emissions from California solid waste operations'(6), the Carbon Mapper folk noted that they observed:

'unexpected large emissions from two organic waste management methods (composting and digesting) that were originally intended to help mitigate solid waste emissions. Our results show that remotely-sensed emission estimates reveal processes that are difficult to capture in biogas generation models." This data was from Airborne sensors.....

Monitoring & measuring emissions

This begs the question as to how AD operators can assure regulators and the public that emissions from their facilities are both low and under control? And without spending a fortune on major Airborne surveys.....

I suggest the following combination:

1. UAVs flying vertically directed sensors can survey a typical AD facility in a few hours, surveying the Feedstock=>Digester=>Power Generation system. TDLAS techniques can assist the detection and geolocation of emissions whilst both spectroscopic and LiDAR capabilities will support the accurate measurement of flow rates.

2. UAVs also support returning to known emission sources quickly and efficiently, also allowing the operator to replan missions in real time to meet asset requirements.

3. Fixed sensor stations can be installed to monitor known 'point sources' 24/7/365.

No need for fugitive emissions from Anaerobic Digesters to remain a 'Known Unknown'!

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SECTION 6

HELPING COMPANIES ACHIEVE ENERGY EXCELLENCE

INDEPENDENT AUDIT THROUGH INTEGRATED EMISSIONS MONITORING

For oil & gas asset owners, pipeline/gas grid and landfill operators in the UK and EU, IMMER offers a ‘regulator ready’ independent audit via integrated monitoring and measurement of emissions and flaring using sensors carried by satellites, aircraft (UAVs)and “walkers”, and if - appropriate - from fixed stations.

For Anaerobic Digesters, the modus operandi will depend on whether the AD is delivering methane from ‘slurry lagoons’ or organic waste (mainly food) but our view is that UAVs carrying suitable sensors are the best, indeed the only, way of conducting such surveys.

UAVs flying vertically directed sensors can fully survey any AD facility in a few hours; TDLAS techniques provide the detection and geolocation of emissions whilst both spectroscopic and LiDAR capabilities support the accurate measurement of flow rates.

UAVs also support returning to known emission sources quickly and efficiently, thus allowing the operator to replan missions in real time to meet asset requirements.

At Future Energy Partners we have decades of global experience across the energy sector. We're not like traditional consultants. We're energy professionals who have worked for some of the best-known global energy companies.

We specialise in upstream asset management consulting services, delivering exceptional results. Our work with National Oil Companies (NOCs), Ministries, Governments, Regulators, and International Oil Companies (IOCs) has given us unique insights and a deep understanding of industry dynamics.

The depth of our experience, our collaborative approach, combined with an extensive network of experts, allows us to offer tailored solutions that align with the specific needs of our clients. This experience enables us to design flexible, fit-for-purpose strategies that harmonise the objectives of all stakeholders, ensuring value for money and enhanced performance within budget.

HOW CAN WE HELP

REMOTE METHANE / FLARING SURVEYS

We use satellite technology to deliver remote surveys detecting flaring, flare volumes at offshore including methane leaks at onshore installations, which can then be prioritised for action.

Measurements of temperature and power of individual or clusters of flare stacks can be detected, measured, and analysed daily from satellites supported by a 10-year-old archive. Using state-of-the-art data processing techniques, we can analyse vast volumes of daily thermal infrared sensing data to map and monitor oil and gas flaring activities in any region around the world.

This analysis can be used in all locations of oil and gas infrastructure to infer activity levels and even production rates over time.

3D VISUALISATION FOR LEAK DETECTION AND MAINTENANCE OPPORTUNITIES

For specific offshore operating platforms, we can deliver a 3D visualisation of an operating facility/platform. Our 3D model can be generated in a variety of formats and used to generate all drawings, cross sections, isometrics, or Piping and Instrumentation Diagrams. This provides a comprehensive basis for all future incremental investments and modifications. Through our partner services we can support the certification process of offshore operations.

Furthermore, using a diverse team of surveying, piping, mechanical and process engineers enables us to support clients with high quality engineering and custom solutions that meet the specific needs of aiding companies in their dialog with regulators and other stakeholders. With this in mind, we advise clients on the process flows in their oil and gas plants.

For mature facilities with no meaningful documentation, we can arrange to scan the as- built infrastructure and generate an intelligent 3D model with all relevant information. On this basis, the process can be optimised in close cooperation with the operators using bespoke and innovative methods. This supports operators to increase production and to reach their environmental goals. The innovative methods in precision measurement, laser scanning and building monitoring enable geo-referencing of existing areas, facilities, or units in a high-resolution display.

About David Bamford

An experienced, passionate explorer and geophysicist, David has spent more than 40 years in the oil and gas industry, including 23 at BP and 18 in consulting. Having completed a physics degree at the University of Bristol as well as a PhD in Geological Sciences at the University of Birmingham, David's particular interests focus is skills development, sub-surface problem solving, digitisation and the carbon agenda. Throughout his career he has occupied high-level roles including working as a Non-Executive Director for Tullow Oil, which had exploration success in Uganda, Kenya and Ghana, and Non-Executive Director for Premier Oil, taking the organisation into Brazil and Mexico. These experiences, as well as time spent as Global Head of Exploration for BP and as BP's Chief Geophysicist, have all given David an in-depth knowledge of the oil and gas industry, its challenges, opportunities and how to maximise them.

Connect with us today

Future Energy Partners provide expert service for the full upstream value chain and asset management, offering consultancy that aligns with the latest regulations and policy. In addition to a general introduction to CBAM, we can assist you with:

- digital technology to aid carbon accounting
- measuring methane emissions and flaring
- gas-to-power solutions
- carbon capture and storage assessments.

Our comprehensive expertise in the energy sector allows us to support your projects from concept to completion. To find out how we can help you navigate the evolving energy landscape and achieve your sustainability goals, contact us today.

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