

Italian Hydrocarbon Upstream: Report on the State and Safety of the Offshore Activities (Years 2016-2023)

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Exploration, drilling, production, transportation, and logistics in offshore environment play a crucial role in the global energy sector, contributing substantially to the world's oil and gas supply. Ensuring safe offshore operations is key requirement for the social acceptability of offshore activities. The Legislative Decree n. 145/2015 (Italian transposition of the European Directive 2013/30) has established the creation of a Competent Authority responsible for overseeing and coordinating various aspects related to maritime safety as a multi-branch structure which comprises key representatives from various public bodies.

This article will delve into key aspects of offshore activities and their safety performance. The available data (years from 2016 to 2023) on offshore operations in the Italian offshore are analysed using specifically developed key performance indicators. The data includes the number and type of offshore installations, total offshore working hours, total oil and gas production rates, reported inspections conducted offshore. Data on past undesirable events occurred in Italian offshore installations were also analysed. Through the examination of these quantitative indicators, the article aims to provide a comprehensive insight of the state and safety of the Italian offshore hydrocarbon upstream activities, crucial for stakeholders, regulators, and industry.

1. Introduction

Offshore drilling and exploration, production, transport, and logistics operations represent a vital component of the global energy industry, providing a significant portion of the world's oil and gas supply (International Energy Agency, 2023). Ensuring the safety of offshore operations is paramount due to the inherently risky nature of working at sea and the potential for catastrophic accidents that can result in loss of life, environmental damage, and severe economic losses as was dramatically proved by high-profile past accidents such as the Deepwater Horizon (2010) and Piper Alpha (1988) disasters (Iaiani et al., 2023). These events underscore the critical need for robust safety measures, sound regulatory frameworks and careful monitoring of performance in offshore hydrocarbon activities.

In the European context, though the vast majority of offshore installations are located in the North Sea, several installations are located also in the Mediterranean Sea. According to the Annual Report on the Safety of Offshore Oil and Gas Operations in the European Union 2021 (European Commission, 2023), "in the Mediterranean, Italy is the most active Member State". The development of the offshore industry in Italy started early in the 1960s and evolved in the following decades also exploring the use of new technologies (e.g., directional and horizontal drilling). Italian offshore Oil&Gas industry counts currently about 140 installations, mostly located in the Adriatic Sea and Strait of Sicily (Figure 1). Several installations date back to the '70 and '80, making the structural aging and maintenance a key factor of attention for the offshore production system. The majority of offshore production is natural gas (particularly in the Adriatic Sea); crude oil constitutes about a fifth, in energy terms, of the current production. As several reservoirs have reached the mature stage, overall production shows a declining trend over the last decade, especially concerning natural gas production; this is due to a drastic reduction of exploration activity, that also affects the reserves replacement ratio.



Figure 1: Italian Continental shelf and marine zones (A to G) open to exploration and production of hydrocarbons in the Italian seas (adapted from (Ministero dello Sviluppo Economico, 2020))

2. The safety of the offshore activities in Italy

The main current regulation about the safety of the Italian offshore production of hydrocarbons is the Legislative Decree n. 145/2015 (Italian transposition of the European Directive 2013/30). This has established in Italy a Competent Authority responsible for overseeing and coordinating various aspects related to maritime safety (Cianella et al., 2019). These include regulatory compliance, risk assessment, emergency response planning, and the promotion of best practices. The primary objective of the Authority is the prevention of accidents (safety), incidents (security), and environmental damage in maritime activities, as well as the protection of human life, vessels, and marine ecosystems. The Competent Authority is a multi-body structure, known as the "Committee for Safety of Offshore Operations", which comprises representatives from various entities including the National Mining Office for Hydrocarbons and Georesources (DGS-UNMIG), the Ministry of Environment and Energy Security, the National Firefighting Corp, the Coast Guard, and the Italian Navy. As required by the regulation, the Authority issues a yearly "Report on the state and safety of the offshore activities in the hydrocarbon upstream sector" which enlists the specifications of the production system (list of the production installations, type, location, etc.), the outlook of the regulatory functions and framework, and the incident and performance data in the reference year.

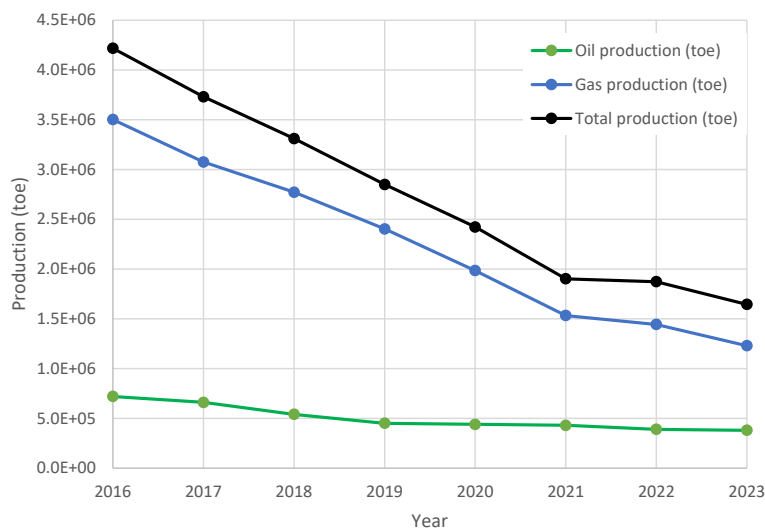


Figure 2: Production of the offshore Oil&Gas industry in the years 2016-2023 (data form (Committee for safety of offshore operations, 2016-2023)).

3. Method of analysis: the Key Performance Indicators

The "Report on the state and safety of the offshore activities in the hydrocarbon upstream sector" constitutes a valuable official source of information to describe the current state of the offshore industry in Italy. The raw data from the report can be better interpreted by the definition of Key Performance Indicators (KPIs).

The use of Key Performance Indicators has a long history in system management and decision making (OECD, 2008), and was more recently extended also to the monitoring of safety performance in petroleum industry (IOGP, 2023). KPIs allow for the definition of hierarchical structures of indicators (i.e., tree of indicators) (Tugnoli et al., 2011), which, allowing a synthetical vision and trade-off approaches, supports more agile monitoring, analysis and decision making. A structured methodology for the definition of KPIs was proposed by Tugnoli et al. (2008) in the context of the sustainability analysis of alternative chemical processes. The approach was later extended to the safety of offshore Oil&Gas sector (Cianella et al., 2017).

The methodology revolves around establishing a "tree of impacts on safety" and delineating a comprehensive set of KPIs for its quantification. Initial stages involve defining the reference basis and process boundaries. Subsequently, in the second step (stemming phase), a specific array of primary impact categories and their corresponding KPIs are chosen. The creation of a tree-like structure draws inspiration from a hierarchical representation widely employed in safety, occupational safety, decision-making, and computer technology, as presented in prior works (Saracino et al., 2015).

The focus of the KPIs has been centred on circumstances, deviating from planned actions, that can cause harm to people, property, or the environment; a short-term scale (acute damage) is assumed. In defining a suitable Key Performance Indicator to quantify various contribution to the safety performance, it becomes important to identify the available data. In facts, proposed KPIs shall be both measurable and significant. The logic of the "Swiss Cheese Model" (Reason, 2000) describes any safety performance of a system as having its root in the presence of a "hazard," or a potential danger, linked to the intrinsic characteristics of the ongoing operations. The connection between hazards and accidents, or between potential danger and actual safety performance, is represented by the efficiency of barriers and safety management measures. If, during the normal operation of an activity, there is a deficiency in barriers' efficiency, such that the barriers are no longer adequate to ensure the desired level of safety, the potential danger could manifest itself by passing through the symbolic "cheese holes/barrier", causing an incidental event accompanied by injuries, deaths, material and environmental damage.

In the definition of KPIs, it is important to differentiate between the so-called leading indicators, indicative of the future performance of the system and therefore identifiable in indicators with an anticipatory (*ex-ante*) character of the undesirable event, and the lagging indicators, historical indicators of events that have occurred (*ex-post*). The former are dedicated to quantifying the presence and extent of the "holes present in individual slices of cheese", or the performance of specific barriers and the management system, while the latter focus on the incidents that have actually occurred (i.e., cases of "hole alignment"). Alongside these two categories, specifically dedicated to evaluating the performance of critical safety elements and the management system, it is useful to prepare indicators capable of monitoring the magnitude of inherent hazards (inherent hazard indicators) (Crivellari et al., 2021), which supports design of inherently safer systems. It should be noted that these aspects of potential danger, although typically not influenced by safety barrier management initiatives, have their own evolution over time due to changes in the operational conditions of the plant (e.g., the effect of reservoir depletion) and any structural modifications.

Table 1: Data used for the definition of lagging and leading indicators (from (Committee for safety of offshore operations, 2016-2023)).

Year	Working hours	Total number of fatalities	Total number of serious injuries	Total number of injuries	Number of offshore inspections	Person-days spent on installation (travel time not included)	Number of inspected installations
2016	3045243	0	5	6	401	408	100
2017	3056478	0	1	2	289	366	88
2018	3669101	0	4	4	236	234	86
2019	2710426	1	9	16	191	168	71
2020	1947435	0	4	7	164	156	69
2021	2240788	0	2	4	222	339	164
2022	2304779	0	0	4	291	325	257
2023	3011307	0	1	1	229	228	229

4. Results and discussion

As concern the definition of lagging indicators, the “Report on the state and safety of the offshore activities in the hydrocarbon upstream sector” contains data on the number of injuries and fatalities (Table 1). The report discriminates between “severe injuries”, which resulted in more than 30 days of lost work for the person affected and, non-severe injuries, that do not meet the threshold. These data allow for considering the analysis of occupational safety performance. Occupational safety depends on multiple factors covering the specific characteristics of the conducted activity, operational procedures, the experience and training of each operator, as well as various contextual conditions. Not all these aspects are quantifiable effectively through indicators, and their full measurement might require data that are not available in the report.

Among the technical standards and international guidelines analysed, the UNI EN 7249:2007 "Statistics on Occupation Injuries" standard (UNI, 2007) has been identified as a reference. The standard defines work-related accidents in various senses and indicates significant parameters and indices useful for understanding the accident phenomenon, especially for preventive purposes, allowing data comparison at the sectoral, territorial, and temporal levels. The practices adopted internationally by some reference countries with a consolidated practice in offshore safety management, such as Norway and the United Kingdom (Petroleum Safety Authority Norway, Health and Safety Executive), were also analysed. It emerged that various competent authorities, despite different interpretations and definitions, use more than one index to describe the frequency and severity of accidents in the Oil&Gas sector. Additionally, the lack of a standardized calculation procedure is evident, and although the indices used by different countries show numerous similarities, differences in approach arise from the absence of a common guideline. This observation can be further extended and confirmed by industry initiatives, such as the annual reports of International Association of Oil and Gas Producers (IOGP, 2023).

The data of Table 1 show that injury cases occurred in all the years analysed. However, the number of injuries cannot be considered in absolute terms, as it is, generally speaking, a function of the exposure of the workers to the different activities carried out. The "Lost Time Injury Frequency" (LTIF) is a consolidated indicator for assessing occupational risks. Its goal is to describe the frequency of incidents that have caused an injury. It measures the number of fatal and non-fatal injury events that occurred in a conventional exposure period of 1,000,000 hours (UNI EN 7249:2007). The equation describing the LTIF index is as follows:

$$LTIF = \frac{N}{E} \times 10^6 \quad (1)$$

Where N identifies the number of injury events that occurred in the considered exposure period, and E represents a measure of exposure to risk, in this case, the hours worked by operators in offshore activities. The term 10^6 is simply a multiplying factor that makes the number readable.

The trend of LTIF in the considered period is reported in Figure 3. It shows that, with the exception of a few years in which several accidents occurred, the LTIF is generally constant over time, in spite of the variations of the number of worked hours. The average value of LTIF over the 8-year period is 2.0.

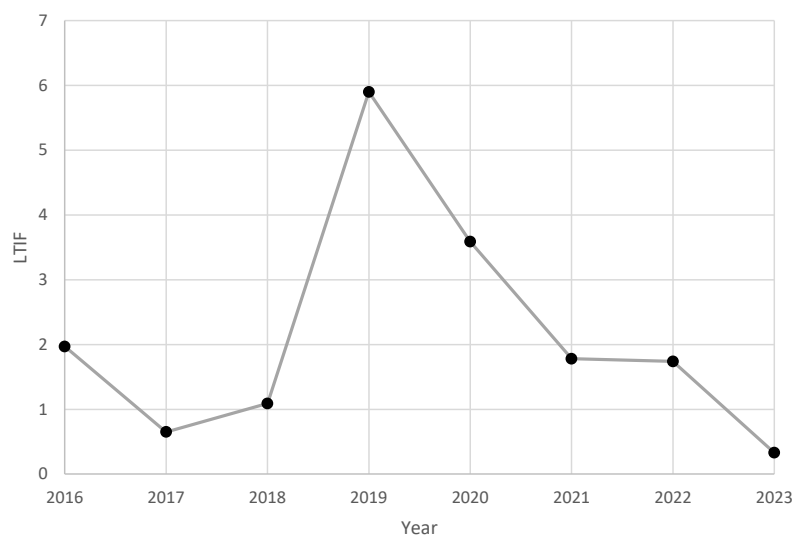


Figure 3: Lost Time Injury Frequency (LTIF) calculated for the offshore Oil&Gas industry in the years 2016-2023.

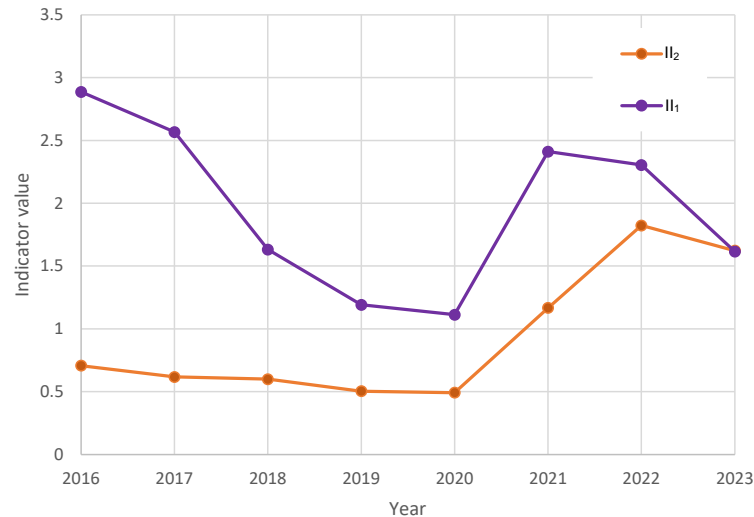


Figure 4: Leading indicators for inspection activities (II_1 and II_2).

Another indicator frequently used for exploring occupational safety performance is the "Fatal Accident Rate" (FAR). FAR is a measure of the number of fatal accidents that occurred in a conventional exposure period of 100,000,000 hours. The FAR is calculated with the following formula:

$$FAR = \frac{N_f}{E} \times 10^8 \quad (2)$$

N_f is the number of fatalities in the considered exposure period. This exposure period, E , is the number of hours worked in each offshore oil and/or gas production installation in a representative observation period. Finally, the term 10^8 is a multiplying factor that makes the number readable. Data collection for defining FAR is characterized by the extreme rarity of the fatal event in the national context, requiring consideration of data over sufficiently long observation periods to obtain meaningful values.

In 2019, a major accident occurred at Barbara F gas installation (Committee for safety of offshore operations, 2020): the collapse of a crane during load transfer from a supply vessel led to a fatality and two injuries. This was the only reportable incident recorded and investigated in the observed period. The calculation of FAR using data for a single fatality occurred in 8 years of observation is deemed to have low statistical significance. However, the data clearly confirm the nature of both fatalities and reportable incidents as rare events.

As regards leading indicators, the reports contain information on the number and duration of the on-site inspections carried out by the inspectors of the national authority (Table 1). The inspections share the common goal to verify the proper conduct of production platforms, both from the perspective of occupational safety (i.e., workplace safety) and from the standpoint of plant and environmental safety (i.e., major risks and environmental damage prevention). The activity of inspectors on offshore platforms is often of a preventive nature and is accompanied by the drafting of reports in case anomalies are identified. Inspections constitute the primary form of regulatory oversight essential for Competent Authorities (CAs) when overseeing offshore exploration or production activities within their jurisdiction (Walker & Tarantola, 2018). These inspections, while not exhaustive in their coverage of every aspect of an installation, should not be regarded as a substitute for the operators/owners' internal audit processes. Instead, CA inspection activities aim to provide a comprehensive assessment of how installation operators and owners adhere to their legal obligations, focusing on key safety and environmental management systems through a representative sampling approach.

The available data allow for the definition of leading indicators that provides a measure of the presence of inspectors on-site: the presence of representatives of the Authority is seen as a deterrent element against the improper conduct of the facilities. Two indicators are defined as follows in order to valorise the available information, named II_1 and II_2 (II stands for Inspection Intensity):

$$II_1 = \frac{PD}{n_0}; II_2 = \frac{NI}{n_0} \quad (3)$$

where PD is the number of person-days dedicated to inspection execution, excluding the time spent on travels, NI is the number of inspections in a year, and n_0 is the total number of installations in the Italian offshore.

Both indicators show a decrease over the first part of the period, which shall be considered also in the perspective of the decrease of production over the observed time period. In the last part of the period, the introduction of new policies by the competent Authorities promoted a steep increase of inspection activity, both in terms of effort (i.e., higher number of person-days as recorded by II_1) and of extension (i.e., higher number of

installations inspected as recorded by II_2). The leading nature of these indicators and the low number of accidents recorded by the lagging indicators in the last two years of the analysis, suggest that the new policies introduced over the observed time period had positive contribution on the safety of the system and that the action shall be carefully maintained in the years to come.

5. Conclusions

The primary regulation governing safety in Italian offshore hydrocarbon production is the Legislative Decree n. 145/2015, aligning with the European Directive 2013/30. This decree establishes a Competent Authority, the "Committee for Safety of Offshore Operations", responsible for the supervision of various maritime safety issues. These include regulatory compliance, risk assessment, emergency response planning, and the promotion of best practices. The Authority's main goal is accident prevention, covering safety, and environmental protection in maritime activities. The Competent Authority issues an annual report to Italian Parliament and European Commission detailing offshore activities, production system specifications, regulatory outlook, and incident data for the reference year.

The analysis of the available data from these reports (years from 2016 to 2023) was possible by the use of Key Performance Indicators. The data includes the number and type of offshore installations, total offshore working hours, total oil and gas production rates, reported inspections conducted offshore and data on fatal and non-fatal accidents occurred. Through the examination of these quantitative indicators, the good state of the safety of Italian hydrocarbon upstream activities was confirmed. The role of inspection as a tool for effectively overseeing the performance and assessing the operator/owner's capacity to adhere to the controls and requirements stipulated in the existing regulations is highlighted.

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