Colorado School of Mines

Payne Institute of Energy Policy

Glossary of Terminology related to Responsible Gas

(Version 5 – March 10, 2023)

Every industry has its own vocabulary. This helps a great deal in discussing operational detail within your group as everyone shares the same context so you can use abbreviations and local terms to make your communications more efficient. But when it comes to communications between different groups these local tribal languages present a barrier to efficient communications. This glossary outlines a number of key terms for the field of Responsible Gas, crossing the discipline gap between oil and gas production operations and data analytics as to create the common understanding needed for correct interpretation of terms. This glossary uses a large number of references which are cited for each definition.

Table of contents:

1. Overview, basic definitions and units

Upstream operations consisting primarily of exploring for, developing, producing, and transporting crude oil and natural as (including liquified natural gas).

Unconventional oil and gas - Unconventional resources are hydrocarbon-bearing units where the permeability and porosity are so low that the resource cannot be extracted economically through a vertical well bore and instead required a horizontal well bore followed by multistage hydraulic fracturing to achieve economic production.

Downstream - The final stage in the oil and gas value chain. Activities include distribution, retail, marketing, product development, and consumption by the end user.

Midstream - A term referring to a stage in the oil and gas value chain following production and preceding distribution. Activities include processing, pipeline transportation, refining and storage.

Gathering - The collection of petroleum products from their extraction point (wells), and their transport to a processing facility. A typical gathering system is highly branched, and consists of small-medium diameter pipelines with medium operating pressures.

Transmission - The transportation of petroleum products from processing facilities to distribution hubs. Transmission systems consist of large-diameter, high-pressure pipelines that transport high volumes of petroleum products across large distances.

API Gravity - The American Petroleum Institute gravity, or API gravity, is a measure of how heavy or light a petroleum liquid is compared to water: if its API gravity is greater than 10, it is lighter and floats on water; if less than 10, it is heavier and sinks.

API gravity is thus an inverse measure of a petroleum liquid's density relative to that of water (also known as specific gravity). It is used to compare densities of petroleum liquids. For example, if one petroleum liquid is less dense than another, it has a greater API gravity. Although API gravity is mathematically a dimensionless quantity it is referred to as being in 'degrees'. API gravity is graduated in degrees on a hydrometer instrument. API gravity values of most petroleum liquids fall between 10 and 70 degrees.

A specific gravity scale developed by the American Petroleum Institute (API) for measuring the relative density of various petroleum liquids, expressed in degrees. API gravity is gradated in degrees on a hydrometer instrument and was designed so that most values would fall between 10° and 70° API gravity. The arbitrary formula used to obtain this effect is: API gravity = (141.5/SG at 60 degF) – 131.5, where SG is the specific gravity of the fluid. https://glossary.oilfield.slb.com/en/Terms/a/api_gravity.aspx

In 1916, the U.S. National Bureau of Standards accepted the Baumé scale, which had been developed in France in 1768, as the U.S. standard for measuring the specific gravity of liquids less dense than water. Investigation by the U.S. National Academy of Sciences found major errors in salinity and temperature controls that had caused serious variations in published values. Hydrometers in the U.S. had been manufactured and distributed widely with a modulus of 141.5 instead of the Baumé scale modulus of 140. The scale was so firmly established that, by 1921, the remedy implemented by the American Petroleum Institute was to create the API gravity scale, recognizing the scale that was actually being used.

Associated Gas - Sweet or sour natural gas that is associated with the production of crude oil or crude bitumen. Often referred to as "solution gas", this gas evolves or "breaks out solution" from crude oil or crude bitumen under specific reservoir or production conditions.

Liquified Natural Gas (or LNG) - Natural gas that has been cooled down to liquid form for ease and safety of non-pressurized storage or transport.

Audit - The verification of an organization's emissions data, practices, or performance by a third party.

Certification - A voluntary initiative that holds participants to binding standards that may include emissions reduction performance targets, use of specific technologies, and adoption of methodologies. Certifications entail an explicit declaration of achievement from the administering organization to the participant.

Commitment - A voluntary initiative requiring participants to pledge efforts towards a goal that is decided upon by a governing body or collectively by participants within a group. Commitments are typically auditable, binding, and focus on achieving future goals.

Mitigation - The amount that emissions are reduced below a baseline.

Voluntary initiative - A coordinated effort managed by an administering organization that enables participants to take standardized voluntary steps towards targeting, achieving, and/or taking credit for emissions reduction

Greenhouse gases: A gas that traps heat in the atmosphere. Those gases, such as water vapor, carbon dioxide, nitrous oxide, methane, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride, that are transparent to solar (short-wave) radiation but opaque to long-wave (infrared) radiation, thus preventing long-wave radiant energy from leaving Earth's atmosphere. The net effect is a trapping of absorbed radiation and a tendency to warm the planet's surface. https://www.eia.gov/tools/glossary/index.php?id=G#greenh_gases

In an oil field, oil is almost always associated with a certain quantity of natural gas: newer oil wells are equipped for the recovery of both natural gas, natural gas liquids and crude oil and hence the gas is an additional resource of the oilfield. In some basins, natural gas is the primary hydrocarbon resource. However, the recovery of natural gas presumes that there are the transportation infrastructures and markets available. When the quantity of gas recovered from the oilfield as a "secondary" product is limited, economic solutions maybe not exist. Hence the problem arises of what to do with the associated gas.

Hydrocarbon - A naturally occurring organic compound comprising hydrogen and carbon. Hydrocarbons can be as simple as methane [CH4], but many are highly complex molecules, and can occur as gases, liquids or solids. The molecules can have the shape of chains, branching chains, rings or other structures. Petroleum is a complex mixture of hydrocarbons. The most common hydrocarbons are natural gas, oil and coal.

Natural Gas - Natural gas is a naturally occurring and flammable hydrocarbon gas that is used for fuel. Its primary component is methane, but it can also contain ethane, propane, butane, and pentanes. Often, impurities including oxygen, hydrogen sulfide (H2S), nitrogen, water, and carbon dioxide (CO2) are also present.

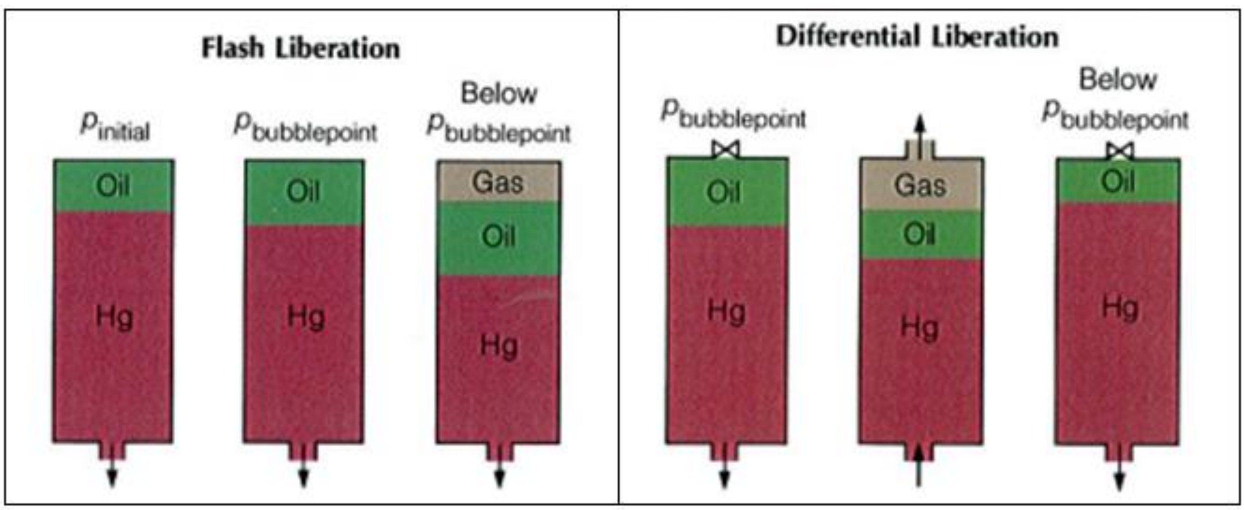
Methane - A colorless, odorless gas that occurs abundantly in nature and as a product of certain human activities. Methane is the simplest member of the paraffin series of hydrocarbons and is among the most potent of the greenhouse gases. Methane is a chemical compound with the chemical formula CH_4. It is a group-14 hydride, the simplest alkane, and the main constituent of natural gas. The relative abundance of methane on Earth makes it an economically attractive fuel, although capturing and storing it poses technical challenges due to its gaseous state under normal conditions for temperature and pressure.

Carbon Dioxide - Carbon dioxide (chemical formula CO2) is an acidic colorless gas with a density about 53% higher than that of dry air. Carbon dioxide molecules consist of a carbon atom covalently double bonded to two oxygen atoms. It occurs naturally in Earth's atmosphere as a trace gas. The current concentration is about 0.04% (412 ppm) by volume, having risen from pre-industrial levels of 280 ppm. Natural sources include volcanoes, forest fires, hot springs, geysers, and it is freed from carbonate rocks by dissolution in water and acids. Because carbon dioxide is soluble in water, it occurs naturally in groundwater, rivers and lakes, ice caps, glaciers and seawater. It is present in deposits of petroleum and natural gas. Carbon dioxide has a sharp and acidic odor and generates the taste of soda water in the mouth. However, at normally encountered concentrations it is odorless.

As the source of available carbon in the carbon cycle, atmospheric carbon dioxide is the primary carbon source for life on Earth and its concentration in Earth's pre-industrial atmosphere since late in the Precambrian has been regulated by photosynthetic organisms and geological phenomena. Plants, algae and cyanobacteria use energy from sunlight to synthesize carbohydrates from carbon dioxide and water in a process called photosynthesis, which produces oxygen as a waste product. In turn, oxygen is consumed and CO2 is released as waste by all aerobic organisms when they metabolize organic compounds to produce energy by respiration. Since plants require CO2 for photosynthesis, and humans and animals depend on plants for food, CO2 is necessary for the survival of life on earth.

Gas to Oil ratio (GOR) - When oil is produced to surface temperature and pressure it is usual for some natural gas to come out of solution. The gas/oil ratio (GOR) is the ratio of the volume of gas ("scf") that comes out of solution to the volume of oil — at standard conditions. The GOR is a dimensionless ratio (volume per volume) in metric units, but in field units, it is usually measured in cubic feet of gas per barrel of oil or condensate.

Bubble Point Pressure – Hydrocarbon bubble point is the pressure at which a pressurized hydrocarbon liquid will become oversaturated with respect to the amount of entrained gas dissolved in it. The bubble point pressure, also known as the saturation pressure, is the pressure, at some reference temperature, that the first bubble of gas is liberated from the liquid phase. The reference temperature is usually the reservoir temperature, but any temperature can be used. The bubble point pressure is determined by an experiment called "Constant Composition Expansion" (CCE), also called: "flash liberation". The device used to perform this experiment is the PV cell,



https://production-technology.org/tag/bubble-point-pressure/

Reid Vapor Pressure (RVP) - Reid vapor pressures (RVPs) are sometimes specified by crude oil purchasers, particularly if the crude is to be transported by tanker or truck prior to reaching a processing plant. Purchasers specify low RVPs so that they will not be paying for light components in the liquid, which will be lost due to weathering. RVP is used to characterize the volatility of gasolines and crude oils. The RVP of a mixture is determined experimentally according to a procedure standardized by the American Society for Testing Materials at 100 °F (37.8 °C). A sample is placed in a container such that the ratio of the vapor volume to the liquid volume is 4 to 1. The absolute pressure at 100 °F (37.8 °C) in the container is the RVP for the mixture.

Pour Point – The pour point is defined as the lowest temperature at which the sample will flow. It indicates how easy or difficult it is to pump the oil, especially in cold weather. It also indicates the aromaticity or the paraffinity of the crude oil or the fraction. Pour point represent the lowest temperature at which oil is capable of flowing under gravity. A lower pour point means that the paraffin content is low. Pour points for the whole crude and fractions boiling above 232 degrees C are determined by standard tests like ASTM D97. When temperature is less than the pour point of a petroleum product it cannot be stored or transferred through a pipeline.

BOE - A barrel of oil equivalent (BOE) is a term used to summarize the amount of energy that is equivalent to the amount of energy found in a barrel of crude oil, natural gas liquids and natural gas. Natural gas volumes are converted to barrels based on energy content. By encompassing different types of energy resources into one figure, analysts, investors, and management can assess the total amount of energy the firm can access. This is also known as crude oil equivalent (COE).

Many oil companies produce both oil and gas, among other petroleum products, but the unit of measure for each is different. Oil is measured in barrels and natural gas is measured in billions of cubic feet (BCFE). To help facilitate like-for-like comparisons, the industry standardized natural gas production into "equivalent barrels" of oil. One barrel of oil is generally deemed to have the same amount of energy content as 6,000 cubic feet of natural gas. So, this quantity of natural gas is "equivalent" to one barrel of oil. BOE can be compared with natural gas equivalent, which translates the energy in an amount of oil (or other energy product) into that of gas.

Converting assets to BOE is fairly simple. In terms of volume, oil is represented per barrel, and natural gas is represented per thousand cubic feet (Mcf). There are 42 gallons (approximately 159 liters) in one barrel of oil. The energy contained in a barrel of oil is approximately 5.8 million British thermal units (MBtus) or 1,700 kilowatt-hours (kWh) of energy. This is an approximate measure because different grades of oil have slightly different energy equivalents. One Mcf of natural gas contains approximately one-sixth of the energy of a barrel of oil; therefore, 6,000 cubic feet of natural gas (6 Mcf) have the energy equivalent of one barrel of oil. For large quantities of energy, BOE can be represented at kilo-barrels of oil equivalent (kBOE), which is 1,000 BOE.

https://www.investopedia.com/terms/b/barrelofoilequivalent.asp

2. Oil and gas industry equipment and operations

Well pad – Once an energy company has taken care of the exploration work, leased the land they are interested in drilling on, selected the initial drilling sites and has applied for and received their drilling permits they can begin to prepare a site for the drilling process, referred to as the well pad. The site preparation work itself may take several months and cost several hundred thousand dollars to construct pending on how much earth-moving work needs to be completed for the well pad.

The area needed for a well pad which typically ranges from 5-10 acres in size, depending on how many wells may ultimately be drilled on it, which may be just one or more than twenty. Where the topography is more sloped it will likely take more excavation work in order to grade out the well pad, which needs to be flat and stable to accommodate the drilling rig and fracturing equipment. The design of the well pad needs to be consistent with state regulations as described in the previous section, and be engineered to handle stormwater, contain spills while maintaining slope stability. In addition, environmental factors such as the presence of wetlands, proximity to surface water, and sensitive wildlife habitat need to factored into the site selection and construction process to minimize any impacts. https://www.e-education.psu.edu/earth109/node/941

Computerized maintenance management system (CMMS), also known as computerized maintenance management information system (CMMIS), is a software package that maintains a computer database of information about an organization's maintenance operations. This information is intended to help maintenance workers do their jobs more effectively (for example, determining which machines require maintenance and which storerooms contain the spare parts they need) and to help management make informed decisions (for example, calculating the cost of machine breakdown repair versus preventive maintenance for each machine, possibly leading to better allocation of resources).

Atmospheric Tank - A storage tank in which product is stored at ambient pressure. Atmospheric tanks are designed to operate at pressures less than 0.5 psig.

Combustion - The chemical reaction where a hydrocarbon reacts with oxygen to create carbon dioxide, water, and heat. Energy is obtained from fossil fuels through combustion of the fuel.

Combustion Efficiency - How efficiently a piece of equipment is burning a fuel. Combustion efficiency is an important consideration when estimating emissions, since combustion of natural gas destroys methane and creates carbon dioxide, which has a lower greenhouse potential. Higher combustion efficiencies will result in a higher degree of methane destruction and lower overall carbon intensity.

Completion - The work incorporating the steps taken to transform a drilled well into a producing one. These steps include, but are not limited to: casing the well, cementing the casing, perforating the casing, installing down hole flow control or isolation equipment, hydraulic fracturing or stimulation, and installing a well head with a production tree.

Handheld instrument - A small, portable methane detection instrument that is often used to detect and diagnose leaks at the component scale. Examples include optical gas imaging (OGI) cameras and handheld organic vapor analyzers (OVAs).

Hot Tap - The ability to safely tie into a pressurized system (e.g., pipeline, process piping, pressure vessels, etc.) by drilling or cutting into it while it is on stream and under pressure

Predictive Maintenance and Condition-based Monitoring- Predictive maintenance (PdM) is maintenance that monitors the performance and condition of equipment during normal operation to reduce the likelihood of failures. Also known as condition-based maintenance, predictive maintenance has been utilized in the industrial world since the 1990s.

Yet, in reality, predictive maintenance is much older, although its history is not formally documented. According to Control Engineering, "The start of predictive maintenance (PdM) may have been when a mechanic first put his ear to the handle of a screwdriver, touched the other end to a machine, and pronounced that it sounded like a bearing was going bad."

The goal of predictive maintenance is the ability to first predict when equipment failure could occur (based on certain factors), followed by preventing the failure through regularly scheduled and corrective maintenance.

Predictive maintenance cannot exist without condition monitoring, which is defined as the continuous monitoring of machines during process conditions to ensure the optimal use of machines. There are three facets of condition monitoring: online, periodic and remote. Online condition monitoring is defined as the continuous monitoring of machines or production processes, with data collected on critical speeds and changing spindle positions ("Condition Monitoring of Rotating Machines," Istec International). https://www.reliableplant.com/Read/12495/preventive-predictive-maintenance

Regulators to consider revising natural gas flaring policy | North Dakota News | bismarcktribune.com

Flaring is the controlled burning of natural gas including associated gas in the course of oil and gas operations. An intentional, controlled burning of natural gas that takes place during production and processing. Gas is ignited at the top of a flare stack, creating a characteristic flame. A gas flare, also known as a **flare stack**, is a gas combustion device used in industrial plants (i.e. petroleum refineries), chemical plants, natural gas processing plants, landfills and at oil and gas production sites, both offshore and onshore. Combustible gases are flared most often due to emergency relief, overpressure, process upsets, startups, shutdowns, and other operational safety reasons. Unplanned flaring happens when an unexpected gas volume has to be addressed as a safety issue. Planned flaring happens when the pipeline infrastructure to economically transport the natural gas to market doesn't exist. Natural gas that is uneconomical for sale is also flared. Often natural gas is flared as a result of the unavailability of a method for transporting such gas to markets. The gases are piped to a remote, usually elevated, location and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and steam or air. https://www.eia.gov/tools/glossary/index.php?id=F

The combustion efficiency of a well-designed and operated flare is generally assumed to be greater than 98%, meaning less than 2% of the gas passes through the flare stack unburnt. At the individual flare level, local parameters, such as gas content and quality, flare-design, flow rates, exit velocities and steam use contribute to the overall combustion efficiency. There are currently no straightforward methods to continuously measure or monitor the actual combustion efficiency or destruction and removal efficiency of a flare.

The practice of flaring has resulted in the burning of large quantities of gas with the release of large amounts of carbon dioxide together with sulfur dioxide and nitrous oxide, which have contributed substantially to atmospheric pollution. In order to better understand the scale of the problem, it is sufficient to observe nocturnal images of Earth from space: the gas flaring activity in regions corresponding to the major petroleum-producing areas are a proof that cannot go unnoticed.

Routine flaring is the flaring of gas during normal oil production operations in the absence of sufficient facilities or amenable geology to reinject the produced gas, utilize it onsite or dispatch it to a market.

Routine venting - Routine venting refers to the intentional release of natural gas into the atmosphere from oil and natural gas equipment. This equipment includes (but is not limited to) pneumatic devices, glycol dehydrators, compressor seals, casing vents, and atmospheric tanks.

Flare Management refers to the process of determining the quantity and energy value of flare gas generated within chemical plants, refineries, power plants and oil & gas fields. Flare gas measurement is subject to national and regional environmental regulations and is used for the assessment of environmental taxes and determining the quantity of hydrocarbons and other hazardous gases. This measurement is used to prove regulatory compliance. The responsible authorities assess fines to those facilities exceeding regulated volumes which very widely across state and even sometimes county lines. Because of this new visibility and pressure, producers have a very practical incentive to measure flare emissions as demonstrably accurate as possible, across the volumetric range potential of their applications, and being able to verifiably report those results to the appropriate authorities as required.

Incinerator or enclosed combustor - Flares are not 100% efficient, and some methane (un-combusted) is emitted during flaring as a result of un-combusted gas being released via the equipment exhaust stream.. Flares cannot be performance tested to guarantee that they achieve the same efficiency as an incinerator or enclosed combustor. Studies suggest that the efficiency of a flare during windy conditions can be as low as 50%. The many components and complex network of small gathering lines in flare are a source of fugitive emissions.

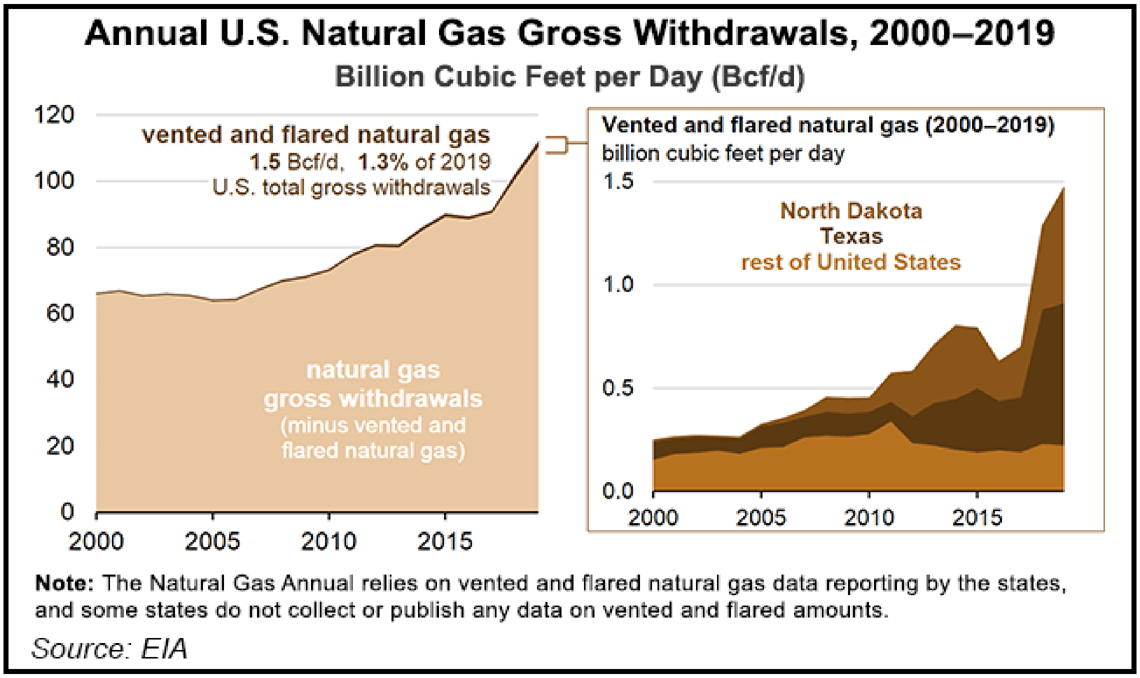
Incinerators are used when flaring is not a viable option. The combustion efficiency of an incinerator is known to be over 99% which is higher than a flare. Plus, they are more suitable for applications involving carcinogenic gases like BTEX and H_2S applications. Incineration of waste gas products may not be a new concept for the oil and gas industry however, in recent years the design and technology have resulted in optimal performance, increased reliability and reduce capital and operating costs for operators.

An **enclosed combustor** is a newer iteration of the incinerator. The combustion device is completely enclosed except for the combustion air intake and the exhaust discharge. It operates like an incinerator with more restriction to allow it to be able to operate in a reduced spacing capacity. The surfaces exposed to the atmosphere operate below the temperature that would ignite a flammable substance present in the surrounding area. Because of the reduced space capacity all air intakes must be equipped with a flame arresting device as a safety feature to allow the unit to be 10 meters away from wells or operating equipment. https://energynow.com/2021/07/the-differences-between-flares-incinerators-and-enclosed-combustors/

Natural gas venting and leaks are the discharge of unburned gases into the atmosphere, often carried out in order to maintain safe conditions during the different phases of the treatment process. During venting operations methane, carbon dioxide, volatile organic compounds, sulfur compounds and gas impurities are released. In many cases gases that are being vented could be flared. Flaring (combustion) oxidizes methane into CO_2 and water vapor which have a smaller short term environmental impact. Methane has more than 80 times the warming impact of carbon dioxide over the first 20 years after it reaches the atmosphere.

Currently, the above-mentioned practices (flaring and venting) are subject to strong restrictions, both for economic (the gas produced could be sold and consumed rather than wasted!) but especially for environmental reasons. Under the Kyoto Protocol, there are incentives for the construction of plants that have minimum environmental impact and which, at the same time, do not waste precious resources.

In more developed countries, this practice has been almost totally abandoned because it is a waste of an important resource and the infrastructures required to utilize the gas in situ are not difficult to implement. On the contrary, in many developing countries the gas is often not required at the production site and the costs of transportation are very high. For this reason, there are incentives to implement practices that are more feasible and less costly such as, for example, natural gas reinjection into the reservoir to increase its pressure and consequently its efficiency, small-scale natural gas liquefaction plants on the production site, the generation of electricity in situ, the distribution of natural gas to neighboring urban areas, its use for transportation, etc. while costly operations, such as the construction of pipelines, are carried out only when the natural gas extracted justifies the high costs. (www.eniscuola.net/en/argomento/natural-gas1/environment-and-territory1/gas-flaring-and-gas-venting/)



https://www.naturalgasintel.com/lower-48-natural-gas-venting-flaring-reached-record-high-in-2019-eia-says/

The flaring intensity in most of the Permian basin drops from about 5% to 1.6% in the fourth quarter of 2020 - the lowest level for eight years. The huge drop is attributed first, to stalled production of oil and gas for several months during which time the price of oil dropped to zero. https://www.forbes.com/sites/ianpalmer/2021/01/29/profit-and-loss-from-flaring-of-natural-gas-in-permian-basin-wells-of-new-mexico/?sh=4544ca7778bf

In 2021, the IEA reduced its estimate of average flaring efficiency to from 98 per cent to 92 per cent, which meant that flaring resulted in emissions of more than 500 MT CO2e in 2020.60 Satellite data from Capterio's FlareIntel Portal suggests that for individual countries, the combustion rate for flares may be closer to 90 per cent.61 If 8–10 per cent of flared gas is vented methane, this results in a much higher level of equivalent carbon dioxide emissions.

The Colorado Oil and Gas Conservation Commission (COGCC) has voted to adopt new rules to eliminate the practice of routine flaring at new and existing wells across the state. The rules will be formally adopted after a procedural vote. Routine flaring occurs when operators burn off natural gas produced from oil wells instead of capturing it and selling it or otherwise putting it to beneficial use. Operators in Colorado currently waste nearly

$12 million worth of natural gas annually through venting and flaring, resulting in hazardous air and climate pollution.

This move makes Colorado the first in the lower 48 to put a stop to the practice of routine flaring, and comes as other oil and gas producing states such as New Mexico and Texas face increasing pressure from investors and companies to zero out routine flaring, while recent surveys have found flaring to be an outsized source of climate-warming methane emissions. https://www.edf.org/media/groundbreaking-move-colorado-ends-routine-flaring

Leaks versus Vents - While definitions vary across regulatory jurisdictions, emissions are categorized as **leaks** if they were a result of component malfunction or emissions from equipment with control devices. **Vents**, on the other hand, include pneumatic devices in normal operations, open-ended lines, abnormal emissions from vent sources (e.g. open thief hatches from an uncontrolled tank battery) and other equipment that emit methane by design. (Large-Scale Controlled Experiment Demonstrates Effectiveness of Methane Leak Detection and Repair Programs at Oil and Gas Facilities, Wang, Barlow, Funk, Robinson, Brandt and Ravikumar, 2020)

Emissions from leak sources can be addressed through maintenance programs. Emissions from vent sources must be addressed through different facility designs. Leaks can come from either operational causes or fugitive causes:

Operational emissions - Some flaring and emissions are essential for safety and maintenance reasons, particularly at the start of operations, during repair or in sudden shutdowns. Here the solutions are better design, process optimization or equipment upgrades. But the more important problem globally is routine flaring and super-emitter sites. That means burning off gas that is found when drilling for oil rather than using, reinjecting or selling it – and it points to the crux of the issue which is a lack of infrastructure, regulations, markets and incentives. When these are not in place, it's far simpler and cheaper to flare the gas – or even worse, vent it – than find a way to use or sell it. https://www.ogci.com/talking-transition-putting-a-stop-to-flaring/

Fugitive emissions are leaks and other irregular releases of gases or vapors from a pressurized containment - such as appliances, storage tanks, pipelines, wells, or other pieces of equipment - mostly from industrial activities. In addition to the economic cost of lost commodities, fugitive emissions contribute to local air pollution and may cause further environmental harm. Common industrial gases include refrigerants and natural gas, while less common examples are perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride.

Most occurrences of fugitive emissions are small, of no immediate impact, and difficult to detect. Nevertheless, due to rapidly expanding activity, even the most strictly regulated gases have accumulated outside of industrial workings to reach measurable levels globally. Fugitive emissions include many poorly understood pathways by which the most potent and long-lived ozone depleting substances and greenhouse gases enter Earth's atmosphere.

> **Blowdown -** The release of gas from processing equipment or pipelines to the atmosphere in order to relieve pressure so that maintenance, testing or other activities can take place.
>
> **Flashing -** Venting that occurs in a storage tank when the pressure of liquid with entrained gas drops and lighter compounds dissolved in the liquid are released/vented off.
>
> **Flash Gas** – the gas that is released from a pressurized hydrocarbon liquid during depressurization, remains one of the most substantial sources of fugitive GHG and VOC emissions at onshore production sites. Flash Gas emissions remain some of the most complicated to quantify. Compositional analysis of pressurized hydrocarbon liquids are key data sets used to characterize flash gas properties such as gas-to-oil ratio in process simulation models.

Surface casing vent flow (SCVF) - A condition where fluid or gas is flowing from the surface casing vent assembly. This term is typically used in conjunction with land wells

Well Unloading - To initiate flow from a reservoir by removing the column of kill fluid from the wellbore. Several methods of unloading the well are used, including circulation of lower density fluid, nitrogen lifting and swabbing. The method used will depend on the completion design, reservoir characteristics and local availability. https://glossary.oilfield.slb.com/en/Terms/u/unload.aspx

Methane slip is an event whereby gaseous methane escapes into the atmosphere. This can happen anytime methane is stored, transported, or used. As awareness has grown about methane's feasibility as a greener fuel for the energy transition, so has the attention on methane slip. Even small amounts of methane can be of particular environmental concern due to methane's potency as a greenhouse gas.

Non-routine Venting - Upset, emergency, or intermittent venting of hydrocarbon emissions. This could include emergency process evacuation events.

Fugitive Emissions Management Program (FEMP) - A program that is intended to complement a duty holder's overall emissions reduction strategy by establishing a plan and supporting systems to systematically detect and manage fugitive emissions. This plan includes the systematic detection and repair of leaks, malfunctioning equipment, and surface casing vent flows. Detection of these leaks relies on regular surveys or screenings of sites for fugitive emissions. The term FEMP is characteristic of Western Canada. In the U.S. and elsewhere, the term 'LDAR Program' is often used.

Setback Distance - A setback is the absolute minimum distance that must be maintained between any energy facility (for example, a drilling or producing well, a pipeline, or a gas plant) and a dwelling, rural housing development, urban center, or public facility. Setbacks vary according to the type of development and whether the well, facility, or pipeline contains sour gas. Setbacks prevent populated areas from developing too close to energy facilities and energy facilities from getting too close to people. In other words, setbacks provide a buffer zone between the public and the facility if there is a problem. https://www.aer.ca/providing-information/news-and-resources/enerfaqs-and-fact-sheets/enerfaqs-setbacks

Shut-in The oil or gas well still has capacity, but it is not being produced/extracted. Oil producers sometimes shut-in wells for safety reasons, but by far the most common reason for 'shutting-in' a well is because the cost of extracting the oil or gas is higher than the current market price for the commodity. The state of Colorado Oil and Gas commission defines a shut-in well as a well which is capable of producing but is not presently producing. Reasons for a well-being shut-in may be lack of equipment, market or other.

Abandoned Well Definition depends on jurisdiction. In Canada, abandoned wells have been plugged but where the site has not been fully reclaimed (similar to a plugged well in the United States). In the U.S., abandoned wells are unproductive wells with a known operator but are often confused with orphaned wells. Due to the confusion and multiple definitions, we recommend avoiding use of the term 'abandoned' unless in a specific regulatory context.

Recent studies have investigated methane leakage from abandoned wells in the U.S. The term "abandoned wells" as typically used in published scientific articles and this memo encompasses various types of wells:

- Wells with no recent production, and not plugged. Common terms (such as those used in state databases) might include: inactive, temporarily abandoned, shut-in, dormant, idle.
- Wells with no recent production and no responsible operator. Common terms might include: orphaned, deserted, long-term idle, abandoned.

- Wells that have been plugged to prevent migration of gas or fluids.

Emissions from abandoned oil and gas wells were not included in previous GHGIs. Commenters on previous GHGIs supported including this source, but noted that the current data were limited, and suggested reviewing data that will become available in the future. https://www.epa.gov/sites/default/files/2018-04/documents/ghgemissions_abandoned_wells.pdf

Reclaimed - A site that has been fully reclaimed, including any wells plugged, topsoil replaced if needed, and vegetation re-established.

Remediation - The process by which soil contaminants are managed and removed, and the site is readied for reclamation. In Alberta, this is done following AER and AEP requirements, in the US the work will follow state or federal standards. Contaminated soil may be hauled to a landfill and then replaced with clean soil, or may be treated onsite until it meets regulatory guidelines.

Pneumatic control Valves A control valve is used in the oil and gas industry to regulate the flow rate of the fluid in a pipeline or process (and the related process parameters as pressure, temperature, and level) according to signals managed by a controller. An automated instrument used for maintaining a process condition such as liquid level, pressure, delta-pressure and temperature.

Instrument air - Air that is used to supply pneumatic devices.

Instrument gas - Natural gas that is used to supply pneumatic devices.

What kind of valves are used in oil pipelines?

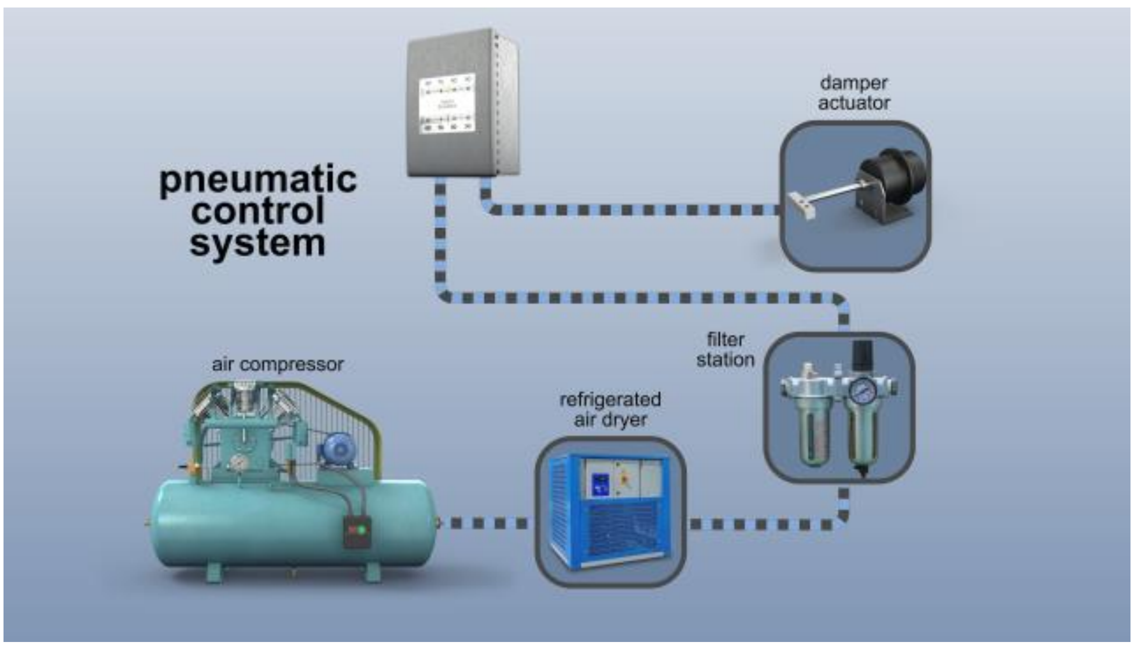
Actuated: the valve is actioned via electromechanical devices, called actuators, that may be electric, pneumatic, hydraulic and gas over oil **GATE VALVE**: This type is the most used in piping and pipeline applications. Gate valves are linear motion devices used open and close the flow of the fluid (shutoff valve).

A pneumatic controller means an automated instrument used for maintaining a process condition such as liquid level, pressure, pressure difference and temperature. Based on the source of power, two types of pneumatic controllers are used:

- Natural gas-driven pneumatic controller means a pneumatic controller powered by pressurized natural gas.
- Non-natural gas-driven pneumatic controller means an instrument that is actuated using other sources of power than pressurized natural gas; examples include solar, electric, and instrument air.

Natural gas-driven pneumatic controllers come in a variety of designs for a variety of uses. For the purposes of this Glossary, they are characterized primarily by their emissions characteristics:

Pneumatic Controllers - Pneumatic controllers are a type of pneumatic instrument used on oil and gas sites. They control conditions such as temperature, pressure, and fluid levels.



Pneumatic instrument - Oilfield equipment powered through pressurized gas (either air or natural gas). They are frequently used when there is no electricity available on a site, and are a known source of methane emissions. Pneumatic instruments are often designed to vent gas with every cycle of their operation, referred to as "bleeding".

Pneumatic pump - Pneumatic pumps are a type of pneumatic instrument. They are used to inject chemicals (such as methanol) into wells and pipelines, or circulate fluids

Continuous bleed pneumatic controllers are those with a continuous flow of pneumatic supply natural gas to the process control device (e.g., level control, temperature control, pressure control) where the supply gas pressure is modulated by the process condition, and then flows to the valve controller where the signal is compared with the process setpoint to adjust gas pressure in the valve actuator. For the purposes of this glossary, continuous bleed controllers are further subdivided into two types based on their bleed rate:

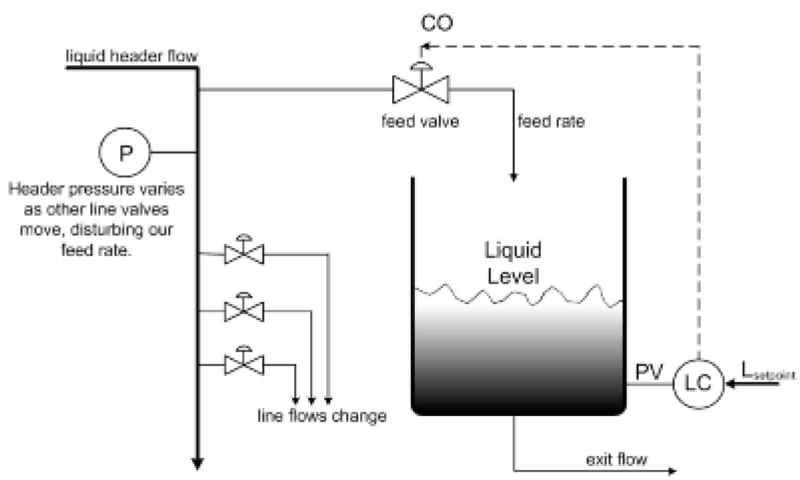
- Low bleed, having a bleed rate of less than or equal to 6 standard cubic feet per hour (scfh).

- High bleed, having a bleed rate of greater than 6 scfh.

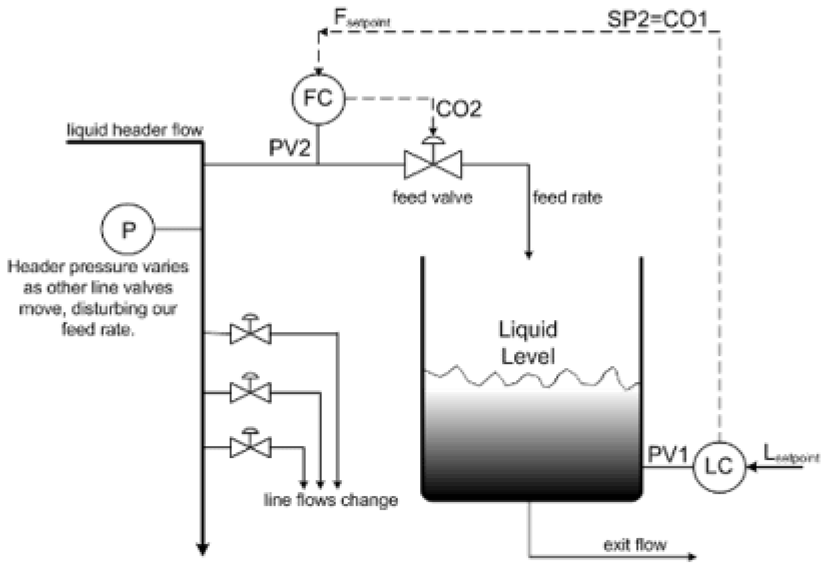
Intermittent pneumatic controller means a pneumatic controller that vents non-continuously. These natural gas-driven pneumatic controllers do not have a continuous bleed, but are actuated using pressurized natural gas.

Zero bleed pneumatic controller means a pneumatic controller that does not bleed natural gas to the atmosphere. These natural gas-driven pneumatic controllers are self-contained devices that release gas to a downstream pipeline instead of to the atmosphere. https://www.ourenergypolicy.org/wp-content/uploads/2014/04/epa-devices.pdf

Concept of a single loop-controlled vs cascade-controlled tank - To better understand the architecture and benefits of Cascade Control it can help to consider it in the context of an industrial process. Shown on the right is a tank system. A shared header supporting multiple lines allows liquid to flow into the tank. Liquid simultaneously exits through a port at the bottom. Using Single Loop Control the tank level is controlled by adjusting a valve and either increasing or decreasing the rate of fluid that flows into the tank. Whereas the exit stream is predictable, the inlet stream from the header can vary dramatically due to changes in pressure associated with demand from other lines. Due to the process 'dynamics the level controller may be unable to respond adequately to such changes in liquid feed. The slow response can result in a level – whether too high or too low – that is either inefficient or even dangerous.



Now consider a similar tank system that employs the cascade control architecture. As before the control objective is to maintain level within the tank. However, a second control loop is effectively "nested" within the architecture outlined above to improve control. Here a secondary flow controller is added that uses the controller output of the level controller as its Set Point. As level shifts within the tank the slower level controller establishes a new Set Point for the faster responding flow controller. Because the flow loop is closer to the disturbance it both experiences and rejects any pressure disturbances before they can have an appreciable impact on the tank's level.



In order to implement cascade control, it is necessary for the process to have access to a secondary control loop that directly influences the primary loop. What's more the dynamics of that secondary loop must be notably faster than the primary loop – a minimum of 3-5 times faster to be precise. The direct influence and faster speed assure that the secondary loop can readily apply a corrective action capable of minimizing the effects of a disturbance. In the example provided the liquid header flow satisfied both criteria.

While the Cascade Control architecture involves only a single Final Control Element, it does require use of a second sensor and a second PID controller. The added investment in those assets along with the time to configure and tune the controllers represent the sum of the costs. On the other side of the ledger, the benefits are measured in terms of performance gains and the associated economic value.

https://controlstation.com/blog/overview-cascade-control/

Pressure relief valve - A pressure relief valve (PRV) is a safety mechanism used to help regulate the pressure in a system. Pressure relief valves are a leading cause of emissions from hydrocarbon storage tanks. As the pressure in these tanks rises, the valve may open, releasing pressure, and in turn, releasing natural gas into the atmosphere. In this sense, PRVs are a source of venting.

Thief Hatch - The purpose of the thief hatch is to work in tandem with the vent valve to minimize the escape of light ends of crude in lease storage tanks by maintaining a pressure on the tank. a vacuum relief function is also standard. the thief hatch permits access to the contents of the tank for sampling and gauging. the vent valve should be set to vent pressure before the thief hatch. https://jayco.org/products-category/jayco-thief-hatch/

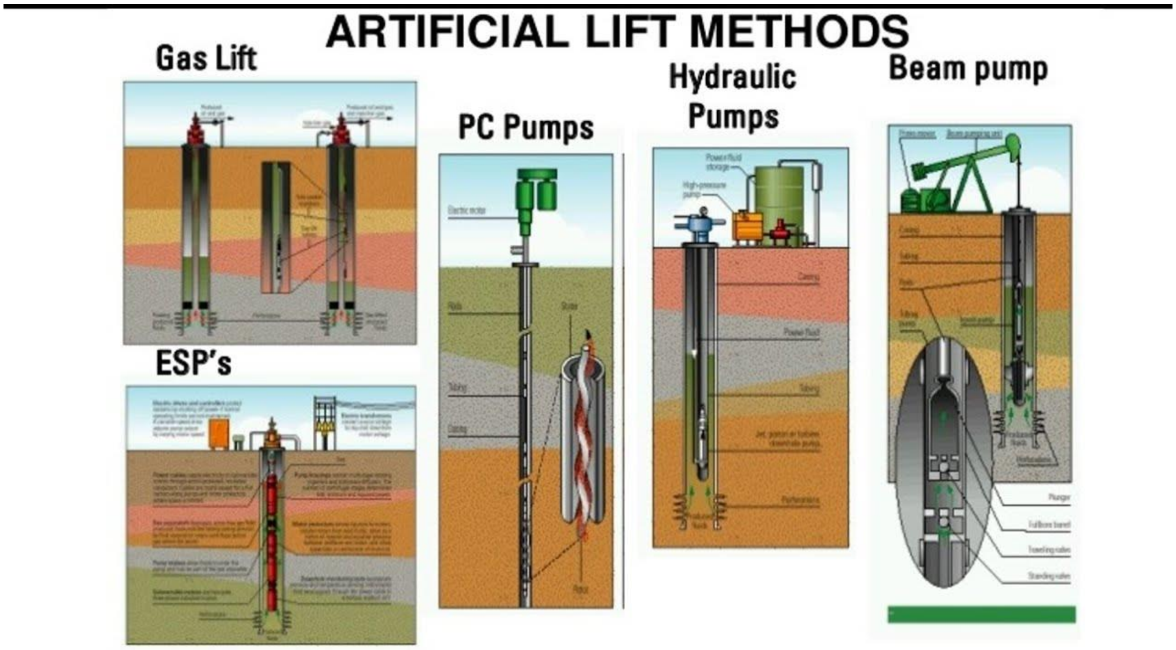
Vapor Recovery Unit (VRU)- Vapor recovery is the process of collecting the vapors of gasoline and other fuels, so that they do not escape into the atmosphere. This is often done (and sometimes required by law) at filling stations, to reduce noxious and potentially explosive fumes and pollution. A Vapor Recovery Unit is an engineered compression package, which aims to lower emissions levels coming from the vapors of gasoline or other fuels while recovering valuable hydrocarbons to be sold or reused as fuel onsite. A package for vapor recovery is designed to capture about 95% of Btu-rich vapors, generating many benefits, guaranteeing less air pollution, and recovering gasoline vapors to be used as fuel. https://www.gardnerdenver.com/en-us/garo/applications/vapor-recovery-units#:~:text=What%20Are%20Vapor%20Recovery%20Units%20%28VRU%E2%80%99s%29%3F%20A%20Vapor,to%20be%20sold%20or%20reused%20as%20fuel%20onsite.

A VRU is often used to compress and recover the vapors for return to the process or collection for sale. Vapor recovery can help oil and gas production companies earn additional revenue through the sale of the recovered vapors and simultaneously meet EPA clean air act requirements. Vapor recovery can help oil and gas production companies earn additional revenue through the sale of the recovered vapors and simultaneously meet EPA clean air act requirements. Currently between 7,000 and 9,000 VRU's are installed in the oil and gas sector with an average of four tanks per recovery unit (EPA, October 2006).

https://www.wika.us/solutions_vapor_recovery_oil_and_gas_en_us.WIKA

Separator - The term separator in oilfield terminology designates a pressure vessel used for separating well fluids produced from oil and gas wells into gaseous and liquid components. A separator for petroleum production is a large vessel designed to separate production fluids into their constituent components of oil, gas and water. A separating vessel may be referred to in the following ways: Oil and gas separator, Separator, Stage separator, Trap, Knockout vessel (Knockout drum, knockout trap, water knockout, or liquid knockout), Flash chamber (flash vessel or flash trap), Expansion separator or expansion vessel, Scrubber (gas scrubber), Filter (gas filter). These separating vessels are normally used on a producing lease or platform near the wellhead, manifold, or tank battery to separate fluids produced from oil and gas wells into oil and gas or liquid and gas.

Artificial Lift - Artificial lift is a process used on oil wells to increase pressure within the reservoir and encourage oil to the surface. When the natural drive energy of the reservoir is not strong enough to push the oil to the surface, artificial lift is employed to recover more production. While some wells contain enough pressure for oil to rise to the surface without stimulation, most don't, requiring artificial lift. In fact, 96% of the oil wells in the US require artificial lift from the very beginning. Even those wells that initially possess natural flow to the surface, that pressure depletes over time, and artificial lift is then required. Therefore, artificial lift is generally performed on all wells at some time during their production life. Although there are several methods to achieve artificial lift, the two main categories of artificial lift include pumping systems and gas lifts.



The most common type of artificial lift pump system applied is **beam pumping**, which engages equipment on and below the surface to increase pressure and push oil to the surface. Consisting of a sucker rod string and a sucker rod pump, beam pumps are the familiar jack pumps seen on onshore oil wells. Above the surface, the beam pumping system rocks back and forth. This is connected to a string of rods called the sucker rods, which plunge down into the wellbore. The sucker rods are connected to the sucker rod pump, which is installed as a part of the tubing string near the bottom of the well. As the beam pumping system rocks back and forth, this operates the rod string, sucker rod and sucker rod pump, which works similarly to pistons inside a cylinder. The sucker rod pump lifts the oil from the reservoir through the well to the surface.

Another artificial lift pumping system, hydraulic pumping equipment applies **a downhole hydraulic pump,** rather than sucker rods, which lift oil to the surface. Here, the production is forced against the pistons, causing pressure and the pistons to lift the fluids to the surface. Similar to the physics applied in waterwheels powering old-fashion gristmills, the natural energy within the well is put to work to raise the production to the surface.

Electric submersible pump systems employ a centrifugal pump below the level of the reservoir fluids. Connected to a long electric motor, the pump is composed of several impellers, or blades, that move the fluids within the well. The whole system is installed at the bottom of the tubing string. An electric cable runs the length of the well, connecting the pump to a surface source of electricity.

An emerging method of artificial lift, **gas lift** injects compressed gas into the well to reestablish pressure, making it produce. Even when a well is flowing without artificial lift, it many times is using a natural form of gas lift.

The injected gas reduces the pressure on the bottom of the well by decreasing the viscosity of the fluids in the well. This, in turn, encourages the fluids to flow more easily to the surface. Typically, the gas that is injected is recycled gas produced from the well.

In the US, the majority of wells, 82%, employ a beam pump. Ten percent use gas lift, 4% use electric submersible pumps, and 2% use hydraulic pumps.

https://www.rigzone.com/training/insight.asp?insight_id=315&c_id=#:~:text=Tweet%20Artificial%20lift%20is%20a%20process%20used%20on,artificial%20lift%20is%20employed%20to%20recover%20more%20production.

Compressor Stations: Used in midstream gas processing and natural gas transportation applications. The pipeline needs to take low volume/low pressure natural gas from the well head and compress the gas to fit into pipeline specs and get the gas to flow down the pipeline.

Compressors used in natural gas transportation system are either positive displacement type or centrifugal type. Positive displacement compressors generate the pressure required by trapping a certain volume of gas within the compressor and increasing the pressure by reduction of volume. The high-pressure gas is then released through the discharge valve into the pipeline. Piston-operated reciprocating compressors fall within the category of positive displacement compressors. These compressors have a fixed volume and are able to produce high compression ratios. Centrifugal compressors, on the other hand, develop the pressure required by the centrifugal force resulting from rotation of the compressor wheel that translates the kinetic energy into pressure energy of the gas. Centrifugal compressors are more commonly used in gas transmission systems because of their flexibility. Centrifugal compressors have lower capital cost and lower maintenance expenses. They can handle larger volumes within a small area compared with positive displacement compressors. They also operate at high speeds and are of balanced construction. However, centrifugal compressors have less efficiency than positive displacement compressors. “Compressor Stations”, E. Shashi Menon, in Transmission Pipeline Calculations and Simulations Manual, 2015

Reciprocating Compressor (or Piston Compressor): The piston compressor, also denoted reciprocating, is a displacement compressor type which consists of a moving piston which compresses the air. It has high efficiency both at full and partial loads, but less positive aspects are that it is noisy and moreover, demands more space than other types of compressors. Also, due to many moving parts in this type of compressor that may wear out, the cost of maintenance is higher than for other compressor types. Piston compressors can come both as oil lubricant free as well as oil lubricant injected compressors.

“Energy efficiency in compressed air, ventilation, and lighting”, Patrik Thollander, ... Jakob Rosenqvist, in Introduction to Industrial Energy Efficiency, 2020

3. Emission measurement technology

Abatement - The use of technologies and operational practices to directly reduce emissions from oil and natural gas systems.

Activity Factor - The population of emitting equipment. For example, activity factor could refer to the mileage of natural gas pipeline, the count of thief hatches on a facility or the mechanical power of gas turbines.

Aggregated Data - Emissions data that has been collected from multiple sources and summarized, usually for the purpose of reporting or statistical analysis.

AVO - Audio, visual, and olfactory (AVO) is a methane detection survey performed using human senses. Regulations often have some form of AVO requirement that is equipment or site specific.

Measurement - Acquiring emissions data directly from the environment at a specific place and time.

Plume - A body of one fluid (natural gas/methane) moving through another (ambient air).

Bottom-up Measurement - A measurement that occurs at a granular scale (e.g., component) that is used to estamiate emissions more broadly. Bottom-up measurements are often averaged into emissions factors and combined with activity factors to build a bottom-up inventory.

Bottom-up inventory – Method based on engineering calculations, manufacturer data and emissions factors for emissions sources/activities and corresponding activities factors. Emissions calculations and factors sometimes including individual source measurements, compiled to develop an account of emissions discharged to the atmosphere from an asset (e.g. a compressor station) or a geographic area (e.g. basin, state, region).

A list of emission sources by category and quantity. Often refers to an aggregate emission rate estimate achieved by multiplying activity factors (counts of components, equipment, or throughput) by emission factors (estimates of gas-loss rates per unit of activity). Most bottom-up inventories use emission factors derived from industry averages rather than measurements specific to the company. Bottom-up inventory emission rate estimates are consistently lower than site-level and regional emissions measurements in academic research.

Bottom-up inventory quantification methodology - Documentation of facility specific details, such as facility process operations, production, and emissions calculations used during a reporting period.

Component - In emissions attribution, a component is the smallest scale of oil and gas infrastructure. Examples include valves, flanges, and threaded connections. Multiple components comprise equipment (e.g., tanks, separators) and a site may have mutliple pieces of equipment or equipment groups.

Comprehensive Monitoring Program - A methane monitoring program that combines screening methods with close-range methods, to diagnose and precisely pinpoint leaking components.

Continuous measurement - Methane detection technology installed at a facility to provide repeated emissions measurements at high temporal resolution. Typical continuous measurement technologies may acquire measurements multiple times per second or multiple times per day.

Controlled Release - Intentional releases of methane at a known location and rate used to test the performance of methane detection and quantification technology. Colorado State University's METEC facility near Fort collins, CO is a well-known testing facility.

Design Emissions - Emissions associated with a piece of equipment or facility under normal operations (operating at design conditions). Includes vented emissions and emissions from incomplete combustion.

Detection - A determination that a source may be present. Typically requires on analysis of one or a series of measured anomalies. Detections can be defined in terms of magnitud and/or duration of elevated mixing ratio or emission rate. For example, a detection event could be defined as an anomaly that reaches an estimated mass emission rate of 5 standard deviations above a 24-hour baseline Unlike an anomoly, a detection is intended to lead to a further action, e.g., follow-up and/or root-cause analysis.

Detection threshold – The minimum quantity or concentration of a gas (e.g. methane) that is reliably detectable by detection equipment. This is sometimes called the minimum detection limit. Detection limits can vary based on the type of technology selected as well as the conditions during the measurement period. Probability of detection is a preferred concept because the minimum is context dependent.

Minimum Detection Limit – The highest flow rate at which a measurement technology is required to detect emissions with 90% probability. Technology with a higher MDL is less sensitve than technology with lower MDL. The MDL is also referred to as the minimum detection threshold. The smallest atmospheric concentration or emission rate that a measurement method capable of discerning above background.

Top-Down Measurements – Methane measurements taken at spatial scales greater than the equipment scale. Typical top-down measurement scales include site, region and basin. In the production segmenet, net emissions from a spatially distinct set of equipment, such as a well-pad, a compressor station, or a central processing facility, or from a set of such facilities. Top-down measurements can also include linear assets such as pipelines, when a pipeline is examined.

Reconciliation – Combining top-down measurements with a bottom-up inventory into an improved emissions estimate. Greenhouse gas emissions can be estimated using emissions factors, measurements, or engineering equations at various spatial and temporal scales. Reconciliation explores whether and why different estimation approaches vary. In some cases, reconciliation can be defined as a methodology for combining multiple different estimates into a single stronger estimate. Greenhouse gas emissions can be estimated using emissions factors, measurements, or engineering equations at various spatial and temporal scales. Reconciliation explores whether and why different estimation approaches vary. In some cases, reconciliation can be defined as a methodology for combining multiple different estimates into a single stronger estimate.

Site-Level Measurements – Methane measurements of the entirety of emissions from individual sites. This can be based on non-continuous "snapshot" technology approaches, which take a measurement at a discrete moment in time and does not automatically repeat at a high frequency: continuous monitoring technologies: or a combination of both.

Measurement-based Inventory – An inventory that contains data from direct site-level measurements of the asset in the inventory. Traditional bottom-up inventories are often not based on site-level measurements but on emissions factors and equipment counts. Examples of site-level measurements are determination o fa single total emission rate for an entire site, such as a compressor station, a well pad, or a central production facility.

A **matching procedure** can be implemented by the test center to pair reported detection data with controlled release data, and to classify each as:

True Positive (TP) - a controlled release and reported detection which were paired.

False Negative (FN) - a controlled release which remained unpaired

False Positive (FP) - a reported detection which remained unpaired.

Continuous Monitoring solutions – A site level detection system that uses autonomous fixed-point monitors to measure ambient air concentrations of methane on the site in order to detect elevated levels of methane emissions. Such a system often includes fied location monitors that may detect in a highly frequent (nearly continuous) fashion. A CM system operates to provide alerts and may or may not have any rate quantification estimates.

Point sensor network: Solution based upon one or more concentration sensors that each sense either methane or hydrocarbons at one point. Analytics combine concentration time series with meteorological data to develop detections.

Scanning/imaging: Solution used a scanning laser - typically LIDAR - or a camera to create 2D images of a portion of the test facility. Analytics combine images (typically a video sequence) with meteorological data to develop detections.

Equipment leak detection is the process of identifying emissions from equipment, components and other points by screening for and detecting fugitive emissions. A screening device may be used to screen a wide area to detect the presence of fugitive methane or vented methane, and a detection device can be used to identify a specific fugitive or vented source of leak. Most detection and screening instruments an ddevices (particularly handheld devices) do not quantify the volume or mass of emissions.

LDAR – Leak Detection and Repair Leak detection and repair (LDAR) refers to U.S. Environmental Protection Agency regulations designed to help reduce volatile organic compounds (VOC) and volatile hazardous air pollutants (VHAP). Leak Detection and Repair is a work practice designed to identify leaking equipment so that emissions can be reduced through repairs. A component that is subject to LDAR requirements must be monitored at specified, regular intervals to determine whether it is leaking. Any leaking component must then be repaired or replaced within a specified time frame. Current regulatory programs require that companies, especially those in petroleum and chemical industries, follow strict LDAR compliance procedures. Its purpose is to reduce and eliminate unintended emissions of liquids and gases. This practice is essential for plants that work with oil, gas, and chemicals. These companies are required by law to implement a thorough LDAR program.

LDAR is particularly concerned with volatile organic compounds (VOC) and volatile hazardous air pollutants (VHAP). By identifying and repairing leaks, companies can promote safety in the workplace, while reducing product losses. These processes can also contribute to environmental efforts by mitigating the release of harmful substances. LDAR technologies include: a gas sensing instrument, optionally configured with a deployment platform and/or ancillary instruments (e.g. anemometers, positioning), that can be used to gather data on emissions.

At operating facilities, emissions consist of non-fugitive emissions, i.e. planned emissions from venting or combusting sources, and unplanned fugitive emissions, caused by process or component failure. The task of the LDAR program is to alert the operator to fugitive emissions while ignoring non-fugitive emissions, which do not require the operator to dispatch personnel to the facility

Specific steps on implementing an LDAR program may be specific to each company. Likewise, government regulations will vary across states. Whatever the circumstances are, LDAR programs have five elements in common.

1. **Identifying components**: Each component under the program is identified and assigned an ID. Its corresponding physical location is verified as well. As a best practice, components can be tracked using a barcoding system to be more accurately integrated with the CMMS (Computerized maintenance management system).

2. **Leak definition**: The parameters that define a leak should be clearly understood by relevant personnel. Definitions and thresholds must be well documented and communicated across the teams.

3. **Monitoring components**: Each identified component should be routinely monitored for signs of leaks. The frequency of checking, also called the monitoring interval, should be set accordingly.

4. **Repairing components**: Leaking components should be repaired within a set amount of time. The first repair attempt is ideally done within 5 days after the leak is detected. For delayed repair work due to any planned downtime, a documented explanation should be provided.

5. **Record keeping**: All tasks and activities that are performed and scheduled are recorded. Updating the activity status on the CMMS helps to keep track.

https://www.onupkeep.com/maintenance-glossary/leak-detection-and-repair

https://www.infrared-camera-blog.com/the-best-infrared-cameras-for-optical-gas-imaging-ogi/

Screening - LDAR screening methods are used to rapidly flag high-emitting sites to direct close-range follow-up source diagnosis and root cause analysis. An example of a common screening method is an aerial monitoring campaign.

Thermal Imaging cameras - Infrared (IR) thermal imaging cameras are commonplace in the oil and gas industry. For years, companies have used them for a number of tasks such examining pipe integrity within process equipment. Recently, though, a highly specialized version of these cameras has made its way into the marketplace for a new application—the monitoring of volatile organic compounds (VOCs), such as methane, being vented into the atmosphere. Forward-looking infrared (FLIR) cameras are one common type of IR thermal imaging camera in use. https://jpt.spe.org/optical-gas-imaging-new-solution-methane-detection

Performance Metric - A quantifiable metric describing an LDAR method's performance. Ideally, performance metrics are constrained with independent, single-blind controlled release testing. The most important performance metric is probability of detection which is commonly expressed as a probability curve or surface. Many other performance metrics exist, including localization and quantification uncertainty, false positive rate, and more.

LACT meter - Lease Automatic Custody Transfer Units, or LACT Units as they are commonly abbreviated are metering equipment designed to accurately gauge the volume and quality of crude oil as it changes custody from one party to another. LACT Units provide the means of correctly determining compensation, which makes them very important to both parties. A LACT Unit is only as good as the meters and parts which comprise it. Different types of LACT Units use different types of flowmeters to accurately measure the custody transfer of the crude oil. The type of meter the system uses will typically depend on a variety of characteristics and considerations about the well. A LACT Unit's flowmeter is a good fit for the particular well when it is designed to successfully overcome the primary hurdles at that well. https://setxind.com/upstream/a-closer-look-at-lact-unit-meters-and-components/

Gas Chromatography - Gas chromatography (GC) is an analytical technique used to separate and analyze samples that can be vaporized without thermal decomposition. Sometimes gas chromatography is known as gas-liquid partition chromatography (GLPC) or vapor-phase chromatography (VPC). Technically, GPLC is the most correct term, since the separation of components in this type of chromatography relies on differences in behavior between a flowing mobile gas phase and a stationary liquid phase. The instrument that performs gas chromatography is called a gas chromatograph. The resulting graph that shows the data is called a gas chromatogram.

GC is used as one test to help identify components of a liquid mixture and determine their relative concentration. It may also be used to separate and purify components of a mixture. Additionally, gas chromatography can be used to determine vapor pressure, heat of solution, and activity coefficients. Industries often use it to monitor processes to test for contamination or ensure a process is going as planned. Chromatography can test blood alcohol, drug purity, food purity, and essential oil quality. GC may be used on either organic or inorganic analytes, but the sample must be volatile. Ideally, the components of a sample should have different boiling points.

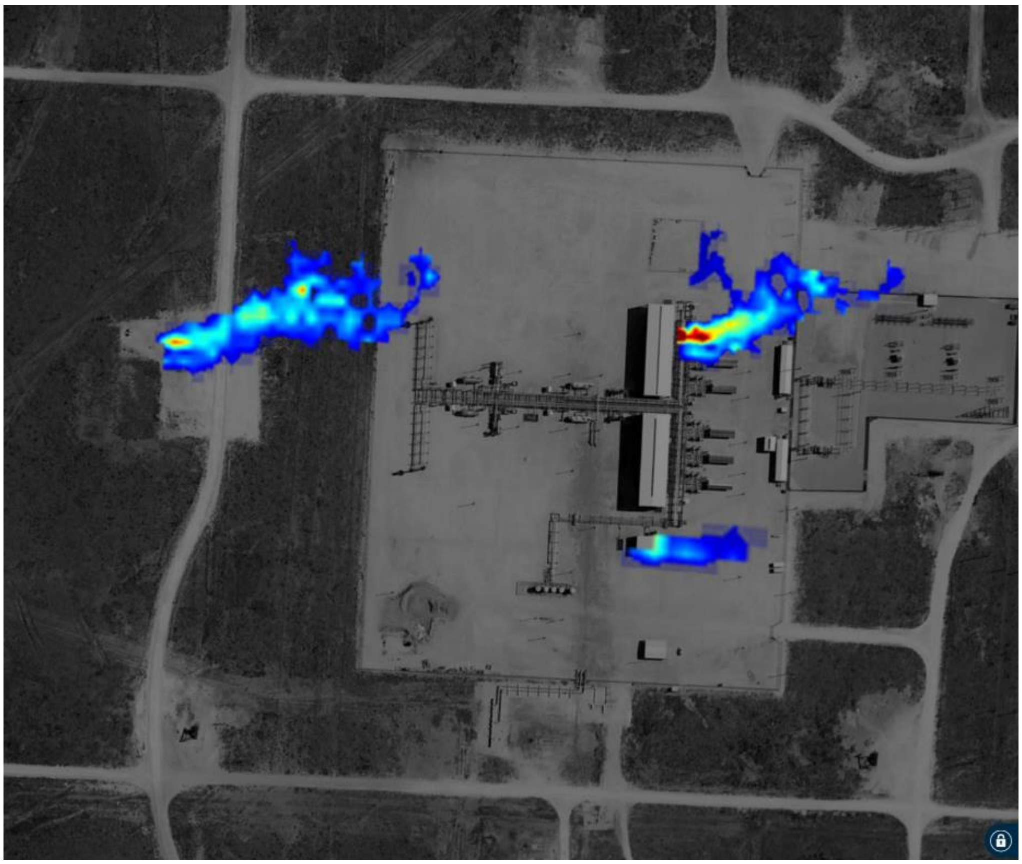
https://www.thoughtco.com/gas-chromatography-4138098

Optical gas imaging (OGI) - A common leak detection approach that uses thermal infrared cameras to visualize methane and various other organic gases. Common OGI cameras create images of a narrow range of the mid-IR spectrum (3.2− 3.4 μm wavelength) which methane and other light hydrocarbons actively absorb.

Quantitative optical gas imaging (QOGI) - Combines optical gas imaging (OGI) camera technology with cross-section pixel absorption algorithms to quantify emissions. The brightness of each pixel seen through the OGI camera is proportional to the amount of infrared radiation incident on the camera along the corresponding line of sight through the plume. The brightness is converted to a concentration and combined with estimated velocities to obtain mass fluxes.

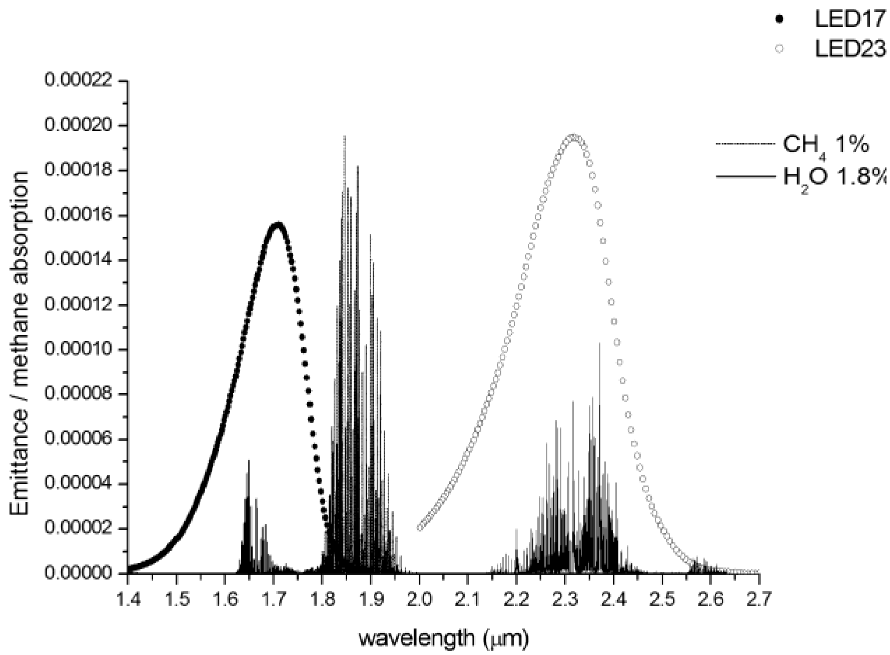
Other test method 33A (OTM 33A) - EPA OTM 33A uses fast response instruments mounted on ground-based vehicles for the geospatial measurement of air pollution (GMAP) near the driving route. Typically, the vehicle remains stationary for an extended period of time as the methane plume washes over it. Location and source emission rate are estimated.

LiDAR -Light detection and ranging (LiDAR) techniques use lasers to create 3D (topographic) or gas concentration (atmospheric) imagery of the surveyed environment. Both uses for LiDAR can be performed using either pulses of laser light (pulsed lasers) or laser light that stays on all the time (continuous-wave lasers). Bridger Photonics makes use of continuous-wave LiDAR to measure both solid surfaces (hard targets) and gases (soft targets).



Laser absorption spectrometry (LAS) - There is a range of methods called laser absorption spectroscopy, where laser light is used to precisely measure absorption features of substances. The purpose of such kinds of spectroscopy is frequently to find out details on such substances, but in other cases one utilizes known details of substances for other purposes. For example, laser absorption spectroscopy is often used for realizing optical frequency standards, e.g. by stabilizing the wavelengths of a laser to a precisely defined absorption transition.

Direct Absorption Spectroscopy - A frequently used method involves that a tunable narrow-linewidth laser (frequently a single-frequency laser) is tuned through some wavelength range, and the light absorption in some sample is measured as a function of that wavelength. The absorption is often obtained by measuring (a) the optical power of a laser beam which is transmitted through the investigated medium and (b) the optical power of a reference beam (obtained with a beam splitter between the laser and the investigated medium), which is not affected by the medium. That way, one can largely avoid that power fluctuations of the laser (intensity noise) affect the results. In many cases, one uses a balanced photodetector, essentially measuring the difference between two optical powers (rather than their ratio). https://www.rp-photonics.com/laser_absorption_spectroscopy.html



https://www.researchgate.net/figure/LED-spectra-and-methane-and-water-absorption-bands_fig1_298904432

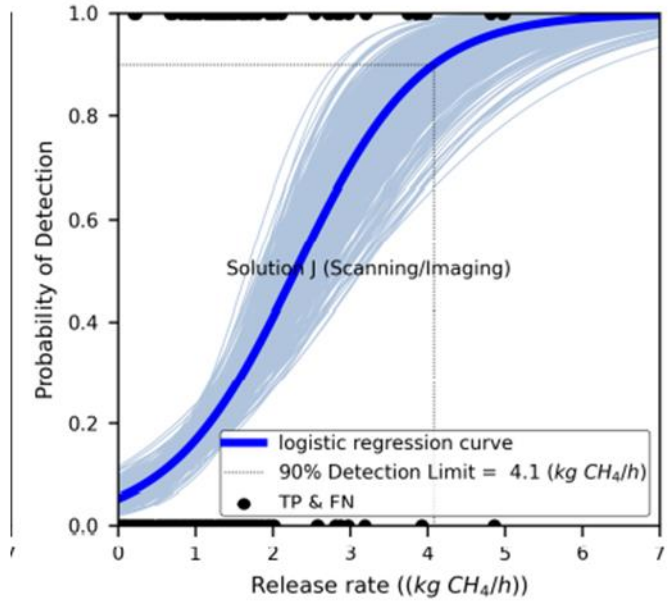
Methane Emissions Technology Evaluation Center (METEC) – The METEC facility, located in northwest Fort Collins on CSU's foothills campus, is a unique test and research facility for emissions detection and quantification, methods development, and training. METEC is fee based and supports research and testing by any interested party. https://energy.colostate.edu/metec/

TROPOMI - The TROPOspheric Monitoring Instrument (TROPOMI) is the gas-sensing instrument on the Copernicus Sentinel-5 Precursor satellite developed by the European Space Agency. TROPOMI has been used to identify methane ultra-emitters around the world.

Visible Infrared Imaging Radiometer Suite (VIIRS) - The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument is aboard the joint NASA/NOAA Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20 satellites. (Note: Prior to launch, NOAA-20 was known as the Joint Polar Satellite System, or JPSS-1, satellite.) https://www.earthdata.nasa.gov/learn/find-data/near-real-time/viirs

https://www.minesnewsroom.com/news/earth-observation-group-wins-galileo-award-international-dark-sky-association

Probability of Detection (POD) - The probability that a given emission source will be detected by an LDAR method. Probability of detection is often depicted as a sigmoid curve or surface, where it is the function of emission rate and other relevant variables (e.g., wind speed).



A POD curve or surface is a key metric required to model the emission mitigation potential of solutions using tools like FEAST or LDAR-Sim. The POD describes the probability that an emission source will be detected by a solution as a function of many independent parameters including characteristics of the emission source itself (e.g. the emission rate, source type, position, etc.) and environmental conditions (e.g. wind speed and direction, precipitation, etc.).

4. Process control

Calibration - The comparison of a measuring device (an unknown) against an equal or better standard.

Drift - A systematic change in reading or value that occurs over long periods. Changes in ambient temperature, component aging, contamination, humidity and line voltage may contribute to drift.

An **alert** is a notification that a particular event (or series of events) has occurred, which is sent to responsible parties for the purpose of spawning action. In general, an **incident** is a human-caused, accidental event that leads to (or may lead to) a significant disruption of business. An **event** in general terms is an observed change to the normal behavior of a system, environment, process, workflow, or person. Events can control peripheral equipment or processes, or act as an input for another control or control loop.

Alarm – A **deviation alarm** warns that a process has exceeded or fallen below a certain range around the set or reference point. Alarms can be referenced at a fixed number of degrees, plus or minus, from an established reference point. A **process alarm** warns that process values exceed the process alarm setting. A fixed value independent of set point. A set point is the desired or target value for an essential variable, or process value of a system.

Alarm Management: When every event triggers a notification, operational staff can become overwhelmed by the volume of non-actionable notifications (i.e., corresponding to operational emissions). When significant alerts trigger notifications, operators are only made aware of significant issues, which makes addressing these issues easier. In short, notifications are the messages that bring events, alerts, alarms, and incidents to the attention of the appropriate staff.

Supervisory control and data acquisition (**SCADA**)– SCADA refers to ICS (industrial control systems) used to control infrastructure processes (water treatment, wastewater treatment, gas pipelines, wind farms, etc.), facility-based processes (airports, space stations, ships, etc.) or industrial processes (production, manufacturing, refining, power generation, etc.).

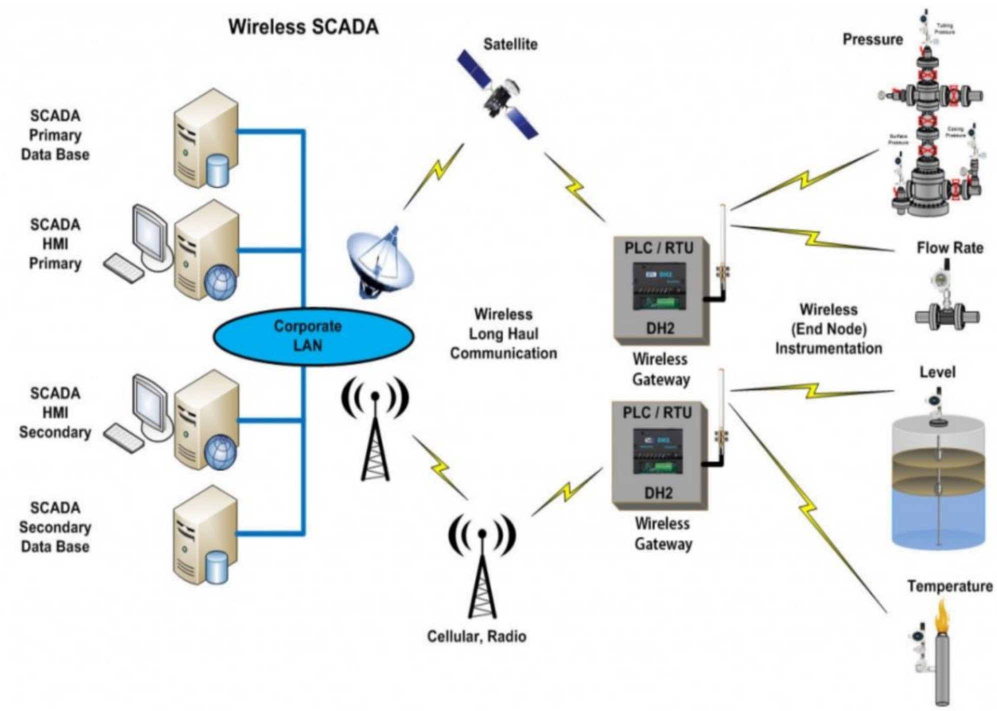
The following subsystems are usually present in SCADA systems:

- The apparatus used by a human operator; all the processed data are presented to the operator
- A supervisory system that gathers all the required data about the process
- Remote Terminal Units (RTUs) connected to the sensors of the process, which helps to convert the sensor signals to the digital data and send the data to supervisory stream.
- Programmable Logic Controller (PLCs) used as field devices
- Communication infrastructure connects the Remote Terminal Units to supervisory system.

Generally, a SCADA system does not control the processes in real time – it usually refers to the system that coordinates the processes in real time.

SCADA refers to the centralized systems that control and monitor the entire sites, or they are the complex systems spread out over large areas. Nearly all the control actions are automatically performed by the **remote terminal units** (RTUs) or by the **programmable logic controllers** (PLCs). The restrictions to the host control functions are supervisory level intervention or basic overriding. For example, the PLC (in an industrial process) controls the flow of cooling water, the SCADA system allows any changes related to the alarm conditions and set points for the flow (such as high temperature, loss of flow, etc) to be recorded and displayed.

Data acquisition starts at the PLC or RTU level, which includes the equipment status reports, and meter readings. Data is then formatted in such way that the operator of the control room can make the supervisory decisions to override or adjust normal PLC (RTU) controls, by using the HMI.



https://www.onupkeep.com/learning/maintenance-tools/scada-system

Human Machine Interface (HMI) - The HMI, or Human Machine Interface, is an apparatus that gives the processed data to the human operator. A human operator uses HMI to control processes. The HMI is linked to the SCADA system's databases, to provide the diagnostic data, management information and trending information such as logistic information, detailed schematics for a certain machine or sensor, maintenance procedures and troubleshooting guides.

The information provided by the HMI to the operating personnel is graphical, in the form of mimic diagrams. This means the schematic representation of the plant that is being controlled is available to the operator. For example, the picture of the pump that is connected to the pipe shows that this pump is running and it also shows the amount of fluid pumping through the pipe at the particular moment. The pump can then be switched off by the operator. The software of the HMI shows the decrease in the flow rate of fluid in the pipe in the real time. Mimic diagrams either consist of digital photographs of process equipment with animated symbols, or schematic symbols and line graphics that represent various process elements.

HMI package of the SCADA systems consist of a drawing program used by the system maintenance personnel or operators to change the representation of these points in the interface. These representations can be as simple as on-screen traffic light that represents the state of the actual traffic light in the area, or complex, like the multi-projector display that represents the position of all the trains on railway or elevators in skyscraper. http://www.scadasystems.net/

5. Data analysis techniques

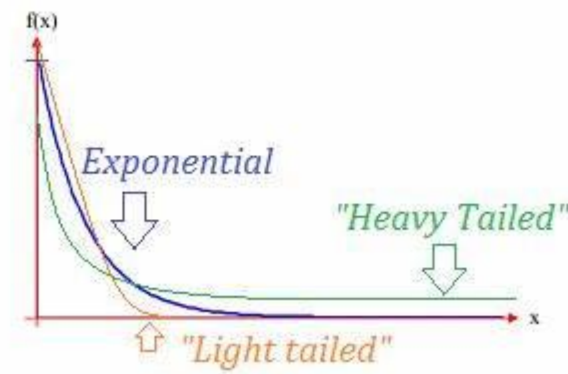
Anomaly - A discernible increase of a measured atmospheric gas over a baseline in which both the discernible increase and baseline are pre-defined. An anomaly occurs when the atmospheric concentration of a gas becomes larger than the minimum atmospheric concentration of that gas a technology can discern above noise. Not to be confused with detection.

Atmospheric Transport Modeling - A remote emissions measurement technique. Downwind mixing ratios of a pollutant, geospatial data (e.g., source height and location), and environmental data (e.g., wind speed and direction) are used to infer the location and/or mass or volumetric flux of a source. Many approaches exist.

Dispersion Modeling - Mathematical simulations that predict how a pollutant will move through the atmosphere.

Gaussian plume model - The most commonly used dispersion model (see dispersion modeling). The Gaussian plume model is a relatively simple model (conceptually and computationally) that assumes the plume follows a normal (Gaussian) distribution in 3 dimensions.

Heavy-tailed distribution - A highly skewed probability distribution. Most emissions distributions are heavy-tailed, with a small number of super-emitters accounting for the majority of emissions.



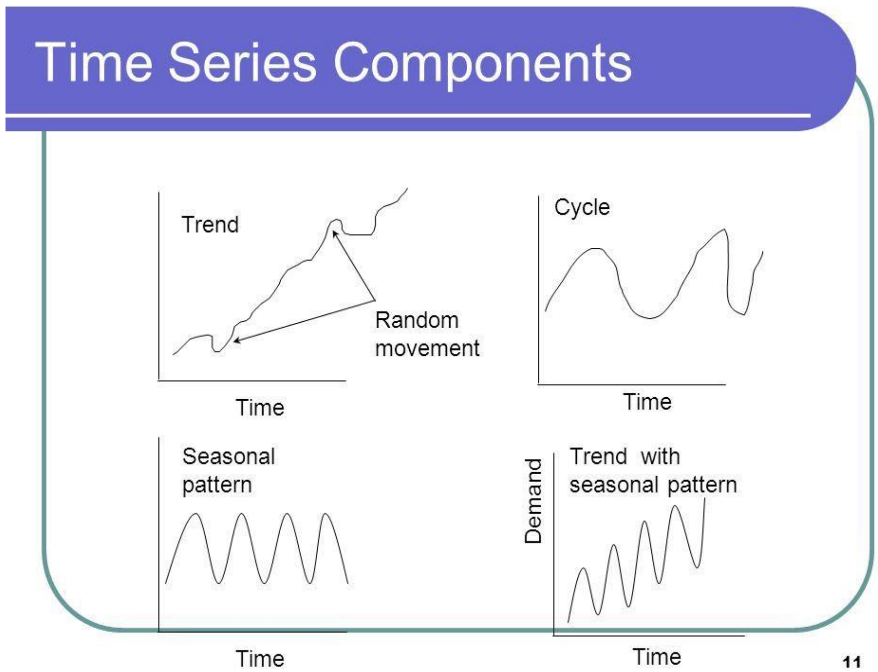
Lifecycle Analysis - A technique for assessing the environmental aspects associated with a product over its life cycle.

Localization - Identifying the physical location of a leak source. Localization can be done at different scales (site-level, equipment-level, and component-level).

Quantification - A general term for characterizing emissions numerically. Can be with emission factor bottom-up inventories or based on measurement. With measurement it often refers to emission rate estimation, but atmospheric mixing ratios may also be quantified.

Time-Series analytics - Time series analysis is a statistical method to analyze the past data within a given duration of time to forecast the future. It comprises of ordered sequence of data at equally spaced interval. Time series data collected over different points in time breach the assumption of the conventional statistical model as correlation exists between the adjacent data points. This characteristic of the time series data breaches is one of the major assumptions that the adjacent data points are independent and identically distributed. This gives rise to the need of a systematic approach to study the time series data which can help us answer the statistical and mathematical questions that come into the picture due to the time correlation that exists.

Time series analysis holds a wide range of applications is it statistics, economics, geography, bioinformatics, neuroscience. The common link between all of them is to come up with a sophisticated technique that can be used to model data over a given period of time where the neighboring information is dependent. In time series, Time is the independent variable and the goal is forecasting. https://www.educba.com/time-series-analysis/



https://devopedia.org/images/article/107/7999.1532720149.jpg

Geospatial analytics - Geospatial analytics gathers, manipulates and displays geographic information system (GIS) data and imagery including GPS and satellite photographs. Geospatial data analytics rely on geographic coordinates and specific identifiers such as street address and zip code. They are used to create geographic models and data visualizations for more accurate modeling and predictions of trends.

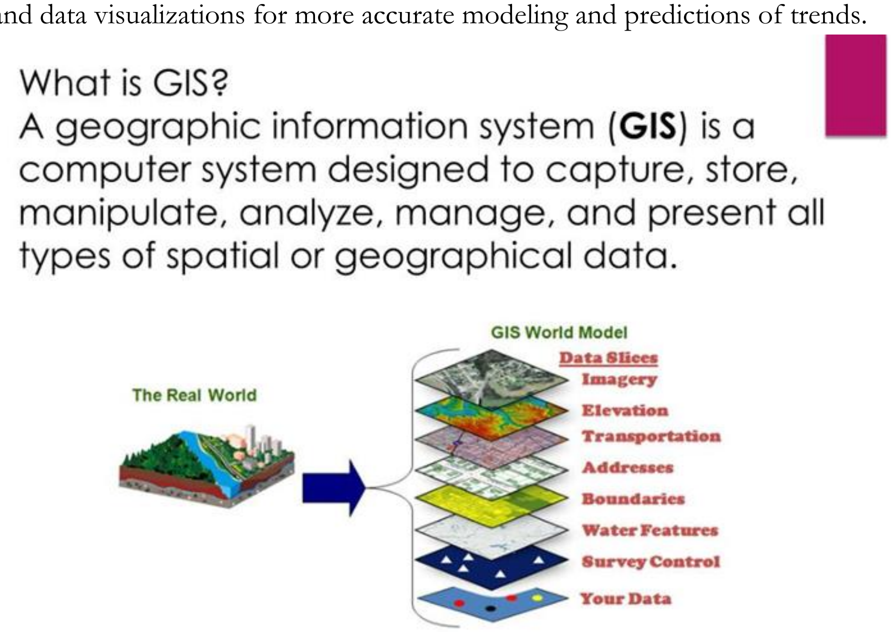
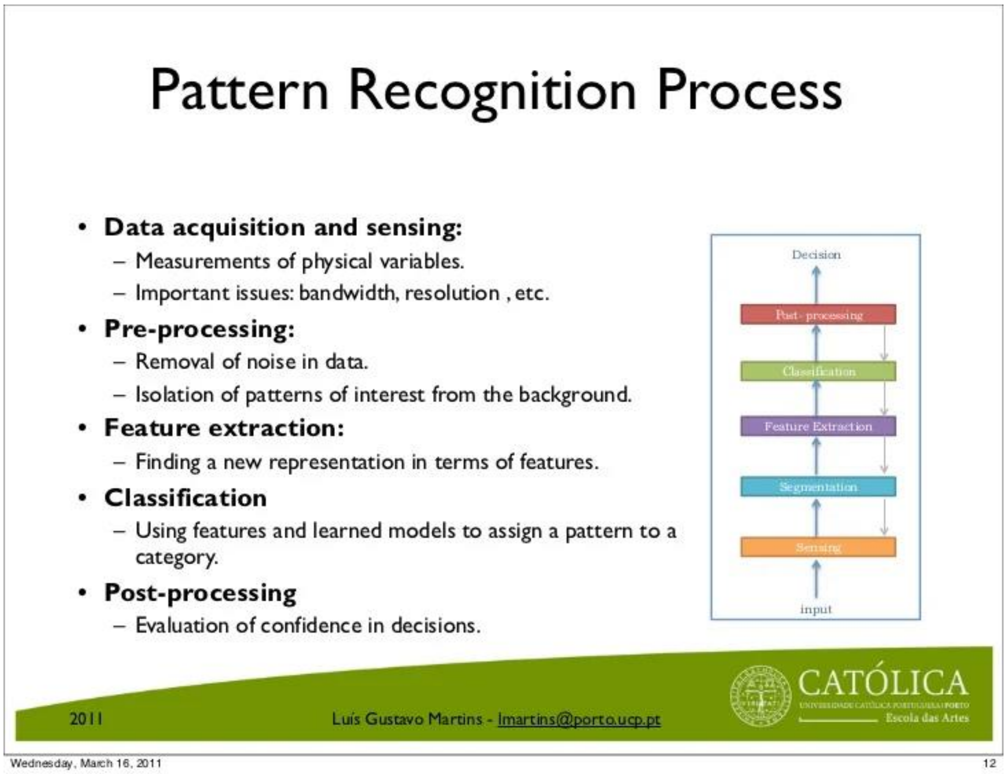


Image Processing and Pattern Recognition – Pattern recognition is a branch of machine learning that focuses on the recognition of patterns and regularities in data. Image processing is a method to convert an image into digital form and perform some operations on it, to get an enhanced image or to extract some useful information from it. It is a type of signal dispensation in which input is image, e.g. video frame or photograph and output may be image or characteristics associated with that image. The two types of methods used for Image Processing are Analog and Digital Image Processing.



Energy Emissions Modeling and Data Lab (EEMDL) - EEMDL is a multi-disciplinary research and education center with a mission to be the global data and analytics hub to support improved greenhouse gas emissions accounting across energy supply chains. EEMDL will build models and tools to improve greenhouse gas emissions accounting across energy supply chains. These models and tools will be peer-reviewed, transparent, timely, measurement-based, and made publicly available for all stakeholders. EEMDL leadership and team members are comprised of talented individuals from The University of Texas at Austin (UT Austin), Colorado State University, and Colorado School of Mines. https://www.eemdl.utexas.edu/about

Fugitive Emissions Abatement Simulation Toolkit (FEAST) - The Fugitive Emissions Abatement Simulation Toolkit or FEAST is a model to evaluate the effectiveness of methane leak detection and repair (LDAR) programs at oil and gas facilities. Recent advances in the development of new fixed (continuous monitoring systems) and mobile (truck-, drone-, plane-, and satellite-based) methane leak detection technologies have led to growing interest in alternative LDAR programs. The FEAST model helps operators and regulators compare a variety of LDAR program configurations such as continuous monitoring systems and hybrid aerial and ground surveys to develop cost-effective mitigation protocols. https://www.arvindravikumar.com/feast/

Methane Emission Estimation Tool (MEET) - The Methane Emission Estimation Tool (MEET) is a high time resolution and spatially resolved emission model that bridges the gap between the spatial and temporal scales of observations and inventories. The model simulates both long-term variability, such as the production declines of unconventional wells, and short-term variability, such as the cycling of compressors or well pad liquid separators. The model also captures the sequencing of emissions and utilizes empirical distributions to capture highly skewed data that underlie emission factors. MEET was developed with support from the Collaboratory to Advance Methane Science (CAMS), the University of Texas and Colorado State University have developed a new community modeling tool for constructing inventories of methane emissions from oil and gas operations. The development of this tool was driven by the need to reconcile methane emission measurements and commonly available emission estimates. https://methanecollaboratory.com/wp-content/uploads/2021/06/Scientific-Insights-MEET-June2021_vFinal.pdf#:~:text=The%20Methane%20Emission%20Estimation%20Tool%20%28MEET%29%20is%20a,capture%20highly%20skewed%20data%20that%20underlie%20emission%20factors.

6. Emissions reporting policy and practices

Anthropogenic - Of, relating to, or resulting from the influence of human beings on nature.

Net Zero - Achieving a state where either (1) no greenhouse gases are emitted, or (2) remaining emissions are offset through other actions or technologies that remove carbon from the atmosphere.

Transparency - The degree to which an initiative or producer discloses their internal operations and standards and allows for accessibility of information regarding an initiative

Corporate Sustainability Reporting Directive (CSRD) - In spring 2021, the European Commission presented its proposal for the Corporate Sustainability Reporting Directive. The CSRD is a reviewed and revised version of the Non-Financial Reporting Directive (NFRD) and promotes the disclosure of sustainability related parameters in companies 'reporting practice. One of its main building blocks: double materiality. This involves that companies report on the effect of climate change on their companies on the one hand, while reporting on the impact of the company's activities on environmental and social aspects. https://hedgehogcompany.nl/csrd-ghg-protocol/

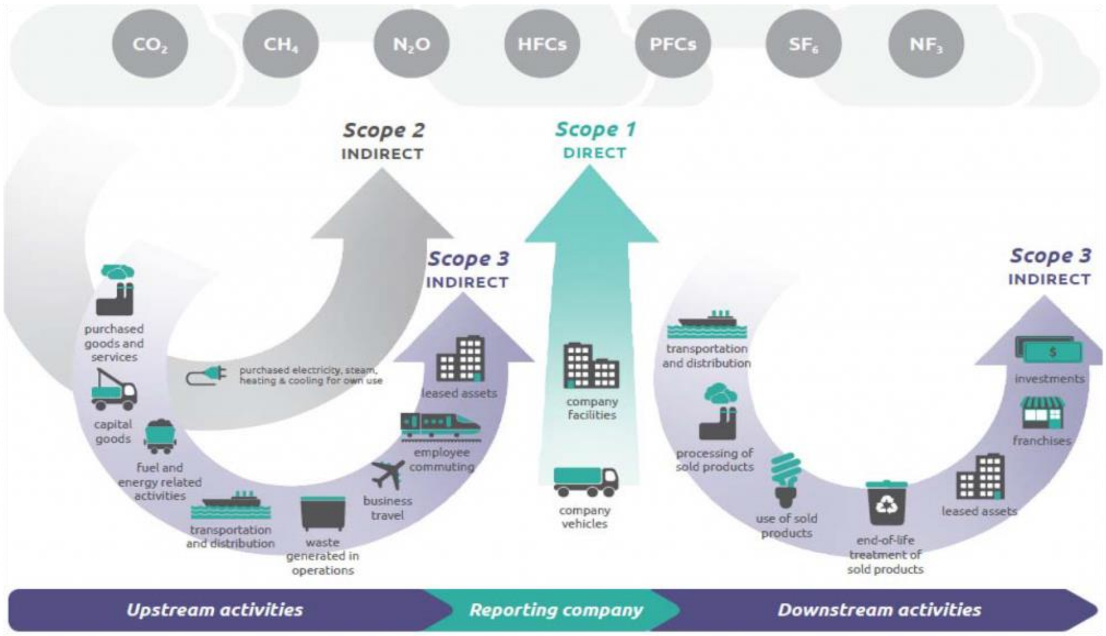
Environmental Protection Agency (EPA) - A United States government agency whose work it is to improve society's understanding of climate change and its impacts on human health and the environment. The data, tools, and resources that EPA develops can also be used by other agencies, organizations, states, tribes, and communities to help tackle the climate crisis effectively, equitably, and sustainably.

Oil and Gas Climate Initiative (OGCI) - A CEO-led initiative that aims to accelerate the industry response to climate change. OGCI member companies explicitly support the Paris Agreement and its aims.

Oil & Gas Methane Partnership (OGMP) - A Climate and Clean Air Coalition initiative led by the UN Environment Programme, in partnership with the European Commission, the UK Government, the Environmental Defense Fund, and leading oil and gas companies.

Green House Gas Protocol (GHG Protocol) - An emissions quantification framework that is widely used by businesses, industry associations, NGOs, and other organizations. Some initiatives use the GHG Protocol for their emissions quantification requirements. GHG protocol has published several standards but is recognized for these two emission quantification guidelines: (1) Corporate Standard – for scope 1, 2, and energy-related scope 3, and (2) Corporate Value Chain (Scope 3) Standard – for life-cycle emissions, both upstream and downstream

The Greenhouse Gas protocol provides standards for both the public and the private sector about measuring greenhouse gasses, such as carbon dioxide, methane, nitric oxide hydrofluorocarbons and other trace gases. Through its standards, it creates a common ground for sustainability certifications and reporting systems. Because of this standardization, it allows companies to thoroughly understand their greenhouse gas emissions and creates collective understanding of the problem. Moreover, it allows companies to critically think about appropriate actions that should be taken to fight these emissions. When a company understands its emissions and has taken steps to reduce these, it enables the company to make environmental claims towards stakeholders. The Greenhouse Gas Protocol (GHGP) was established through a partnership between the World Resources Institute and the Business Council for Sustainable Development. The GHGP is divided into 3 scopes:



Scope 1 covers all direct emissions. The company or organization itself is responsible for these emissions. For example, the CO2 emissions which are emitted due to the combustion of diesel from machines on the production location of the company. An exception is the combustion, fermentation, or gasification of biomass.

Scope 2 covers all greenhouse gas emissions that are emitted from the production of energy. For example, grey electricity production emits CO2. This means scope 2 is not about emissions on location, but about the emissions produced at the location where the electricity is produced needed by the company or organization.

Scope 3 covers all GHG emissions that are not covered by scope 1 or 2 and needs to cover the entire value chain of the company or the organization. This scope often represents the largest source of emissions and covers both upstream and downstream activities of the organization. Examples of these are; capital goods, business travels, purchased goods and services and franchises.

QMRV - (quantification, monitoring, reporting and verification) is a record keeping protocol of greenhouse gas (GHG) emissions at natural gas production hubs. The motive behind the QMRV goal to interact with the natural gas producers is gaining better knowledge of the upstream GHG emissions and accelerating the adoption of sophisticated monitoring technology and methods.

Emissions Factors - A representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of a pollutant, divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate an estimation of emissions from various sources of air pollution. In most cases, these factors are simply averages of all available data of acceptable quality, and are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).

Emissions factors have long been the fundamental tool in developing national, regional, state, and local emissions inventories for air quality management decisions and in developing emissions control strategies. More recently, emissions factors have been applied in determining site-specific applicability and emissions limitations in operating permits by federal, state, local, and tribal agencies, consultants, and industry.

The general equation for emissions estimation is:

$$E = A \times EF \times (1-ER/100)$$

where:

- E = emissions;
- A = activity rate;
- EF = emission factor, and
- ER =overall emission reduction efficiency

https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification

Emissions rate – The size of an emissions source in terms of customary units, such as mass per time (e.g. kilograms per hour) or volume per time (e.g. standard cubic meters per hour). emission rate
A measure of how quickly a pollutant is being introduced to the atmosphere. Typically expressed in either mass per unit time (e.g., kg/hr) or volume per unit time (e.g., SCF/hr). Many units exist and are used.

Emissions inventory - A list of an organization's emissions sources and their magnitude, which may be estimated using emissions factors, engineering estimates, measurement, or a combination.

Equipment - In emissions attribution, equipment is the second most granular piece of oil and gas infrastructure. Examples include tanks and separators.

Measurement-informed inventory – means a greenhouse gas emissions inventory adjusted or informed by measurements of greenhouse gas emissions from regional, local or point-source monitoring or through parametric monitoring including but not limited to measurement of pressure, temperature, flow or control efficiency.

Measurement-informed Inventory reporting - Recent legislation in the United States requires updating current methane reporting programs for oil and gas facilities with empirical data. While technological advances have led to improvements in methane emissions measurements and monitoring, the overall effectiveness of mitigation strategies rests on quantifying spatially and temporally varying methane emissions more accurately than the current approaches. Including measurements of methane at the facility level and adjusting facility specific emissions factors can lead to more accurate reporting of methane emissions levels.

Carbon Intensity – is the amount of carbon dioxide or carbon dioxide equivalent per unit of measure. The ratio of carbon emissions to some measure of productivity, such as natural gas production or energy content of oil.

Carbon Market - A greenhouse gas trading system that enables monetization of emissions reductions and/or strong performance relative to other market participants. Participants may buy or sell units of GHG emissions in order to operate within the limits outlined by the agreement governing a particular market.

Carbon Offsets - A unit of greenhouse gas emissions reduced by one actor that can be traded to compensate for emissions by another actor.

Emission trading system (ETS) - Market-based instruments that create incentives to reduce emissions where these are most cost-effective. In most regulatory trading systems, the government sets an emissions cap in one or more sectors, and the entities that are covered are allowed to trade emissions permits. Rapid growth of voluntary ETSs is also underway.

Equivalence - The concept that two LDAR programs mitigate equal amounts of emissions. In the context of LDAR programs, alternative work practices and technologies are required to demonstrate that they meet or exceed mitigated emissions under regulatory frameworks and voluntary initiatives (e.g., MiQ).

Global Warming Potential - GWP was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO2). The larger the GWP, the more that a given gas warms the Earth compared to CO2 over that time period. The time period typically used for GWPs is 100 years. GWPs provide a common unit of measure, which allows analysts to add up emissions estimates of different gases (e.g., to compile a national GHG inventory), and allows policymakers to compare emissions reduction opportunities across sectors and gases.

CO2, by definition, has a GWP of 1 regardless of the time period used, because it is the gas being used as the reference. CO2 remains in the climate system for a very long time: CO2 emissions cause increases in atmospheric concentrations of CO2 that may last thousands of years.

Methane (CH4) is estimated to have a GWP of 28–36 over 100 years. CH4 emitted today lasts about a decade on average, which is much less time than CO2. But CH4 also absorbs much more energy than CO2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH4 GWP also accounts for some indirect effects, such as the fact that CH4 is a precursor to ozone, and ozone is itself a GHG.

Nitrous Oxide (N2O) has a GWP 265–298 times that of CO2 for a 100-year timescale. Chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) are sometimes called high-GWP gases because, for a given amount of mass, they trap substantially more heat than CO2. The GWPs for these gases can be in the thousands or tens of thousands.

GWP is a major analytical and policy issue impacting how methane emissions are reported concerns how to translate methane emissions into carbon dioxide equivalent. Methane is a much more potent greenhouse gas than carbon dioxide, although it has a much shorter atmospheric life. Emissions are very often reported in terms of carbon dioxide equivalent (CO2e), which requires an assessment of the global warming potential (GWP) of methane. The most-common metrics are that the radiative forcing impact of methane is 28–36 times that of CO2 measured over a 100–year time horizon, and 84–87 times over a 20-year horizon.

The measurement, reporting and verification of methane emissions using a transparent and globally accepted methodology has become a crucial issue. Given the level of public scrutiny and policy focus on this issue, it has become absolutely vital that the gas industry takes proactive steps to create and implement a global plan both to reduce, but first to accurately document, methane emissions,

https://www.oxfordenergy.org/wpcms/wp-content/uploads/2022/01/Measurement-Reporting-and-Verification-of-Methane-Emissions-from-Natural-Gas-and-LNG-Trade-ET06.pdf

Methane Intensity - Methane emissions intensity is a measure of methane emissions relative to natural gas throughput. Methane intensity can be determined for a facility (e,g, compressor station), an area (e.g. production basin), or even an entire value chain (e.g. from antural gas production to distribution).Investors, customers, environmental groups, and other stakeholders are increasingly requesting information on natural gas company performance based on methane emissions intensity. While intensity is becoming a preferred approach for communicating methane emissions data throughout the industry, there is no standard methodology for calculating it. This is an obstacle to managing, tracking, and more transparently communicating current efforts to reduce methane emissions. https://www.aga.org/contentassets/c87fc10961fe453fb35114e7d908934f/ngsi_methaneintensityprotocol_v1.0_feb2021.pdf

Methane Management - is a holistic approach to addressing methane emissions performance across multiple dimensions, including actions to reduce methane emissions intensity through facility design and operational best practices; deployment of advanced technology to detect, measure and quantify site- and source-level emissions; and development and assurance of methane emissions inventories for reporting and disclosures.

Methane measurement is the process of taking a reading of the methane concentration or methane emissions rate within an air sample at a specific point in time. Typically, measurement units are parts per million, parts per billion and kilograms per hour. Understanding global and local background methane concentrations is necessary to contextualize the data. Emissions measurements may be performed as one-time activities (snapshots), at regular intervals or on a continuous basis, but whatever the frequency, obtaining representative measurement is important.

Methane quantification methods for determining the size of a methane emission source in customary units if emissions rate, such as mass per time (e.g. kilograms per hour), or volume per time (e.g. standard cubic meters per hour). Methane can be quantified through engineering estimations, direct measurement of a methane source (e.g. by utilizing bagging procedures) and modeling that uses ambient measurements and meteorological data to infer an emissions rate.

Super-emitter – A methane source that emits a disproportionate amount compared to emissions from the total source category. Super-emitters can be continuous or episodic and can have a wide range of underlying issues, such as a failing tank control, lack of takeaway or pipeline blowdown. A recent study by NASA defines a super-emitter as a source that emits greater than 10 kilograms of methane per hour. An uncharacteristically large point source of methane. Given that most methane emissions distributions are heavily skewed, a small number of super-emitters can account for most aggregate emissions across the supply chain. Emissions distributions vary widely by basin and production type, so there is some debate over what constitutes a super-emitter.

Responsible Gas - The natural gas industry has seized upon consumers' environmental consciousness and is beginning to market "responsibly produced" gas - at a premium price. The first public transaction involving gas certified under the Responsible Gas program by Independent Energy Standards Corp. took place in September 2018 when Southwestern Energy sold an undisclosed volume to local utility company New Jersey Natural Gas. The transaction represents part of a small but growing niche of the natural gas market, in which end-users can specify that they want to purchase gas with certain attributes, such as gas produced without hydraulic fracturing or gas produced with low levels of methane emissions.

Under certifications programs, gas wells and related facilities are rated based on four key metrics: impacts to water, impacts to air and impacts to land, as well as community and social considerations. Wells are scored on a zero-to-150 scale, with wells scoring 125 to 150 given a Platinum rating, which comprises the top 10% of operators. The next tier is Gold, which includes wells scoring 100 to 125 and includes the top quartile of producers. Wells scoring 75 to 100 fall into the Silver category, and those that rate below 75 are classified as actively improving. https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/040519-us-industry-turns-to-responsible-natural-gas-to-fetch-premium-price

Third-party Verification - Third-party reviews check the veracity of both financial and non-financial reports so your readers and benchmarking organizations can trust that your reports are accurate. This additional step can also identify issues in your reporting methodology and underlying data, which can result in substantial improvements to your broader ESG program. Examples of this verification process include Project Canary's TrustWell process (https://www.projectcanary.com/operationalize/) and RMI's MiQ process (https://miq.org/about/). GTI is sponsoring a broad effort to establish gas measurement and verification protocols in a program called Veritas (https://www.gti.energy/veritas-a-gti-differentiated-gas-measurement-and-verification-initiative/)

Many of the terms are used inconsistently, which can cause confusion. While they all describe validation processes, they differ when it comes to precision and coverage. So let's first get these definitions straight:

> **Assurance**: a data check process that requires the same methodologies and standards as financial data and must be performed by an accredited auditor.
>
> **Verification**: a data check process used when reviewing non-financial data and collection processes compared against predefined criteria and must be performed by an accredited auditor.
>
> **Alignment**: an established methodology (e.g. a rationale for how it was prepared, what was included and excluded, and why these decisions were made) that a report follows. https://www.measurabl.com/how-assurance-and-verification-help-your-sustainability-efforts/

The Intergovernmental Panel on Climate Change (IPCC) - The United Nations body for assessing the science related to climate change. It was created to provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options.

National inventory report (NIR) - At its eighth session, the Conference of the Parties (COP), the decision-making body responsible for monitoring and reviewing the implementation of the United Nations Framework Convention on Climate Change, requested the secretariat to publish on its website the annual inventory submissions consisting of the national inventory report (NIR) and common reporting format (CRF) of all Parties included in Annex I to the Convention. The NIRs contain detailed descriptive and numerical information and the CRF tables contain all greenhouse gas (GHG) emissions and removals, implied emission factors, and activity data.

Technology Innovation and Emissions Reduction Regulation (TIER) - The Technology Innovation and Emissions Reduction Regulation requires regulated facilities to reduce greenhouse gas emissions. The regulation applies to facilities which emit more than 100,000 tonnes of carbon dioxide. Facilities which emit less than the threshold may opt-in to the regulation, and conventional oil and gas facilities under the same ownership may be combined into a single aggregate facility. The regulation sets out high-performance benchmarks or enables the director to set facility-specific product benchmarks. To meet the emissions reduction requirement, facilities can reduce their emissions or use emission performance credits, emission offsets or pay into the regulated fund. Regulated facilities must provide annual compliance reports and facilities that emit more than 1 million tonnes of carbon dioxide must also provide a yearly forecasting report.

Global Methane Pledge - Participants joining the Pledge agree to take voluntary actions to contribute to a collective effort to reduce global methane emissions at least 30 percent from 2020 levels by 2030, which could eliminate over 0.2˚C warming by 2050. This is a global, not a national reduction target. Participants also commit to moving towards using the highest tier IPCC good practice inventory methodologies, as well as working to continuously improve the accuracy, transparency, consistency, comparability, and completeness of national greenhouse gas inventory reporting under the UNFCCC and Paris Agreement, and to provide greater transparency in key sectors.

The Pledge aims to catalyze global action and strengthen support for existing international methane emission reduction initiatives to advance technical and policy work that will serve to underpin Participants' domestic actions. The Pledge also recognizes the essential roles that private sector, development banks, financial institutions and philanthropy play to support implementation of the Pledge and welcomes their efforts and engagement. https://www.globalmethanepledge.org/

ESG Investing - ESG investing is undoubtedly one of the fastest-growing trends in finance and alternative data over the past few years. ESG stands for Environmental, Social, and Governance and is an evolution of socially responsible investing (SRI)—an investment strategy that seeks both financial returns as well as a positive social and environmental impact. By integrating environmental, social, and governance factors into valuing a company, the goal is to enhance traditional analysis by identifying risks and opportunities that go beyond fundamental metrics. https://www.mlq.ai/esg-investing/

Let's look at each of these three criteria in more detail.

Environmental

Environmental factors that go into a company's ESG score attempt to quantify the impact—positive or negative—that their operations have on the planet. A few of the core sub-factors that go into evaluating a company's environmental impact highlighted by Motley Fool include:

- Carbon footprint
- Water consumption
- Water disposal
    - Recycling practices
- Climate change policies
- Use of renewable energy
- Relationship with regulatory bodies such as the EPA (Environmental Protection Act)

Social

Social factors that go into a company's ESG rating are related to how the company addresses issues concerning customers, employees, suppliers, and so on. A few of the sub-factors that go into social ESG scores include:

- Employee compensation, benefits, and turnover
- Employee training
- Employee safety
- Diversity and inclusion in hiring and promotion practices
- Ethical supplier and supply chain sourcing
- Customer ratings and feedback
- Government lobbying efforts
- Consumer protection, such as recalls, lawsuits, and regulatory actions

Governance

Finally, factors that go into a company's governance rating include topics such as business ethics, quality of management, and the board's independence. Specifically, a few examples of governance metrics include:

- Ethical business practices and policies
- Executive compensation levels
- Addressing conflicts of interest at the board or executive level
- Shareholder voting rights for nominating board candidates
- Transparency between shareholders and the executive team
- History of legal issues with shareholders
- History with SEC or other regulatory bodies

Key Sources

Highwood Emissions Management https://highwoodemissions.com/glossary/
Energy Information Administration https://www.eia.gov/tools/glossary/
Schlumberger https://glossary.oilfield.slb.com/en/Terms/
IPIECA methane glossary https://www.ipieca.org/resources/methane-emissions-glossary