Gravity-based structure for offshore wind

Status and development

WHITE PAPER
January 2026

Summary

As offshore wind continues to scale up in both turbine size and project complexity, the industry faces increasing pressure to identify robust, cost-effective, and environmentally sustainable foundation solutions. While monopiles currently dominate the market, gravity-based structures (GBS) are emerging as a competitive alternative—particularly in areas with challenging seabed conditions, noise restrictions, or a need for high local content requirements.

This white paper explores the evolution of GBS from their origins in oil and gas to their growing role in offshore wind. It highlights the technical maturity of concrete GBS, their long design life, and their potential for industrialization through methods such as slip-forming. With more than 650 GBS units installed globally across both sectors, the technology is proven and adaptable.

GBS offer several key advantages:

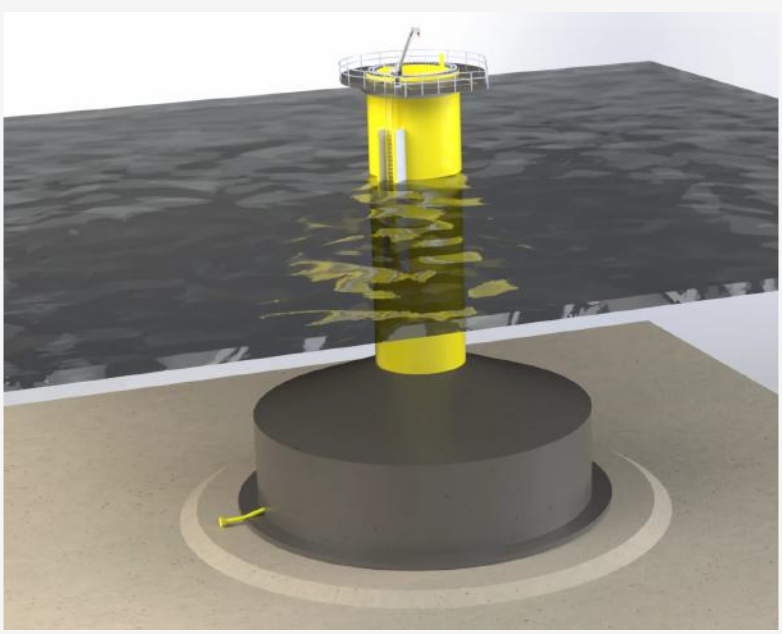
- Cost-competitive today
- Low-risk deployment and efficient installation
- Made in Europe
- Scalable solution
- Sustainable by design
- Built for longevity and circular economy

Introduction

Offshore wind has been facing headwinds the past years; high inflation, uncertainty regarding government policy and support, and the continuous increase in turbine size. However, The EU remains a strong offshore wind market and a key component of the energy supply solution.

As offshore wind is evolving from small <1MW turbines, to the predicted >25MW turbines, the optimal design of the foundations is still under development. The wind farm locations are also pushing into deeper waters and / or more challenging soil conditions. The majority of foundations in offshore wind are monopiles. This paper presents Gravity-based structures as a viable solution for the coming generations of offshore wind foundations.

GBS are large, heavy structures typically made of reinforced concrete, designed to rest directly on the seabed. Their stability is achieved through self-weight and, in some cases, additional ballast or skirts. GBS are used to support both oil & gas (O&G) platforms and offshore wind turbines. GBS offer a robust and maintenance-free alternative to steel piled foundations. As no piling is needed, it is ideal for noise-sensitive or hard seabed environments.



Objective

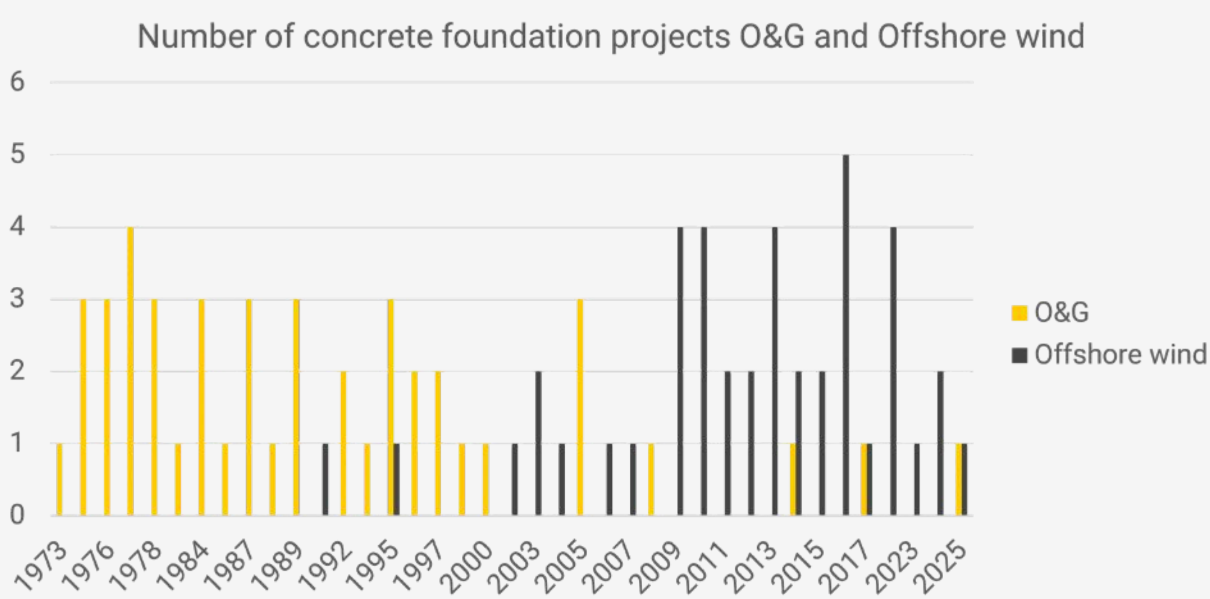
The objective of this white paper is to provide a detailed examination of the evolution and key characteristics of concrete GBS for offshore wind, and recent advancements in the sector.

This paper aims to trace the development of GBS technology from its origins in O&G applications to its current and future use in offshore wind, highlighting the significant knowledge transfer and design adaptations. Additionally, the paper outlines the differences between O&G and offshore wind requirements for GBS. To support these aims, the paper presents a comprehensive overview of installed GBS in both sectors and summarizes the various design methodologies and innovations developed to date.

Historical development of GBS

GBS are far from being a recent development; their history dates back several decades to the 1970s. Since their inception, these structures have played a crucial role in supporting offshore operations, particularly within the O&G industry as well as the rapidly expanding offshore wind sector. Over the years, GBS technology has proven its reliability and versatility, leading to widespread adoption across numerous projects. By 2025, it is estimated that around 45 oil and gas projects and 42 offshore wind projects will have implemented GBS solutions, bringing the combined total to roughly 650 installed units worldwide [4].

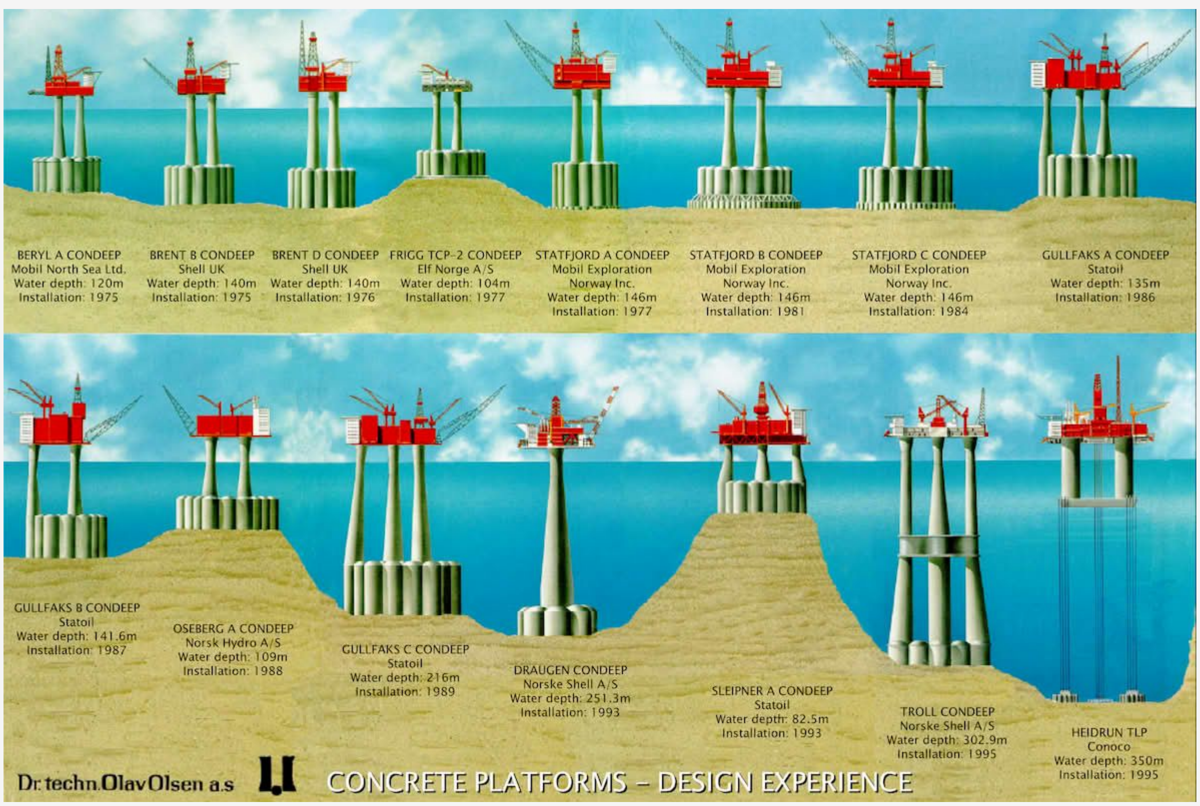
The accompanying graph illustrates the progression of GBS usage over time, showcasing a clear trend: while these structures were initially developed and predominantly used for O&G platforms, there has been a clear shift toward their application in offshore wind foundations. This transition reflects broader industry trends as renewable energy gains momentum globally. Although the fundamental principles of GBS remain consistent, the specific design requirements for oil and gas platforms versus offshore wind turbines differ due to variations in operational demands, environmental conditions, and load characteristics. The offshore wind sector has significantly benefited from the extensive engineering expertise and practical experience accumulated through decades of O&G projects.



GBS in Oil & Gas

O&G platforms have been built as one-off structures, engineered specifically for each project. These structures are tall and heavy, with shaft heights up to 300m and weighing between 300,000 and 900,000 tonnes (including ballast). The structures often feature large concrete caissons at the base and 1-4 vertical shafts extending to the surface to support the topside facilities.

The most prominent family of GBS designs in this sector is the Condeep series, developed by Dr. techn. Olav Olsen during the 1970s–1990s. One of the most iconic examples of the Condeep design is the Troll A foundation. The platform was installed in 1995. Standing at 472 meters, it remains the tallest structure ever moved by humans. The structure was built in Vats on Norway's west coast. The concrete foundation was designed to be in operation for 70 years as a gas production facility. Troll A is still operated by Equinor and is located at the Norwegian Continental Shelf [1].



Troll A, completed at what is now
AF Environmental Base Vats, is pictured
here during the tow-out in Yrkjefjorden.

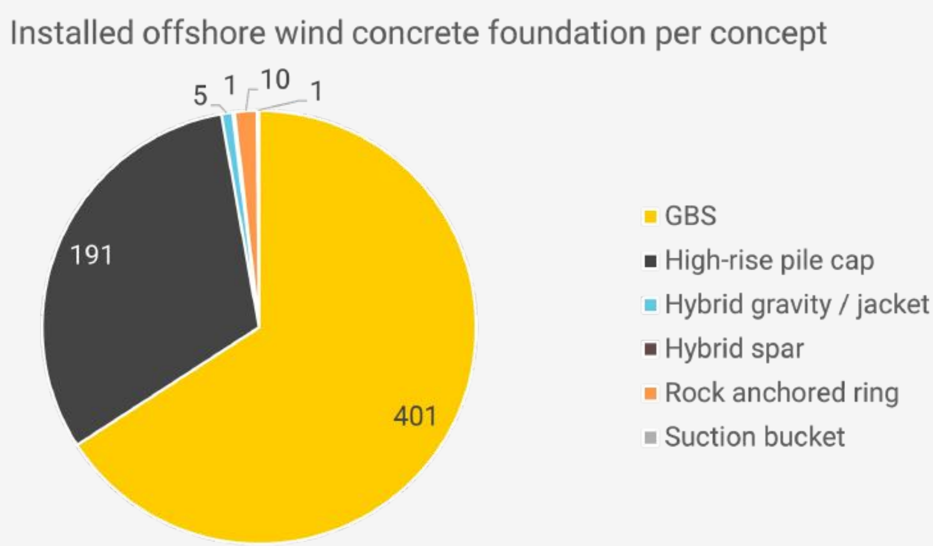
Picture: Stavanger Aftenblad, Rune Sævig

GBS in offshore wind

In contrast to traditional offshore structures from oil and gas, gravity-based structures used for offshore wind farms are distinguished by their simplified designs, which are specifically optimized for efficient mass production. These designs typically feature a single central shaft coupled with a bottom caisson, creating a stable foundation that can be manufactured and deployed relatively quickly and cost-effectively.

As of 2025, a total of 625 GBS units have been successfully installed across 42 offshore wind projects worldwide [4], underscoring the growing adoption of this technology in the renewable energy sector—see the chart below for detailed breakdown. The history of gravity-based structures in offshore wind dates back to Denmark in the 90s, where the earliest installations were situated in shallow coastal waters. Notable examples include the Vindeby, Middelgrunden, and Rodsand projects, which proved the viability of GBS foundations in relatively shallow marine environments. These initial projects paved the way for further innovation and adaptation as offshore wind development expanded into deeper waters.

With this shift to greater depths, the design of GBS foundations evolved accordingly: shafts were lengthened to accommodate increased water depth, and the weight distribution was intentionally concentrated near the seabed to enhance stability—an approach similar to traditional oil and gas platform designs.

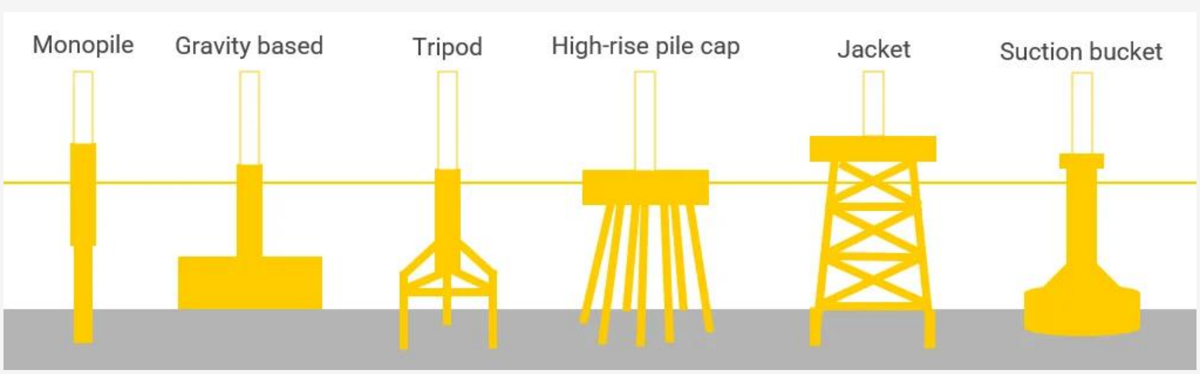


GBS designs in offshore wind

In both China and Japan, the high-rise pile cap design has been successfully implemented in several offshore projects. This approach typically involves a tall, robust pile cap structure that provides strong support for offshore installations. On the other hand, in Europe, engineers and developers generally prefer a more traditional approach with flat-bottom caissons and monopod shaft gravity-based structures. Such designs have gained widespread adoption thanks to their demonstrated reliability and suitability for the unique environmental conditions prevalent in Europe.

When considering the Baltic Sea region, additional challenges arise that influence foundation design choices. Certain areas within the Baltic Sea require ice-resistant skirts to protect structures from damage caused by ice movement during harsh winter conditions. Additionally, adaptations for shallow-water environments are necessary to ensure the stability and durability of the foundations in these settings.

The figure below illustrates the most common types of bottom-fixed structures currently available on the market for offshore wind applications. It is important to note that, with the exception of gravity-based structures and high-rise pile caps, most of these foundations are constructed primarily from steel. Furthermore, some designs incorporate hybrid material solutions, typically combining steel with concrete to optimize strength, corrosion resistance, and cost-efficiency.



The latest offshore wind GBS installation is France's FéCamp project, commissioned in May 2024. All 71 gravity-based foundations, each weighing 5,000 tonnes, were built onshore over two years and then transported and installed offshore within just two months [3].

Picture: Bouygues Construction

Strategic benefits of GBS

Cost-competative today, even better tomorrow

- Competitive with monopiles today—and improving as learning curves and production efficiencies drive costs down. Designed to scale easily for larger turbines.

Low-risk deployment and efficient installation

- Avoid subsurface surprises like boulders or cavities. Streamlined installation reduces time at sea, cutting project timelines and costs.
- Bypassing traditional installation vessel dependencies.

Made in Europe

- Made in Europe with reliable manufacturing and logistics for a secured supply chain.

Scalable solution

- The GBS solution improves with larger turbines and scales easily.

Sustainable by design

- No piling required—protect marine ecosystems by eliminating underwater noise.
- Produced locally using low-carbon materials to minimize emissions.

Built for longevity and circular economy

- Long operational life supports multiple turbine generations. High potential for reuse and recycling, reducing waste and environmental impact.

Future of GBS

As turbine sizes have increased, monopiles—the traditional foundation choice—have become significantly larger and more challenging to manage. Frequently, the installation process now necessitates pre-drilling for monopiles and pre-piling for jackets, which introduces additional costs and operational risks offshore. GBS are more adaptable to scaling up and accommodate larger turbine dimensions more effectively than monopiles. While GBS installations do not require piling, some seabed preparation is typically needed. This preparation can be completed prior to installing the GBS, resulting in a more predictable installation process.

Gravity-based structures for offshore wind have yet to undergo the same level of industrialization as the monopile solution. As a result, there remains significant opportunity for learning, which can drive further reductions in cost and environmental impact.

AF Gruppen identifies considerable untapped potential in applying slip-forming techniques to offshore wind concrete structures. Drawing on extensive experience from slip-forming harbour caissons, there is substantial scope to reduce construction time and costs while enhancing quality through a more consistent construction methodology.

Together with Multiconsult and DOF, AF Gruppen has formed a partnership for delivery of EPCI contracts for offshore concrete gravity based WTG foundations in Northern Europe. Together the three companies have an extensive track record for design, construction and installation of offshore structures worldwide, including offshore concrete structures. Together, the three partners deliver comprehensive turnkey solutions for clients.

Conclusion

Gravity-based structures have evolved into a competitive alternative for future offshore wind projects. As turbine sizes increase and sites move into deeper waters with challenging seabed conditions, GBS offers a robust, cost-effective, and environmentally sustainable foundation option. Proven through decades of use in the oil and gas industry and with more than 600 units already installed in offshore wind, the technology is mature and adaptable. However, further industrialisation through techniques such as slip-forming and standardised production will unlock additional cost reductions and efficiency gains.

GBS delivers clear advantages: cost competitiveness, no piling, high local content, and strong potential for reuse and recycling. These attributes align with circular economy principles and help reduce the carbon footprint of offshore wind developments.

To fully realise this potential, the industry must integrate GBS into early-stage project planning and design strategies. With continued innovation and collaboration, gravity-based structures can become a cornerstone of the global energy transition combining technical reliability with environmental responsibility.

Gravity-based structures offers a robust, cost-effective, and environmentally sustainable foundation option.

References

1. Equinor, https://www.equinor.com/no/energi/troll
2. Muhammad Aleem, Subhamoy Bhattacharya, Surya Biswal, Ganga Prakhya, Chapter 26 - Gravity-based foundation for offshore wind turbines, Editor(s): Trevor M. Letcher, Wind Energy Engineering (Second Edition), Academic Press, 2023, Pages 383-396, ISBN 9780323993531
3. EDF, https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/fecamp-frances-first-offshore-wind-farm-in-normandy-is-now-operational
4. Mathern, A.; von der Haar, C.; Marx, S. Concrete Support Structures for OffshoreWind Turbines: Current Status, Challenges, and Future Trends. Energies 2021, 14, 1995. https://doi.org/10.3390/en14071995

About the authors

Feel free to contact the authors with your questions or thoughts.

Eirik Lind Hånes is Project Manager for Offshore Wind at AF Gruppen, leading strategic initiatives and front-end engineering to grow the company's presence in renewable energy. With over a decade in structural and offshore engineering, he has held key roles like Technical Manager and Engineering Manager, working on complex design, fabrication, and installation projects.

Eirik holds a Master's in Mechanical Engineering from NMBU and studied at UC Davis. Since joining AF Gruppen in 2012, he has gained expertise in gravity-based structures, decommissioning, and foundation solutions. He drives AF Gruppen's offshore wind efforts, focusing on early-phase engineering and sustainable, integrated solutions. **EirikLind.Hanes@afgruppen.no**

Frida Mattson is Engineering Manager for Offshore Wind at AF Gruppen, leading offshore wind engineering initiatives that drive innovation and sustainability in the energy transition. With expertise in marine technology and hydrodynamics, she delivers cost-efficient foundation concepts for bottom-fixed and floating wind projects.

Frida holds a Master's in Marine Technology from NTNU and studied Sustainable Economics at NMBU. Previously, she worked as a wind consultant at DNV on feasibility studies and technical assessments. At AF Offshore, she leads early design strategies and market engagement to ensure safety, efficiency, and circularity. **Frida.Mattson@afgruppen.no**

AF Gruppen

AF Gruppen is a leading contracting and industrial group forged from an entrepreneurial spirit and an ability to execute. We provide services in the areas of Civil Engineering, Construction, Energy and Environment, Property and Offshore, primarily in Norway and Sweden. AF creates value for its employees, customers and owners, while helping to solve important social challenges. In brief, we clear the past, and build for the future.

Standardveien 1
0581 Oslo
www.afgruppen.com