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Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio

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Worldwide improvement in offshore risk levels – will it extend to green energies?

Jan-Erik Vinnem

Preventor, Norway. E-mail: jan.erik.vinnem@preventor.no

Worldwide offshore safety statistics are published by the IOGP and IRF, the PSA is publishing extensive statistics for Norway. The components of the fatality risk picture are occupational accidents, major accidents on the installation, and transportation accidents during transfer between shore and offshore installations. While some of these accidents were relatively common in the first 15-20 years, there has been a significant reduction of the number of fatal accidents, and there is now often a few years between fatal accidents in the North Sea and associated waters, even the occupational accidents, which are the least rare occurrences.

These components of risk are considered to be applicable to emerging offshore energy industries, such as offshore wind, sun and waves, as well as offshore mining. Risk exposure for these industries is discussed on the basis of experience from the offshore petroleum industry, making observations about the likely risk exposure and which remedial actions that should be taken.

Keywords: Fatality risk, major hazards, occupational accidents, helicopter accidents, offshore petroleum, green energies.

1. Introduction

The offshore industry in the North Sea and associated waters has operated for almost 60 years, since the first exploration activities were conducted in the early 1960s.

The safety records were not good at all in the beginning, especially in the Norwegian sector where the conditions were hostile. In the Norwegian sector in the late 1970s there were a few dozens of fatalities virtually every year, from occupational accidents, helicopter accidents and major accidents (i.e. an acute occurrence like large spill, fire, explosion or structural failure that immediately or latently may cause several fatalities, serious injuries, large spills or loss of assets). The high levels peaked in 1980 with the capsizing of the flotel Alexander Kielland, resulting in 123 fatalities in the ice-cold water of the North Sea in late March (NOU, 1981). This accident had massive influence on the development of Norwegian offshore safety regulations for the petroleum industry.

UK had a similar devastating experience in 1988, with 167 fatalities on the Piper Alpha platform due to an uncontrolled explosion and fire (Lord Cullen, 1990), which initiated a regulatory development of the Safety Case Regulations (HSE, 1995).

Both countries have had dramatic improvements in offshore safety statistics since then, the latest major accident with fatalities in Norway was in 1985, and in 1989 in the UK. Fatal helicopter accidents as well as fatal occupational accidents have also been very significantly reduced.

Norwegian Petroleum Directorate (NPD) started up in 2000 the annual reporting of risk and safety for offshore and onshore petroleum activities (RNNP), which give an excellent source of statistical data as well as more qualitative information about safety aspects. This was taken over by Petroleum Safety Authority (PSA) when formed in 2004. UK reporting is more limited, but essential data are available. There has also been improvement in other offshore petroleum regions, but not as dramatic as in the North Sea and associated waters (Norwegian Sea, Barents Sea, West of Shetland, etc). There is also a lack of data sources that give complete worldwide coverage.

There was a national tax relief scheme in Norway from mid 2020 to the end of 2022, to stimulate new developments during the Covid period. There is an expected surge of new projects to be developed in the Norwegian sector for the coming few years, mainly subsea tie-ins, but also a handful of surface installations, the majority of which will be unmanned.

The climate concerns are obviously important for the offshore petroleum industry being one of the main sources of fossil fuel producers. The Norwegian petroleum industry is claiming the cleanest production operations worldwide, but this does not affect the climate effects of fossil fuels. The Petroleum production in UK and Norway is expected to fall significantly towards 2050, but petroleum is still expected to be in use in 2050, and then to be climate neutral through carbon capture and other techniques. More and more installations are expected to be normally unmanned and manned a few times per year for maintenance purposes.

Offshore wind energy is expected to grow rapidly in the coming years, especially in the North Sea, and often in the same areas that also have the petroleum installations. The offshore wind energy installations are normally unmanned and pose as such a much lower risk for personnel. They also are lacking the high explosion and fire hazard involving hydrocarbons that is the main major hazard source on offshore petroleum installations. Some hazards will inevitably be mainly the same as for the offshore petroleum installations, during manned periods. It is therefore considered that major hazard risk management for the offshore wind energy installations to a large extent should take lessons from the offshore petroleum industry and employ several of the preventive and protective measures, although at a reduced scale due to the reduced hazards.

The author published a review of offshore risk levels in 2008 (Vinnem, 2008), which recently was updated in Vinnem & Røed, 2020). Tan et al. (2018) considered safety indices for the offshore petroleum industry and found that the attempts to develop a comprehensive safety performance index for the offshore oil and gas sector were few and far from comprehensive as well as mainly focused on lagging indicators.

Apart from these publications, there are very few published works on risk to personnel on offshore petroleum installations in recent years.

2. Worldwide Statistical and Factual Sources

2.1. *Fatality Statistics*

There are two independent sources of statistical data about fatal accidents in the offshore petroleum sector:

- Annual statistical summary by the International Association of Oil & Gas Producers (IOGP)
- Annual statistical summary by the International Regulators' Forum (IRF)

The most extensive data source for accidents in the worldwide offshore industry (as well as onshore operations) is the IOGP annual statistical summaries, which have been published since 1998. The report covers occupational accidents, major accidents and transportation accidents, for company personnel as well as for contractors. Data for 2021 has been published.

One critical limitation of IOGP data is that the reporting is based on company membership in IOGP, and there are several well-known companies that are not members, such as ONGC in India, Petrobras in Brazil and Pemex in Mexico. The members are known, but it is not known what accidents that are excluded from the IOGP statistics, except what can be inferred from media reports.

The other source is annual statistics published by the IRF, based upon reporting from their 11 member countries;

- Australia
- Brazil
- Canada
- Denmark
- Ireland
- Mexico
- The Netherlands
- New Zealand
- Norway
- United Kingdom
- United States

Many countries are missing, India, China, Middle East and African countries. The data set is therefore limited. Data for 2021 has not been published, 2020 is the latest year available.

It should be added that the statistical data is particularly good for the Norwegian petroleum sector, as PSA publishes the annual risk level report (RNNP). This report is one of the main sources of the present section.

2.2. *Investigation of Serious Major Accidents*

Investigations from authorities and/or private companies regarding serious accidents and near-misses are valuable information sources which can provide essential experience that may help other companies to learn how to avoid similar occurrences. Some companies publish investigation reports, Equinor in Norway is probably the most open company.

It is therefore valuable that authorities (sometimes investigation boards) in the following countries publish investigation reports from serious occurrences:

- Australia
- Brazil
- Canada
- Norway
- United Kingdom
- United States

There may actually be more countries that would publish investigation reports, but so far they have not experienced severe accidents, this may apply to Denmark, Ireland, The Netherlands and New Zealand.

Mexico on the other hand has had several serious accidents during the last ten years, but no reports have been published from these occurrences. The National Agency for Safety, Energy and Environment of Mexico was contacted some years ago to inquire about investigations, but none were available in the public domain. Other authors have also focused on these limitations (Bud's offshore energy, 2022)

None of those countries that are not members of the IRF are known to publish investigation reports.

3. Experience from Fatal Accidents – Norway

Figure 1 shows the development of Fatal Accident Rates (FAR) in the last 30 years, presented as 20-year rolling average values for production installations, mobile drilling units and attendant vessels for the Norwegian Continental Shelf (NCS).

It is essential to distinguish when reporting FAR values between manhours expressed as 'working hours' or 'exposure hours', which is the sum of working hours and off-duty hours. Exposure hours is usually twice that of working hours. This paper uses exposure hours consistently.

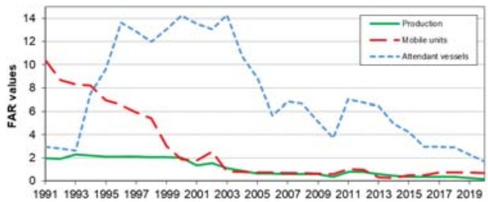

Figure 1 FAR development, NCS, 1991–2021 (Source: Preventor)

For production installations in Norway the last fatality occurred in 2009, for MODUs the latest fatality occurred in 2017, whilst the corresponding year was 2007 for vessels. The values reported for 2021 are (fatalities per 108 exposure hours):

- Production: 0.17
- MODU: 0.67
- Attendant vessels: 1.10

Figure 1 shows that there has been a significant reduction in FAR-values, especially for MODUs and for attendant vessels after 2003. For production installations there has been a gradual decrease over the entire period.

The values presented in Figure 1 are in practice occupational accident rates, as there have been no major accidents with fatalities in the period 1991–2021, see further discussion below.

3.1. *Major Accident Fatality Rates*

Norway had several major accidents in the 1970s but has had very few major accidents in the last 30 years. The latest major accidents are:

- Production installations:
    - Subsea gas blowout, Snorre Alpha, 2004, no fatalities
- Mobile drilling units:
    - Shallow gas blowout, explosion and fire, West Vanguard, 1985, 1 fatality

It is therefore not possible to predict a frequency of major accidents for the Norwegian sector, based on statistics. The frequency is not zero, and the RNNP annual report has presented mainly stable levels of precursor events (see below).

An attempt to predict FAR values from major accidents in the Norwegian sector (Vinnem, 2008) reported the following predictions, as average FAR values for the period 1990–2006:

- Production installations: 0.59 per 10^8 exp. hours
- Mobile drilling units: 1.40 per 10^8 exp. hours

It would not be unrealistic to assume 50% reduction in major accident fatality rates since 2006. With respect to occupational accidents, there is an improvement factor of almost 4.0 from 2006 to 2021, for MODUs there is only a slight improvement.

If this 50% improvement is assumed, then the contribution from major accidents would be somewhat higher (75%) than the contribution from occupational accidents for production installations, and about equal contributions for MODUs.

3.2. *Severe Injury Cases*

The annual RNNP report presents statistics also for occupational injuries for all injuries and for severe injuries. There is a definition of 'severe injuries' in the regulations, but in practice it corresponds to injuries that need hospitalisation. The advantage of using severe injuries is that underreporting is unlikely, whereas underreporting is a know aspect in relation to occupational injuries in general.

The frequency of severe occupational accidents for the Norwegian sector has been virtually constant in the period 2011 to 2021, see Figure 2. The value is around 0.6 severe injuries per 10^8 working hours (exposure hours not relevant for occupational accidents) with some limited variations from year to year. Some variation is to be expected, as the number of such cases is around 30 per year for the entire NCS.

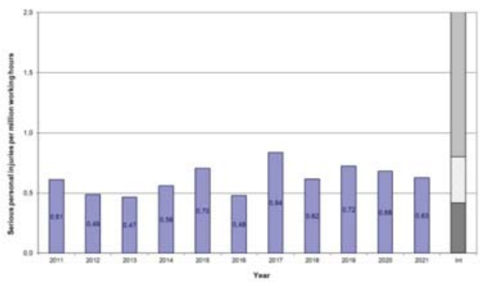

Figure 2 Serious occupational injuries, NCS, 2011–2021, (Source: PSA)

3.3. *Evacuation Cases*

Emergency evacuation of personnel to sea in the case of major accidents was a hot topic 40 years ago in Norway after several major accidents where evacuation was the main source of numerous fatalities:

- Alexander Kielland, Norway, 1980, 123 fatalities
- Ocean Ranger, Canada, 1982, 84 fatalities
- Enchova, Brazil, 1984, 42 fatalities
- Piper Alpha, UK, 1988, 167 fatalities
- Usumacinta, Mexico, 2007, 22 fatalities

All these accidents occurred more than 30 years ago, with one exception. Only one of these accidents occurred in Norway. Nevertheless, there was high focus on improvement of evacuation means in Norway some 40 year ago, and the free-fall lifeboat concept was developed. This is now the requirement for evacuation means on production installations in the Norwegian sector. Also a number of MODUs as well as commercial ships have installed free-fall lifeboats.

All emergency evacuation cases in the UK and Norwegian sectors in the last 30 years have been carried out by helicopter. But there is still a requirement to install free-fall type lifeboats in Norway, as there are some accident scenarios where helicopters would not be available, typically involving fire and/or explosion (such as the Piper Alpha).

It is also noteworthy that no offshore installation nor ship with free-fall type lifeboat installed has ever had a real-life need for evacuation by these free-fall lifeboats. Tens of thousands of training launches have been carried out but no real-life evacuations.

3.4. *Precursor Events Statistics*

PSA in its annual risk level report (PSA, 2022) publishes major accident precursor events statistics, for precursor events that are considered to have major accident potential, typically fire, explosion, blowout, major structural failure, marine system failure and external impacts (ship collision).

Figure 3 shows the trend from 2005 to present, where the clear reduction from 2005 to 2013 can be seen. The virtually constant level from 2013 until present is similarly obvious.

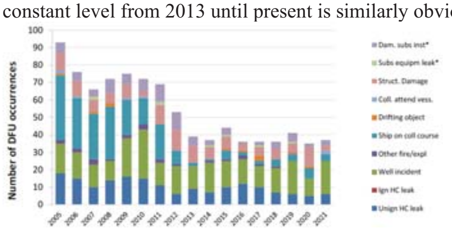

Figure 3 Reported precursor events by category, NCS, 2005–2021 (*-within safety zone, Source: PSA)

The influence of scenarios with release of hydrocarbons (HC leaks, blowout) is obvious. The contributions are varying from year to year but are in all years at least 50%. Each of these precursor events may develop into a full scale major accident with numerous fatalities if several barriers fail simultaneously, and there are in average around 3 such events every month. This underlines that the risk for major accidents with multiple fatalities is not zero, although the last such accident with fatalities was more than 35 years ago.

3.5. *Helicopter Accidents*

30 years ago the thumb rule with respect to risk exposure of offshore employees was that one third of their risk exposure was from occupational accidents, another third was from major accidents on the installations and the final one third from helicopter accidents. Vinnem (2008) showed that the relative contributions had changed somewhat, but not dramatically, at least not for production installations.

A new distribution is not the scope of the present paper, but this reference aims to remind us that helicopter risk is a significant risk contributor for offshore employees.

Helicopter safety has improved significantly during the last 30 years, both with respect to technical barriers as well as operational procedures and constraints. This applies mainly to regions where all helicopters are twin engine and two pilots.

But the risks can never be eliminated, helicopters have one significant disadvantage compared to fixed wing aircrafts, in that the main gearbox and rotors can never be designed with redundancy, if the main gearbox, the main or tail rotor fail, then a fatal crash is the quite likely outcome.

The annual RNNP report from PSA has some indicators for helicopter safety, one indicator is presented in Figure 4. This also shows that the level has been approximately constant the last ten years or so.

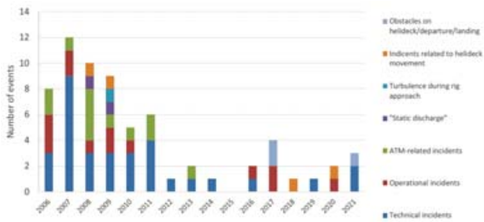

Figure 4 Helicopter accident precursor events, NCS, 2006–2021 (Source: PSA)

Vinnem & Røed (2020) predicted 80 helicopter fatalities per 10^8 person-flight hours by helicopter. This applies to modern large twin-engine, two pilots helicopters (all personnel transportation on NCS carried out by Sikorsky S92 at present) operated with the high safety standards that apply to all offshore helicopter traffic on NCS, with higher standards than the international level.

But helicopter accidents have not been eliminated, they occur seldomly, but still with a notable frequency. Two fatal accidents have occurred in the Norwegian operations int the last 30 years, in 1997 and 2016. No survivors in any of these two crashes, with respectively 12 and 13 fatalities.

4. Experience from Accidents – Worldwide Operations

The preceding chapter has presented a high level picture of the risk levels for personnel in the Norwegian offshore petroleum sector. The aim in this chapter is to illustrate the same for the worldwide petroleum industry and compare that to the levels in Norway.

4.1. *Major Accident Fatality Rates*

Figure 5 presents the development of worldwide offshore FAR-values, based on exposure hours, for IOGP members, noting the limitations described in Section 2.1 above. We have manually added some major accident fatalities from known major accidents that have occurred (and manhours), irrespective of whether the companies involved were IOGP members or not. Only accidents on installations are included.

The contributions from major accidents are significant, in the last 20 years six out of seven years when the risk levels have peaked have been due to major accidents.

The falling trend in occupational accidents is very significant, the value in 2004 is 3.0 which drops by a factor of 10 to 0.31 in 2021.

It is also noteworthy that there has been one dozen known major accidents during the last ten years worldwide:

- Explosion & fire, FPSO Sao Mateus (Brasil, 2015)
- Explosion & fire, Abkatun production platform (Mexico, 2015)
- Fire, SOCAR production platform (Azerbaijan, 2015)
- Fire, Abkatun production platform (Mexico, 2016)

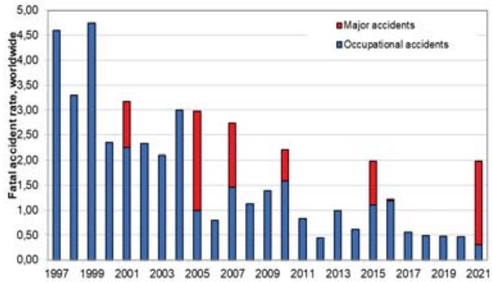

Figure 5 Worldwide FAR values for IOGP members, 1997–1921 (Source: Preventor)

- Structural loss, accommodation unit (Azerbaijan, 2016)
- Collision, supply vessel, production platform (Malysia, 2020)
- Burning blowout, Penglai 19-3 V platform, Bohai Bay (China, 2021)
- Capsized liftboat, Seacor Power, GoM (US, 2021)
- Jack-Up rig sinking after punch through, Velesto Energy (Malaysia, 2021)
- Capsized and sinking accommodation barge due to cyclone, ONGC Mumbai High (India, 2021)
- Fire in turbine/compression area on Production platform, Pemex (Mexico, 2021)
- Explosion and fire on FPSO Trinity Spirit, Shebah Exploration & Production (Nigeria, 2022)

It is noteworthy that at the present time, the only accident where an investigation report has been published is the explosion and fire on FPSO Sao Mateus in Brazil 2015 (ANP, 2016). Not all of these accidents have caused fatalities, but some are unknown. There is no official source for these accidents, information has to be collected from media reports.

Figure 6 presents the development of worldwide offshore FAR-values, based on exposure hours, for IRF members, noting the limitations described in Section 2.1 above. We have manually sorted the reported fatalities into occupational and major accident fatalities from known major accidents that have occurred. Only accidents on installations are included.

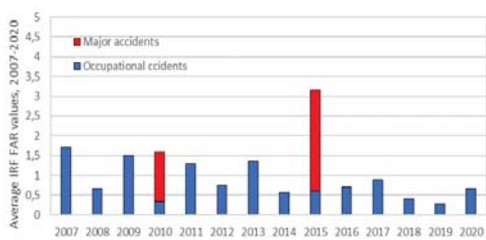

Figure 6 Worldwide FAR values for IRF members, 2007–2020 (Source: Preventor)

Not all IRF members report all relevant data each year. The Usumacinta accident in Mexico in 2007 with 22 fatalities during evacuation was not included in Mexico's data for 2007.

The values in Figure 6 are lower than in Figure 5, which probably reflects that most of the countries that are members of the IRF organisation have a high focus on systematic offshore safety, i.e. those countries with lower focus are not members.

It could be noted that the values in the last five years are not very different.

If we compare occupational and major accident fatalities based on IOPG data, we get the following average FAR-values worldwide for the period 2011–2021:

- Occupational accidents: 0.66 per 10^8 exposure hours
- Major accidents: 0.27 per 10^8 exposure hours

4.2. *Severe Injury Cases*

Figure 7 presents a comparison of FAR-values and severe injury frequencies for IRF members.

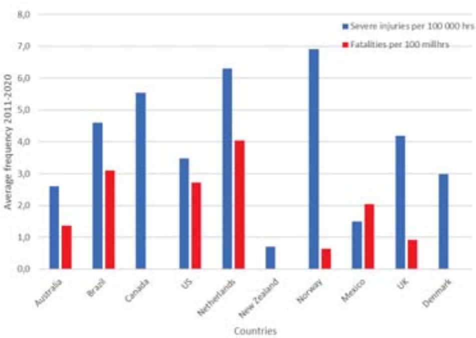

Figure 7 Severe injuries and FAR-values, IRF members, average 2010–2020 (Source Preventor)

All countries have reported severe injuries, at least for some years. Some countries have never reported fatalities, most likely because there have been none. These countries; Canada, New Zealand and Denmark together have just over 2% of the total manhours reported by IRF.

When these three countries are disregarded, Norway has by far the lowest FAR-value between these ten countries. Norway has on the other hand the highest frequency of severe injuries, New Zealand has the lowest frequency, Canada has a relatively high value, and Denmark is in the middle.

What is unknown is if all countries have the same definition of 'severe injury' and information about reporting completeness. The comparison is thus somewhat uncertain.

4.3. *Evacuation Cases*

Section 3.3 listed cases of emergency evacuation to sea, from which it could be noted that only one case has occurred the last 30 years, in Mexico in 2007, where an investigation report was published by the company.

This is probably not representative, because it is known that evacuation to sea has occurred in some of the major accidents listed in Section 4.1, but the details are not known, since all accident investigations are missing from the public domain. For instance, media reports indicate that most of the 22 fatalities in the capsized and sinking of accommodation barge in the ONGC Mumbai High field were due to failed life-rafts, but the details are unknown.

The lack of investigation reports is thus a severe restriction on the possibility to learn from these accidents.

4.4. *Precursor Events Statistics*

Figure 8 presents the only statistics related to precursor events that are available from worldwide operations, based on those IRF members that report such data. Reporting thresholds are not known. Mexico has only reported for three years, and the values appear to use different thresholds compared to the other countries.

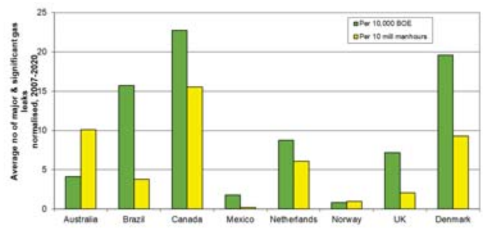

Figure 8 Number of major & significant gas leaks, IRF members, average 2011–20, normalised against production and manhours (Source: Preventor)

If Mexico is disregarded, the countries with the three highest levels are Canada, Denmark and Brazil. The two lowest countries are Norway and UK, followed by Australia and the Netherlands.

4.5. *Helicopter Accidents*

Helicopter statistics is based on accidents in Canada, Norway and UK in the period 2006–2020, which according to Vinnem & Røed (2020) have had the following fatal helicopter accidents:

- 2006: UK, close to North Morecambe platform, 7 fat.
- 2009: UK, cruising Miller–Aberdeen, 16 fatalities
- 2009: Canada, cruising over sea, 17 fatalities
- 2013: UK, outside Sumburgh airport, 4 fatalities
- 2016: Norway, cruising from Gullfaks to Bergen, 13 fat.

Originally it was intended also to include all helicopter accidents in US Gulf of Mexico operations, until statistics from Helicopter Safety Advisory Conference[1] showed that all fatal accidents (13 with 23 fatalities) in the period occurred with single engine helicopters, used mainly for near-shore installations. If only data for twin engine helicopters are included for the US, no accidents and reduced number of flight hours and exposure hours result.

A total of 57 fatalities has occurred in the five helicopter accidents. There may also be one or two additional helicopter accidents in other countries, but the details are not known. There are also a number of non-fatal accidents. We will therefore base the frequencies on data from Canada, Norway, UK and US limited to twin engine two pilots helicopters.

Average helicopter FAR-value (per 10^8 hrs) for these four countries may then be expressed as follows (assuming total of 20 hours flight time per person per year):

- FAR per offshore exposure hours: 1.17
- FAR per person flight hours: 117

The FAR-value for helicopter transportation of personnel to/from offshore installations was predicted at 80 per person flight hours for the Norwegian sector in Vinnem & Røed (2020).

[1] www.hsac.org

5. Emerging Offshore Energy Industries

The sections above have shown that offshore petroleum risk levels have been substantially improved over the last 20–30 years, to levels that often are lower than for onshore industries. It would seem natural to build on these experiences when it comes to emerging offshore energy industries, at least to the extent that the hazards are similar.

5.1. *Overview of Technologies*

Climate issues are being debated intensely in relation to fossil fuels energy sources. Some will abandon fossil fuels 'tomorrow', but many acknowledge that fossil fuels will have a significant part to play for still many years but will be substantially reduced and have to become CO_2 neutral in order to be able to continue. The use of fossil fuels is in any case likely to start to decline from around 2030, and new green energy sources will have to take its place.

Wind and sun energy are two obvious green candidates to be expanded rapidly to replace fossil fuels. Wind turbines on land have become somewhat unpopular during the last few years (at least in Norway), and there are considerable expectations for offshore wind to be expanded rapidly in Norway in the coming years. Offshore Norway has hostile environment which may be a challenge technologically but provides a large scale wind power source. Both fixed structures and floating structures will be utilised, depending on the water depth.

The structural issues can be solved based on extension of the offshore petroleum structural technology. Operation and maintenance will have a lot in common with the latest unmanned offshore installations but will probably be less.

Offshore sun is also a possible candidate, but offshore Norway is perhaps not the best locations for this technology.

Offshore waves should on the other hand be a good candidate offshore Norway, but it is not apparent that technological challenges have been solved so far.

Offshore mining may represent a stretch of the term 'emerging offshore energy', but minerals that are being searched by offshore mining companies are claimed also to be important for the 'green transition'. The extraction technologies appear to have a lot in common with offshore petroleum production technologies, which also makes it natural to include it in the present context.

Offshore mining is assumed to take place from surface vessels that are linked physically to extraction equipment on the sea bottom, which compares to offshore petroleum Drilling ships and FPSO (Floating Production Storage and Offloading) vessels of the ship-shaped type, which are connected to production wells on the sea bottom. The flowlines between sea bottom and the surface vessel may not be identical but would be expected to show some similarity.

The Petroleum Safety Authority of Norway which has had responsibility for the petroleum industry for about 20 years since being separated out of the Norwegian Petroleum Directorate in 2004. PSA has recently been given the responsibility for the new emerging offshore energy technologies, including offshore wind, sun, waves and offshore mining in addition. Nevertheless, there is a debate about which safety regime to follow, this is discussed below, with the main focus on offshore wind.

5.2. *Main Hazards – Offshore Wind*

The main hazards for personnel are associated with the periods when the installations are manned, which will be just a few periods per year. The types of hazards will be the same as for offshore petroleum installations:

- Occupational accidents
- Major accidents
- Personnel transportation accidents

Occupational accidents will be parallel with offshore petroleum and result from occupational hazards on the installations, including Man Overboard (MOB) accidents.

Major accidents will be quite different from offshore petroleum since hydrocarbons as source of explosion and fire are not present in significant quantities. Major accidents will be limited to catastrophic structural failure. Some fire scenarios will still be possible, but not similarly dramatic as with hydrocarbon fuelled scenarios.

Emergency evacuation will be a potential scenario during manned periods, associated with major accidents, thus limited to catastrophic structural failure or external impacts from vessels. Vessel collision between a service vessel and wind turbine structure is also a relevant hazard and has occurred in 2020 in the Southern North Sea (Jersey Maritime Admin., 2020), with significant but not catastrophic structural failure.

Personnel transportation accidents imply helicopter accidents for offshore petroleum installations. This is unlikely to be used for transportation of maintenance personnel to offshore wind installations but may be used for some other technologies.

Maintenance personnel for offshore wind installations would be transported with so-called Walk-To-Work (W2W) vessels, which also will serve as their 'homebase' (for off-duty and accommodation purposes) during the maintenance periods on the wind energy installations. There vessels are connecting to the installations with a heave-compensated bridge for personnel transfer, and the operations need relatively calm weather.

Personnel transportation by vessel is significantly less hazardous compared to helicopter transportation especially due to the calm weather restrictions (personnel transfer between vessel and facility need calm sea). Such personnel transportation is therefore neglected with respect to transportation risk.

The following are the applicable hazards for an offshore wind energy installation:

- Occupational accidents, including MOB
- Major accidents, including emergency evacuation

5.3. *Main Safety Challenges*

The offshore safety regime as it has been developed during the last 40 years in Norway has been very successful, as was demonstrated in Section 3 above. Similarly for the UK offshore petroleum industry the last 30 years. It may therefore appear as a natural evolvement that new offshore energy technologies should be based on the same regime.

But industry representatives in Norway appear to favour the marine safety regime, as opposed to the offshore safety regime. The international marine safety regime is based on IMO (including SOLAS) regulations. Norway and some other countries have stricter requirements in some areas. The marine safety regime is claimed to represent lower costs for the industry.

It is outside the scope of this presentation to present an extensive comparison of the marine and offshore safety regimes. It is this author's conviction that the offshore safety regime has demonstrated significantly better safety-wise performance than the marine safety regime.

Partial illustration of some of these aspects can be found in Sections 3 and 4, where vessels in Norway in association with the offshore industry have over several decades shown higher risk levels for the crew members. Also the differences between risk levels offshore in Norway compared to countries that mainly base their regulations on the marine safety regime tend to illustrate such a difference.

The logic of deselecting the offshore safety regime is difficult to understand, except as a cost reduction exercise. The offshore petroleum safety regime has been shown to give very high safety standards in both UK and Norway. The emerging offshore energy industries are supposed to build on the offshore petroleum technologies and represent the green solutions for the future.

But the safety regime which has been shown to be superior will not be extended to the new technologies, according to the wishes of the offshore wind industry. This does not appear to be logical.

Some of the main players in the offshore wind industry are the same companies that also are heavily involved in the offshore petroleum industry in Norway and thus very well familiar with the offshore petroleum safety regime in Norway. Their lack of willingness to adopt the same regime for offshore wind, tends to suggest that they may wish in the future to abandon the offshore petroleum regime also.

If the new industries cannot afford the high safety standards, then they are not the sustainable green solutions for mankind for the future.

5.4. *Main Lessons from the Petroleum Industry*

If the ambition is to let the high Health, Environment and Safety (HES) standards of the offshore petroleum industry be adapted to the emerging offshore energy industries, it would be expected that several initiatives and ambitions would be applied to this industry:

- Utilising experience and best practice from the offshore petroleum industry in the design of structures
- Utilising experience and best practice from the offshore petroleum industry operation of such structures
- Utilising experience and best practice from the offshore petroleum industry in the maintenance periods, especially with respect to use of W2W vessels connected to the wind energy facilities
- Planning of emergency evacuation in the case of abnormal incidents in the same manner as offshore petroleum (lower frequency likely)
- Planning assistance to man-over-board scenarios in a similar manner as the offshore petroleum industry (lower frequency likely)
- Planning rapid assistance to persons who are seriously injured or fall ill during maintenance work including transportation to onshore hospitals.

It should be noted that all cases of evacuation in the UK and NCS waters have been completed by helicopters landing on the helidecks during the last 30 years. This would not be available on wind energy facilities, as they would not have helideck. Picking up personnel by winching personnel from the facilities to the helicopter would normally take too long time in an emergency situation. Only SAR helicopters would in any case have this capability.

The new offshore energy industries may take an advantage from location in the same areas as the offshore petroleum activities take place. The Norwegian offshore petroleum industry has established emergency cooperation schemes in areas of the NCS, that in many cases could be extended also to new energy facilities.

6. Discussion

6.1. *Representativity of past experience*

The use of accidents statistics (from the past) to predict future risk levels always builds on the assumption that the future will be similar to the past. New technologies are on the one hand developed continuously, it is for example expected that complex unmanned petroleum production installations will be installed in the North Sea in the coming few years.

But at the same time, more than 80% of the offshore installations in operation today are likely to be still in operation ten years from now. This tends to suggest quite strongly that the future will be similar to the past, at least for the large majority of operations. The applicability of accident statistics should therefore be reasonably good, at least as long as the framework conditions are mainly unchanged. There are indications in Norway that framework conditions have been changed significantly (Safetec, 2023), but this is outside the scope of this paper.

The more difficult question is relating to the quality of the statistics. We have seen in Section 2.1 that none of the two main sources of worldwide fatality accident statistics are complete, both IOGP and IRF report statistics for their members, and there are very significant limitations in their membership. Other authors have also focused on these limitations (Bud's offshore energy, 2023)

We may fear that only the responsible actors are members of the IOGP, and the limitations of the membership in IRF was noted in Section 2.1. The worldwide statistics shown in Section 4 could in theory have significant omissions.

It is on the other hand unlikely that major accidents are not reported by media, and information about major accidents not included in the IOGP and IRF statistics have been added, as explained in Section 4.1. But occupational accidents with one or two fatalities may very well be unpublished and unnoticed. For instance, a media report informs about two fatalities on an FPSO in 2021 in the Ivory Coast waters[2], but the IOGP statistics for 2021 has no offshore fatalities in Africa.

The fact that both IOGP and IRF statistics show a falling trend is positive, but it is not known what is not included in the statistics.

6.2. *Offshore Major Accident Risk Levels*

In spite of the limitations regarding the statistics as discussed above the IOGP and IRF are the best available sources of risk to personnel in offshore petroleum operations, and they have to be used. If we sum up the fatality risk contributions worldwide from Section 4, these frequencies are (per 10^8 exposure hours):

- Occupational accidents: 0.66 (33%)
- Major accidents: 0.27 (14%)
- Helicopter accidents: 1.05 (53%)

The following contributions were reported by Vinnem & Røed (2020) for the Norwegian sector:

[2] https://www.marineinsight.com/shipping-news/bw-offshore-confirms-2-fatalities-in-an-incident-on-board-fpso-espoir-ivoirien/

- Production installations:
    - Occupational accidents: 13%
    - Major accidents: 44%
    - Helicopter accidents: 44%
- Mobile drilling units:
    - Occupational accidents: 39%
    - Major accidents: 30%
    - Helicopter accidents: 31%

6.3. *Is Norway the Worldwide Leader in Offshore Safety?*

The Norwegian government expressed in a White paper in 2001 that Norway's ambition was to become world leader in offshore petroleum HES. This was accepted by the parliament ('Storting') of Norway and has been reaffirmed several times since 2001, and also accepted by Offshore Norway, the industry's umbrella organisation. The present position may be summarised as follows:

- Accident statistics in Section 3 and 4 show that Norway has the lowest levels of the main components.
- Several countries have functional regulations, but Norway is the only country to have additional minimum prescriptive requirements in addition to functional requirements and ALARP.
- Norway has had an ambitious working environment law since 1977 which also early on was applied to offshore operations and installations in an unparalleled way.
- Norway is the only country to have emergency resources stationed offshore in order to provide rapid response to personnel in need of rapid assistance, either to be rescued from the sea or transferred to hospital for intensive care.

When we consider the statistics in Chapter 3 and 4, the conclusion is that Norway, possibly together with the UK, is in the forefront of the worldwide offshore petroleum industry. Without going into the discussion in detail, we may observe that the strict Norwegian regulatory framework appears to pay off in terms of low risk levels.

The challenging question to respond to is whether this situation can be expected to last or not? Some indications that at least parts of the industry are not so focused on this ambition were suggested in Section 5.3.

There are also other indications of less focus on offshore HES in Norway. There have been very significant changes of the operational concept on offshore installations since the middle of 2010s. The overall effect of these changes is summarised as reducing the robustness of the operations with respect to occupational accidents as well as major accidents (Safetec, 2023).

It is therefore not at all certain that the leading position can be maintained during the next couple of decenniums, although the hope is still there.

6.4. *Applicability to Emerging Offshore Energies*

Offshore wind energy, especially in hostile environments such as the Northern North Sea and the Norwegian Sea is a new industry in Norway and also elsewhere. Should it be allowed to make its own experiences, possibly with severe consequences, as was the case for offshore petroleum in the North Sea in the 1970s and 1980s?

This does not appear to be logical, as it would be significantly better to build on the experience and best practices from the offshore petroleum industry in order to avoid that the industry makes its own negative experiences.

7. Conclusions

Fatality risk levels have been reduced significantly in worldwide offshore petroleum operations since year 2000. The reduction has been particularly strong in Norway and the UK.

We have considered the completeness of worldwide statistics and have shown that there are significant gaps in the international reporting of accident statistics. Also investigation reports in the public domain for experience sharing, are lacking from many countries and companies.

It is important for the offshore industry to be able to learn from past accidents in order to improve in the future. The lack of publication of investigation reports from major accidents is a serious disadvantage and a strong limitation on the possibility to learn from such occurrences.

The IRF is a very useful organisation and its statistics is valuable. It may now be time for IRF to take a next step, possibly to take a responsibility for publication of offshore statistics and investigations from members as well as non-member countries.

The offshore wind industry of Norway and similar countries should adopt the offshore petroleum safety regime, obviously tailored to the extent of the applicable hazards. If the new industries cannot afford the high safety standards, then they are not the sustainable green solutions for mankind for the future.

References

ANP, (2016). Investigation report of the explosion incident that occurred on 11/02/2015 in the FPSO Cidade de São Mateus. ANP

Bud's offshore energy, (2022). Needed: an international standard on disclosing major incidents and releasing findings. https://budsoffshoreenergy.com/2022/02/16/needed-an-international-standard-on-disclosing-major-incidents-and-releasing-findings/

Bud's offshore energy, (2023). Concerns about the timeliness and completeness of IRF safety performance data. https://budsoffshoreenergy.com/2023/05/16/concerns-about-the-timeliness-and-completeness-of-irf-safety-performance-data/

HSE (1995) Prevention of fire and explosion, and emergency response regulations. HMSO, London

Jersey Maritime Administration, 2020. Investigation into the Causes of an Allision between the Windfarm Support Vessel Njord Forseti and a Windfarm Tower in the Southern North Sea on 23rd April 2020.

Lord Cullen (The Hon, 1990) The public inquiry into the piper alpha disaster. HMSO, London

NOU, 1981 Alexander L. Kielland Accident, NOU Report 1998:11. Oslo

Safetec, 2023. Changed framework conditions and consequences for working environment and safety in the petroleum industry (in Norwegian only), Safetec report ST-16962-3, 13.3.2023

Tang, KHD., Md Dawa, SZ: and Olugu, EU (2018). A review of the offshore oil and gas safety indices, Safety Science, 109, 344–352

Vinnem, J.E. (2008). On the risk to personnel in the offshore industry, presented at PSAM9, Hong Kong, 18–23 May, 2008

Vinnem, JE. and Røed, W. (2020). Offshore Risk Assessment, Springer, 4th Edition