International Renewable Energy Agency

RENEWABLE ENERGY BENEFITS

LEVERAGING LOCAL CAPACITY FOR OFFSHORE WIND

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ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

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DISCLAIMER

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KEY FACTS

OFFSHORE WIND

» The cumulative installed capacity of offshore wind energy rose from 67 megawatts (MW) in 2000 to around 20 gigawatts (GW) in 2017. IRENA expects continued growth to 128 GW by 2030 and 521 GW by 2050. Cumulative investments in offshore wind are projected to reach USD 350 billion by 2030 and USD 1.47 trillion by 2050.

» Along the way, ample opportunities arise for local value creation. Local income generation and job creation in the sector can be maximised by leveraging existing economic activities and building domestic supply chains. In particular, offshore wind energy can benefit from the many synergies in skills and occupational patterns that it shares with the offshore oil and gas sector.

» The interaction of the offshore wind energy industry with other economic sectors generates additional revenue, both through supply chain activities and through induced demand for goods and services.

» IRENA estimates that the wind sector employed 1.1 million people in 2017. Most of these jobs are in the larger and more mature onshore segment. By 2050, the wind sector can potentially create up to 2 million jobs.

» In total, the development of a typical 500 MW offshore wind farm requires around 2.1 million person-days of work.

» The labour requirements vary across the value chain, with a heavy concentration in manufacturing and procurement (59 percent of the total). The manufacturing of equipment offers the bulk of job opportunities in the sector.

» Countries that do not have a sufficient capacity to manufacture equipment locally can derive jobs and other benefits in segments of the value chain that are easier to localise. For example, O&M accounts for 24 percent of total labour requirements; installation and grid connection represents another 11 percent of the total.

» In order to avoid skills gaps, educational and training programmes need to be attuned to the emerging needs in the offshore wind industry. Training and skill-building form an important part of efforts to generate capable local supply chains.

» Maximising local value creation depends on successfully leveraging existing expertise and capacities in other industries that can provide expertise, raw materials and intermediate products. In particular, steel, copper, lead and fiberglass are heavily used for the development of an offshore wind project.

» To strengthen the industrial capability of domestic firms, policy measures and interventions are needed that contribute to increased competitiveness. Measures include industrial upgrading programmes, supplier development programmes, promotion of joint ventures, development of industrial clusters and investment promotion schemes.

INTRODUCTION

Renewable energy and energy efficiency technologies, with their increasing maturity and cost-competitiveness, can help bring economic and environmental objectives into closer alignment. The energy transition can only be considered within the framework of the broader socio-economic system and changes in the energy sector have impacts throughout the broader economy. Achieving the energy transition would have significant socio-economic impacts. The latest analysis by the International Renewable Energy Agency (IRENA) shows that accelerating the deployment of renewable energy and energy efficiency as required to move towards a more sustainable development path (the REmap Case),[1] generates a number of benefits in terms of gross domestic product (GDP), human welfare and employment relative to the Reference Case[2].

At the global level, the energy transition generates a 1 percent increase in GDP by 2050, compared to the Reference Case. The socio-economic benefits go well beyond GDP improvements, including marked social and environmental benefits, or welfare, with a 15 percent increase. As for jobs, the transition could greatly boost overall employment in the energy sector and the shift to renewables would create more jobs than are lost in the fossil fuel industry. The same pathway would result in the loss of 7.4 million jobs in fossil fuels by 2050, but 19.0 million new jobs would be created in renewable energy, energy efficiency, and grid enhancement and energy flexibility, for a net gain of 11.6 million jobs (IRENA, 2018a).

At the regional level, the outcome of the energy transition depends on regional ambition as well as regional socio-economic structures. Despite fluctuations in GDP and employment, welfare will improve significantly in all regions. However, as is the case with any economic transition, there will be regions and countries that fare better than others due to diverging structures, capacities and dynamics. Policy makers can help to make the transition process a just one by supporting the transition in the context of energy access, adopting social protection measures for people dependent on declining industries (including fossil fuels) and initiating economic

Box i.1 ■ IRENA's work on renewable energy benefits

This study is the latest edition in a series that analyses the opportunities for value creation through the deployment of renewable energy technologies, that started with large-scale solar photovoltaics and onshore wind (2017). The series is part of a body of work by IRENA that began in 2011 that analyses the socio-economic benefits of renewable energy. It includes the *Renewable Energy and Jobs: Annual Review* (published yearly since 2014), the *Global Energy Transformation: A roadmap to 2050* (2018), the *Perspectives of the Energy Transition* (2017), and *Renewable Energy Benefits: Measuring the Economics* (2016), among others.

These and other reports can be downloaded from **www.irena.org/Publications.**

1 IRENA's REmap 2030 and 2050 IRENA's global roadmap for scaling up renewables, known a s REmap. The roadmap, suggests that renewables can make up 60 percent or more of many countries' total final energy consumption (TFEC). Further details are available at www.irena.org/remap

2 The Reference Case is based on current and planned policies including Nationally Determined Contributions (NDCs).

diversification investments. In addition, supporting initiatives that help build and strengthen domestic supply chains capable of responding to new economic opportunities is crucial to achieve a successful global energy transition.

This study analyses the potential of the offshore wind industry to participate in the energy transition through the opportunities it offers for local value creation for countries that choose to develop the technology. The report starts with an overview of trends and drivers in the sector (Section 1). It then analyses the potential for value creation in terms of jobs and income along the segments of the value chain with a focus on synergies with the offshore oil and gas sector (Section 2). Section 3 goes into the activities in each segment of the value chain to analyse requirements for developing a sector focusing on human resources, skills and materials. The objective is to provide policy makers with an understanding of what is required to develop a local industry and the existing capabilities that can be leveraged or potentially developed to do so. Finally, a set of recommendations are presented to support informed decisions in policy-making to maximise value creation from the development of a domestic offshore wind industry while leveraging existing industries, and contribute to a just energy transition.

The scope of the study is global; therefore, the data presented in the report were obtained through surveys and interviews with internationally recognised experts and from desktop research that gathered information published by leading companies and specialised institutions in the offshore wind industry. A significant number of leading stakeholders were interviewed and/or responded to questionnaires on the requirements to develop an offshore wind industry. They included project developers, component manufacturers, service providers, energy authorities and national and global associations for wind and renewable energy. The study also draws on public reports of wind energy companies, including annual reports, technical specifications and equipment handbooks, and public price lists.[3]

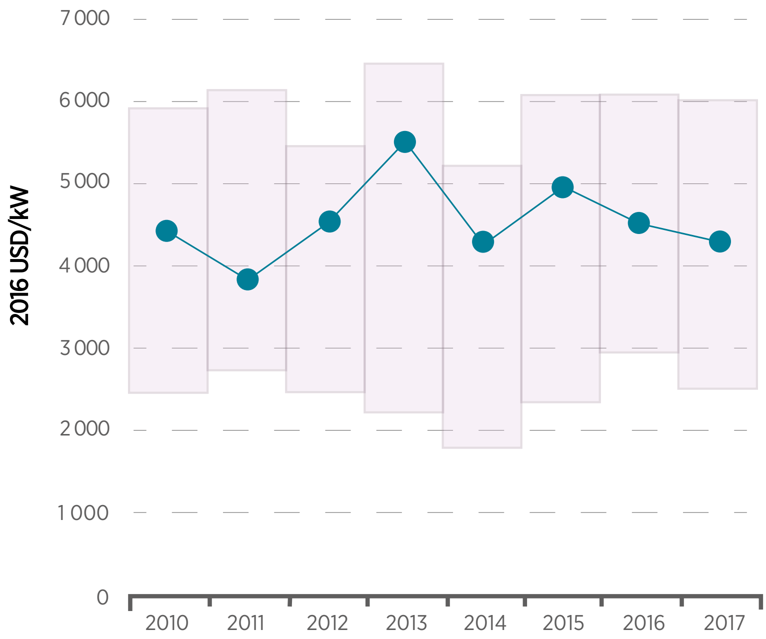
[3] Public information from the following institutions has been taken into consideration in the elaboration of the assessment: Adwen, E.ON, EDF, EDP Renováveis, Elia, Energinet, ENTSO-E, Exide, General Electric, Global Wind Energy Council, Iberdrola, MHI Vestas, National Grid, Ørsted A/S (previously DONG), RWE, Siemens-Gamesa, SIF, SP Energy Networks, SPE Group, SSE, Statkraft, Statnett, Stattoil, Stiftung Offshore-Windenergie, Vattenfall, WindEnergie e.V. and WindEurope.

1. TRENDS IN THE OFFSHORE WIND ENERGY SECTOR

In the last two decades, the installed capacity of offshore wind energy rose steadily increasing from 67 megawatts (MW) in 2000 to almost 20 gigawatts (GW) in 2017 (IRENA, 2018d). Higher annual increases in the last three years have been driven by falling costs, targeted policies, and technological advancement.

The total installed cost of offshore wind decreased by about 13 percent between 2010 and 2011 after which it climbed by almost 44 percent reaching a peak in 2013 (Figure 1.1) as projects moved farther from shore into deeper waters and more advanced technology started to be used. After that year, projects became larger and the industry standardised the use of new wind turbines and optimised manufacturing processes, giving developers the chance to offset some of the cost increases related to siting projects further from shore and in deeper waters. The global weighted average installed costs decreased by 22 percent, from USD 5 452 per kilowatt (kW) in 2013 to USD 4 239 in 2016 (Figure 1.1) (IRENA, 2018c). It should be noted that the cost depends heavily on the distance to shore and the water depth.

Figure 1.1 Trend in the global weighted average total costs of installed offshore wind capacity, (2010-17)



Source: IRENA (2018c).

The falling cost of technology was reflected in the price of electricity generated by offshore wind, driven by policies such as auctions. Several policy options exist to drive the sector such as administratively set tariffs, technology-specific quotas or auctions (IRENA, 2018e). Offshore wind auctions are adopted in a growing number of countries, including China, Denmark, France, Germany, Japan, the Netherlands and the United Kingdom. In 2016 alone, the generating prices of auctioned offshore wind projects fell by 22 percent (BNEF, 2016). Prices decreased substantially in Denmark (by almost 25 percent) and in the Netherlands (by almost 30 percent). In 2017, Germany held its first auction for offshore wind where developers showed high confidence in the industry. Out of the four winning projects, three (1 380 MW out of the total 1 490 MW) offered a strike price of EUR 0/MWh meaning that they did not request any support on top of wholesale electricity prices (IRENA, 2017a). These developments were mainly driven by a supportive auction design that instilled investor confidence (Box 1.1).

Box 1.1 ■ The design of policies to support offshore wind energy

Policy instruments, such as auctions, can be designed in a way to increase investor confidence resulting in lowered prices, among other potential objectives that could be achieved:

Site-specific auctions can help reduce investor risks and transaction costs. They reduce project developers' risks and facilitate obtaining necessary permits and documentation by centralising this task to the government. In addition, qualification requirements tend to be less stringent in site-specific auctions, since sites are pre-determined and bidders only need to prove their technical and financial capability to deliver the project. Indeed, site-specific auctions have been the norm for offshore wind auctions in China, Denmark, Germany, Japan, the Netherlands and the United States. Pre-selecting a site typically implies that the installed capacity and grid interconnections are determined beforehand, allowing policy makers and project developers to concentrate their efforts on the particular challenges and features of the chosen site.

How winners are selected can affect the resulting price. Most countries, including Denmark, the Netherlands, the United Kingdom, and the United States, have adopted a minimum-price criterion to select the winner. In Japan, however, a weighted score considering multiple aspects was used, highlighting other important policy objectives besides attaining the minimum price possible.

The contract design and sellers' liabilities affect investor interest. The price outcome is heavily impacted by: the date of project delivery; structure of the contract, including the remuneration profile of the developer; and the penalties and liabilities involved. One very important factor that contributed to the low bids in the German offshore auction is the date of project delivery, which is not until 2024–25 for most of the projects. Projects commissioned in later years are expected to incur lower technology costs, as turbine and construction costs decline and technology advances (*e.g.*, bigger and more corrosion-resistant turbines). In contrast, projects awarded in the United Kingdom are expected to come online between 2017 and 2019, leaving little time for costs to fall.

Source: IRENA, 2017a.

Technological advancement and innovation driving the sector include bigger turbines, enhanced construction know-how, experimental technologies such as floating platform solutions, continuous improvements in foundation design and installation methods (Box 1.2). Developments in access, operation and system integration have also permitted moves into deeper waters, further from shore, to reach larger sites with better wind resources.

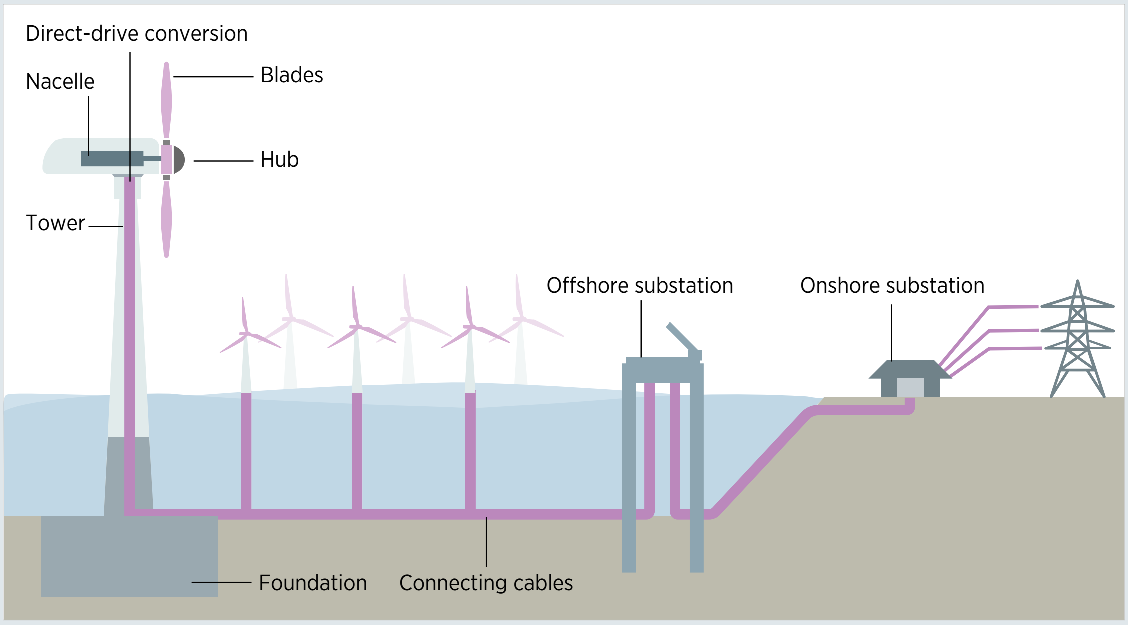
Together, these developments are making offshore wind competitive on a large scale (IRENA, 2016c). In addition, some developments in the sector have also contributed to falling technology costs and electricity prices and they include a growing and competitive supply chain, cross-industry collaboration, and economies of scale (IRENA, 2016a). Meanwhile, the investment climate for long-term infrastructure projects has been favourable in recent years, expanding access to finance.

Box 1.2 ■ Developments in the main components of offshore wind projects

The main components of an offshore wind farm are the turbine (including rotor, nacelle, tower and cabling), the turbine foundation, and the onshore and offshore substations (Figure 1.2). See Annex A for a more detailed description.

The most essential developments in the offshore wind energy sector are related to the foundation, typically needed to support the turbine in offshore waters. In recent years, the development of floating turbines for deeper water (more than 50 meters deep) has eliminated the need for a foundation, allowed developers to tap into areas with the largest wind potential and overcome constraints related to depth, while benefitting from less invasive activity on the seabed during installation. More details on floating foundations can be found in Annex A.

Figure 1.2 **Main components of an offshore wind farm**



Source: Siemens, n.d.

Considering the most recent trends and the latest developments in the sector, offshore wind energy can be seen as a very promising technology with potential for creating local value.

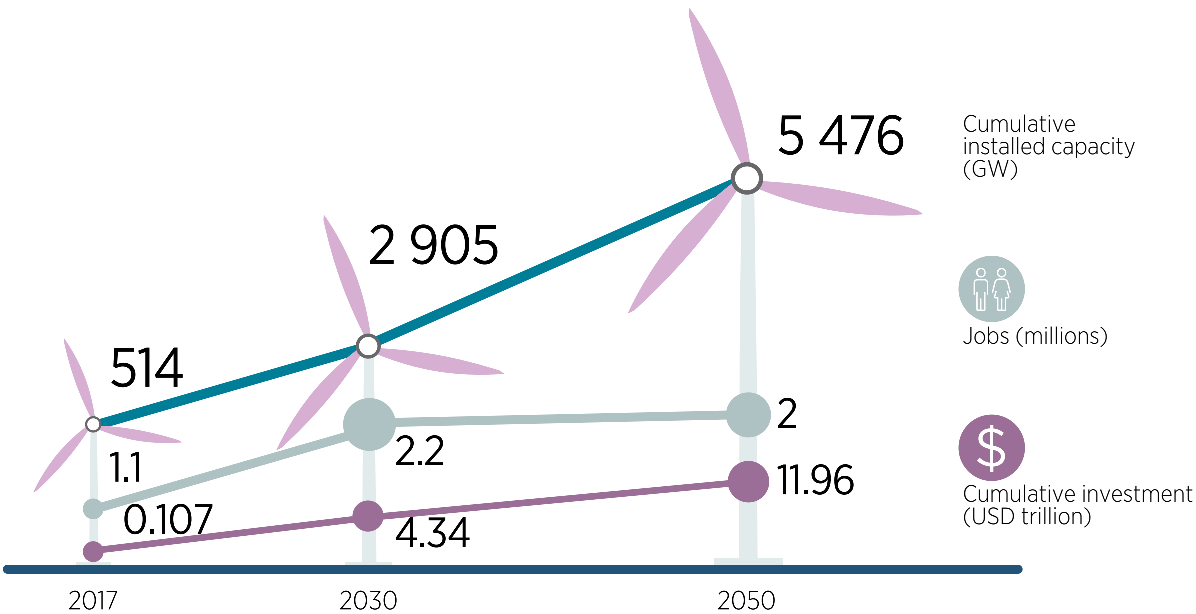
2. POTENTIAL FOR VALUE CREATION FROM THE DEPLOYMENT OF OFFSHORE WIND

In IRENA's REmap 2050 scenario, total wind installed capacity is expected to reach 2 906 GW by 2030 and 5 476 GW by 2050 with cumulative investments in the sector of about USD 4.34 trillion by 2030 and USD 11.96 trillion by 2050. Out of the total, the deployment of offshore wind is expected to reach 128 GW by 2030 and 521 GW by 2050 with cumulative investments in the sector of about USD 350 billion by 2030 and USD 1.47 trillion by 2050 (IRENA 2018a). These developments can present ample opportunities for local value creation in countries deploying offshore wind, with considerable benefits such as jobs and income, depending on the extent of which activities are carried out domestically.

2.1. Jobs in offshore wind

The wind sector currently supports 1.1 million jobs, and could support more than 2.2 million jobs in 2030 and up to 2 million jobs in 2050 (Figure 2.1) (IRENA, 2018a). In offshore wind, many of the newly created jobs could be filled by labour previously employed in the fossil fuel sector. Figure 2.1 presents the estimated cumulative capacity, investments and employment in wind, in 2017, 2030 and 2050. Designing policies to maximise the local benefits from the deployment of offshore wind requires an analysis of where the jobs are created along the different segments of the value chain. This section analyses jobs in offshore wind: their concentration in the value chain and the potential of the offshore wind sector to welcome labour affected by the energy transition.

Figure 2.1 **Estimated cumulative capacity, investments and employment in wind, 2017, 2030 and 2050**

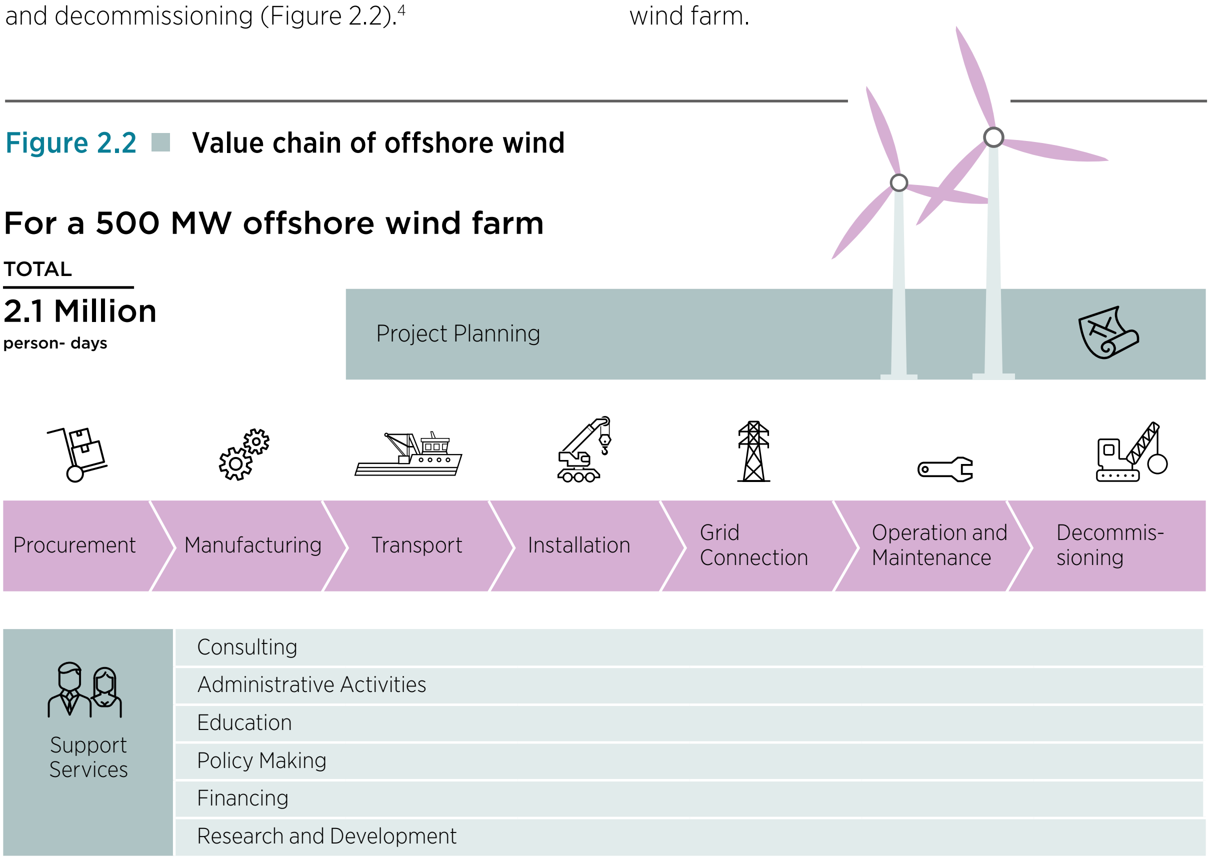


Note: Investment in 2017 is annual, not cumulative.
Source: Based on IRENA, 2018a; IRENA, 2018b; Frankfurt School-UNEP Centre/BNEF, 2018.

The analysis of the distribution of jobs along the different segments of the value chain focuses on its core segments: project planning, procurement, manufacturing, transport, installation and grid connection, operation and maintenance (O&M), and decommissioning (Figure 2.2).[4]

It is estimated that a total of 2.1 million person-days is needed to develop an offshore wind farm of 500 MW. This is an estimate of direct jobs and does not include indirect or induced jobs, derived from the economic activity of the offshore wind farm.

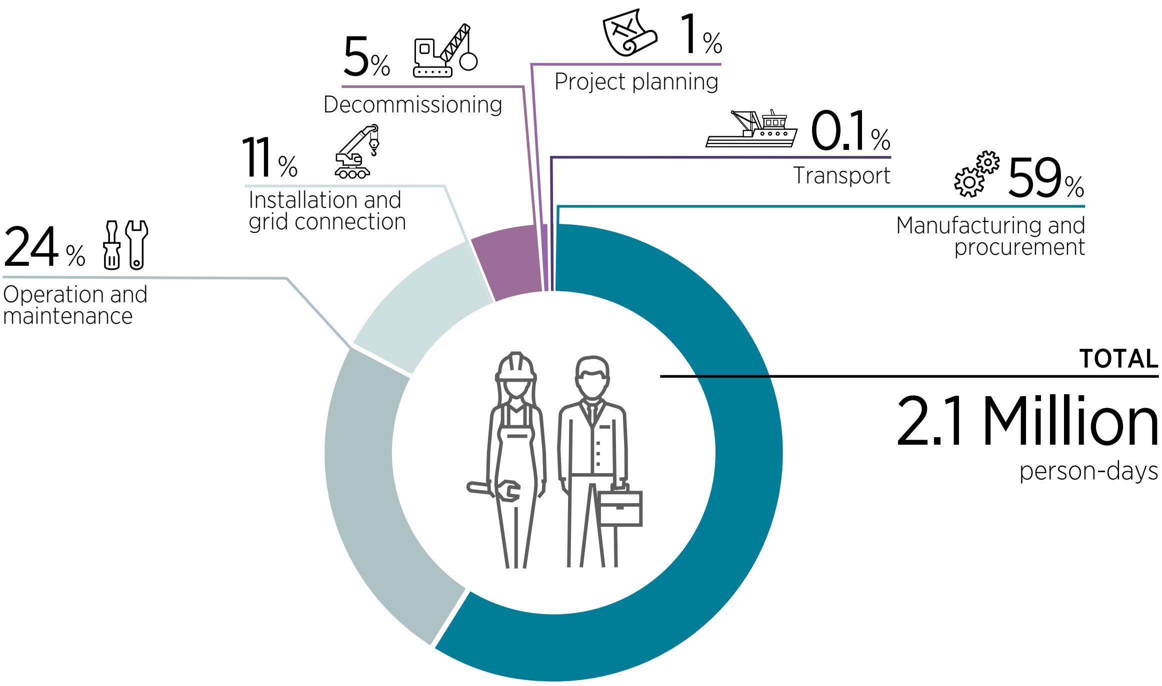
Figure 2.2 Value chain of offshore wind



[4] Other activities from various sectors that support deployment (support services) include financial services, insurance, consulting, education and training, research, development and innovation, policy making, and administrative activities. Many of these activities can be developed locally, but analysis of the support services is beyond the scope of this study.

As illustrated in Figure 2.3, labour requirements vary across the value chain. There is a heavy concentration in manufacturing and procurement (59 percent of the total), O&M (24 percent),[5] as well as installation and grid connection (11 percent). This shows that although the manufacturing of equipment offers the bulk of job opportunities in the sector, countries that do not opt to manufacture equipment locally can benefit from considerable opportunity for job creation in other segments that are always localised, such as O&M and installation and maintenance.

Figure 2.3 ■ Distribution of human resources required along the value chain for the development of a 500 MW offshore wind farm



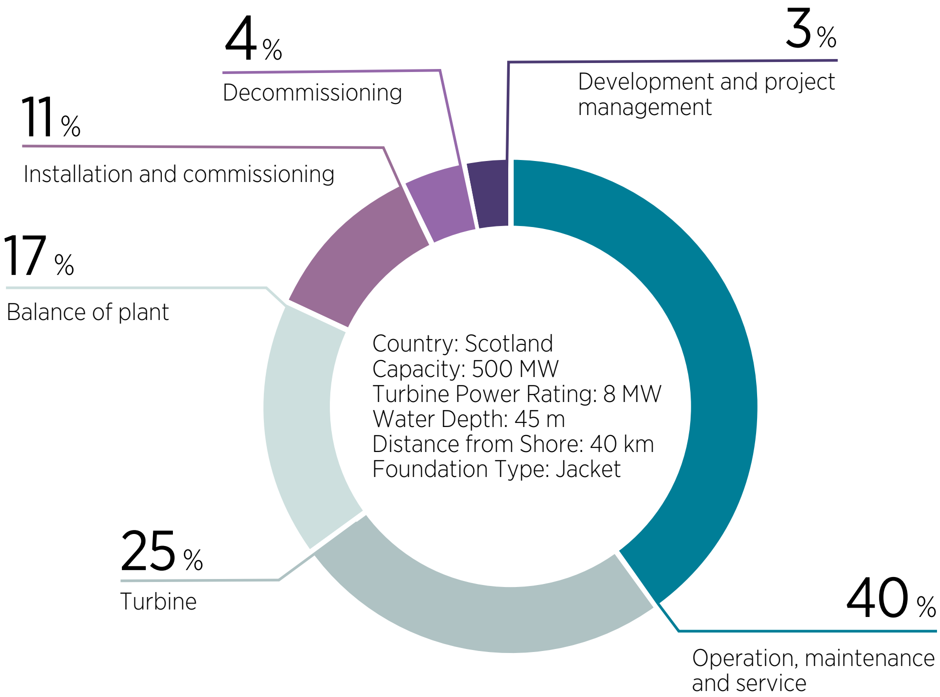
An assessment of the types of jobs created in order to provide policy makers with an understanding of the human resources and skills required to produce, install and decommission offshore wind plants is presented in Section 3.

In addition to job creation, value is created through economic activities in the sector. Those are related to the procurement of materials, the installation of turbines, O&M activities, among others.

The breakdown of costs in offshore wind projects provides an indication of where value can be created. Figure 2.4 shows the cost breakdown of a 500 MW offshore wind farm in Scotland reaching final investment decision in 2020 using 8 MW turbines, on jacket foundations, in 45m water depth, 40 km from shore (total cost estimated at EUR 5.4 billion) (Scottish Enterprise, 2017).

[5] The number of person-days required for the first year of O&M is estimated to be 25 070. The total represents the cumulative person-days over 25 years of project lifetime, assuming average labour productivity improvements of 2 percent a year (Rutovitz, Dominish, and Downes, 2015).

Figure 2.4 **Cost breakdown of an offshore wind farm reaching final investment decision in 2020**



Source: Scottish Enterprise, 2017.

As shown in figure 2.4, the bulk of the cost goes into O&M. Although the percent of total cost that goes into O&M varies greatly among countries, according to the cost of labour, the example of Scotland can be used to demonstrate the potential for value creation in this segment of the value chain in countries with similar conditions, such as European countries. The second largest cost component is the turbines, and this also depends on the level of access to equipment of countries and how far they need to be imported in cases where they are. The figure also shows great potential for value creation in the balance of plant (supply of cables, foundations, and offshore and onshore substations) and in installation and grid connection (Scottish Enterprise, 2017).

This breakdown differs from that of onshore wind costs, where the cost of wind turbines represents between 66 and 84 percent of the total cost (IRENA, 2017b). This is due to the additional balancing costs of foundations and cables and substations, the expense of operating offshore and designing requirements for the harsh marine environment.

Whether departing from a locally established oil and gas industry or an economy relying on energy imports, the potential to generate income and create jobs from the deployment of offshore wind will depend on the extent to which the local industry can leverage existing economic activities and create new ones. As the world transitions from a fossil-fuel based energy sector to one that relies on renewables, there are many synergies that can be leveraged with the offshore oils and gas sector.

2.2 Potential for synergies with offshore oil and gas

The global energy system must undergo a deep transformation to evolve from its present reliance on fossil fuels to a focus on renewable energy. The share of renewable energy must rise from around 18 percent of total final energy consumption (in 2015) to around two-thirds by 2050 (IRENA, 2018a).

This transformation will come about as investments shift from fossil fuels to renewables (as well as to greater energy efficiency), with wide implications for the economy, including employment. IRENA's latest macro-econometric modelling suggests that the energy transformation required to meet the decarbonisation and climate mitigation goals set out in the Paris Agreement would result in the loss of around 7.4 million jobs in the fossil fuel sector by 2050, compared with business as usual. But in terms of sheer numbers, this loss is more than offset by a gain of jobs in the renewable energy sector, which are projected to rise from close to 10.3 million in 2017 to 28.8 million in 2050 (IRENA, 2018a).

Fossil fuel sector job loss is already an established fact. In 2015 and 2016, the loss of more than 440 000 jobs was reported in the oil and gas industry worldwide, mainly due to low oil prices and oversupply (Jones, 2017), rising automation in extraction, overcapacity, industry consolidation, and regional shifts in the power sector. At least some sets of skills and occupational know-how from the offshore oil and gas sector may be applicable to careers in offshore wind, enabling some laid-off workers to find new jobs. In some cases, it will be an easy re-skilling and tailoring existing skills process while in others, there will be some need for new and specific skills (CBI, 2012). Similarly, In Germany, the know-how of former shipyard workers has been leveraged to support the building of foundations and towers for offshore wind farms (Hülsen, 2012).

As the offshore wind energy sector grows, it offers greater opportunities for individuals and businesses from the offshore oil and gas sector in different segments of the offshore wind value chain (IRENA, 2017b; knowRES, 2016; Scottish Enterprise, 2017):

Project planning. Large surveying companies from the oil and gas sector are already offering a full range of services covering environmental, geophysical and geotechnical surveying and even offshore installation. Moreover, oil and gas companies are already offering skills in managing complex projects offshore given the similarities between the two sectors in the marine environment, the common challenges of working in a harsh environment and the resulting implications for health and safety, for instance. In fact, a number of companies with a background in oil and gas have already carried out work in offshore wind, including DNV-GL, ODE, and TNEI.

Manufacturing. Synergies with the oil and gas sector relate to the manufacturing of support structures. Expertise in designing and manufacturing support structures in offshore oil and gas is highly relevant, especially at more challenging deep water sites.

Installation and grid connection. Many synergies exist in these areas and they relate to the turbine foundations, array cables, substation structures, steelwork, and installation in terms of equipment and services (Box 2.1). Some oil and gas companies have won offshore wind installation work (*e.g.*, 3sun, Ecosse Subsea and ROVOP) leveraging on existing skills.

Box 2.1 Synergies between offshore oil and gas and offshore wind in the installation phase

Synergies in installation and grid connection between the two industries include:

Foundations. The construction and decommissioning of the foundations of an offshore wind farm are comparable to those of an oil or gas platform, and therefore some of the expertise can be leveraged. Traditional oil and gas manufacturers such as Bladt, EEW, Sif and Smulders have made the transition to offshore wind. Foundation supply offers a good opportunity for increasing local content in some markets, and a new entrant from oil and gas would be welcomed if it has sufficient infrastructure and a good manufacturing track-record.

Array cables. Although array cable requirements slightly differ between sectors, most oil and gas suppliers are capable of supplying offshore wind projects without significant investment. Lower tier cable components (connectors, terminations, hang-offs and cable protection) have strong synergies with the oil and gas sector. For instance, JDR Cables, previously a supplier to the oil and gas sector, has become the number one array cable supplier for offshore wind projects in Europe.

Substation structures. There is significant synergy between offshore wind substations and oil and gas platforms and accommodation modules. Substation contracts are often outsourced with developers seeking partners with strong energy transmission or offshore marine engineering credentials. Oil and gas suppliers can be ideal, given their understanding of the prevailing contracting models for these types of structures and their strong track-record in a more mature sector. In fact, several large international companies with a presence in oil and gas have been successfully supplying offshore wind with foundations (in addition to topside structures and architectural components). These include Bladt, Heerema, HSM Offshore and Sembmarine SLP.

Steelwork. Although offshore wind structures have different load strength requirements, leading to differences in for example welding requirements, there is a high degree of synergy in the types of fabrication used in both sectors with many common standards and certifications. Additional opportunities for oil and gas suppliers include the manufacture and supply of ancillary equipment such as flanges, cable pull and protection equipment and access systems. Oil and gas companies such as Hutchison Engineering have been successful in winning work and in many cases, these steel companies are active in several sectors, including civil engineering, defence and industrial equipment and in many countries.. As such, supporting secondary steelworks is a good entry point for companies looking to enter the sector although investment in skilled labour for specific manufacturing requirements is likely to be the element with the longest lead-time.

Cable installation. Oil and gas suppliers have a solid track-record in cable installation and many have successfully diversified into offshore wind such as Canyon Offshore for trenching works, DeepOcean, Van Oord and VMBS. In addition, cable manufacturers such as Nexans and Prysmian operate in both sectors and have the capability to install cables. However, it should be noted that cable installation is a highly specialised and competitive market and some companies (*e.g.*, Reef Subsea, SubOcean and Technip Offshore Wind) have experienced financial difficulties or decided to exit from the offshore wind sector. New entrants must become familiar with the pull-in of cables and the much larger geographical installation areas involved.

Sources: IRENA, 2017b; knowRES, 2016; Scottish Enterprise, 2017.

Operation and maintenance. Oil and gas suppliers have considerable experience in maintaining assets offshore and synergies in terms of planned maintenance, defect detection, and asset repair are very strong. Moreover, oil and gas offshore safety standards and maintenance practices are highly transferrable to offshore wind and the skills required to carry out underwater inspection, maintenance and repair could potentially be transferred after minimal re-training, given a highly skilled workforce and existence of a comprehensive training infrastructure. In fact, many oil and gas suppliers have successfully provided maintenance and inspection services (*e.g.*, Briggs Marine, 3Sun, Hughes Sub Surface Engineering, Sea Energy and Sub C).

The synergies between sectors can only be exploited with targeted policies and measures. With adequate dedicated retraining policies to properly anticipate the required labour shift, the renewable energy sector could absorb part of the surplus workforce. Some managerial expertise, soft skills and technical knowledge is in principle transferable and highly valued in the offshore wind and other marine energy sectors (Box 2.2).

Box 2.2 ■ Policies and measures to facilitate re-skilling of oil and gas workforce for the offshore wind industry

The recent glut in fossil fuel prices has prompted governments and the industry to take measures to soften the impact of sector fluctuations on the labour force.. One among them has been to launch re-skilling programmes for the oil and gas workforce looking for opportunities in the booming renewable energy sector. Scotland, for instance, established the GBP 12 million Transition Training Fund to offer training opportunities to workers affected by the downturn to work in industries that include renewables and low-carbon technologies. Several training providers in and around Scotland are utilizing the Fund to offer training courses. Maersk Training, for example, provided oil and gas workforce with essential safety and technical competencies required to target new roles in the wind energy sector. Upon completion of the training, the provider also supports candidates to secure employment opportunities utilizing its extensive industry connections.

Recognising the transferability of skills between the two sectors, industry players have also taken steps in this direction. For example, 3sun group recruited more than 100 new technicians with the relevant electrical, mechanical and inspection qualifications to service GBP 6 million worth of new and extended offshore and onshore wind farm contracts. 3sun targeted local oil and gas workers experiencing difficulties finding work; new recruits train at the 3sun academy for work in the construction, installation and inspection of wind turbines.

Source: Transition Training Fund, n.d.; 3sun Group, n.d.

3. REQUIREMENTS FOR OFFSHORE WIND DEVELOPMENT

To design effective policies to support value creation through the development of a domestic offshore wind industry, a deep and detailed understanding of the requirements for labour, skills, materials and equipment is needed across the value chain. The analysis presented here estimates the direct person-days required to develop an offshore wind project. It should be noted, however, that indirect and induced effects are not included, and so the value of domestic activities goes well beyond the estimates presented. According to WindEurope, for example, the wind energy industry and activities related to it added EUR 36.1 billion to the European Union's GDP in 2016. Over 60 percent (EUR 22.3 billion) was the direct result of activities within the onshore and offshore wind energy industry, including developers, turbine and component manufacturers, service providers and offshore wind energy substructures. The remaining revenue (around 40 percent) was generated from the interaction of the wind energy industry with other economic sectors. In fact, every EUR 1 000 invested in wind energy was estimated to generate EUR 250 in other economic sectors in the region (Deloitte and WindEurope, 2017).

3.1 Project planning

Activities in the project planning phase include **site selection**, **environmental impact assessments**,[6] **technical feasibility studies** (including coastal, wind and seabed assessments), **financial feasibility studies, engineering design and project development**. First, the resource potential of a site is measured and the environmental and social impacts of the development are assessed in order to select the best site. Then, a feasibility study is undertaken and includes different technical aspects such as of the coastal, wind and seabed characteristics is required to evaluate erosion, sedimentation, geological and wave dynamics. The engineering design stage covers the technical aspects of the mechanical and electrical systems, the civil engineering work and infrastructure, the construction plan, and the O&M model. Finally, the project development consists of administrative tasks, such as obtaining marine permits, licenses and approvals from different authorities; managing regulatory issues; negotiating and securing financing and insurance contracts; contracting engineering companies; and managing the procurement processes.

Site selection

Feasibility studies

Engineering design

Project development

[6] To evaluate the impacts on the species living in the area, benthic (species in seabed and sediments), pelagic (species living in the sea waters), ornithological (native birds and migration routes) and sea mammal (cetacean) environmental surveys must be carried out.

Planning a 500 MW offshore wind farm requires an estimated 23 828 person-days of labour. Table 3.1 presents a breakdown of the total labour force needed in project planning by activity. Project development activity accounts for about 34 percent of the total (8 012 person-days), while engineering design for about a 17 percent (4 008 person-days). Altogether, the technical assessments account for about 38 percent of the total (adding up to 9 073 person-days), the seabed analysis being the most labour-intensive one. This is followed by the environmental impact assessment which reaches a share of 11 percent of the labour force in project planning.

Table 3.1 Human resources required for the project planning of a 500 MW offshore wind farm (person-days) and breakdown by activity

TYPE OF HUMAN RESOURCE	Site selection	Environmental impact assessments	Technical assessments			Access to grid assessment	Financial feasibility	Project development	Engineering design	Total by occupation
			Coastal	Wind	Seabed					
Ship crew	-	1 830	1 296	1 350	3 456	-	-	-	-	**7 932**
Legal, energy regulation and taxation experts	13	-	-	-	-	16	32	4 006	668	**4 735**
Energy, electric, electronic, mechanical, telecom and computer engineers	7	-	-	-	346	32	-	-	2 004	**2 389**
Financial analyst	-	152	-	-	-	-	16	2 003	-	**2 171**
Logistic experts	-	-	-	-	-	-	-	2 003	-	**2 003**
Geotechnical experts	7	-	432	135	692	-	-	-	-	**1 266**
Drilling system operators	-	-	-	-	691	-	-	-	-	**691**
Civil engineers (foundations experts)	7	-	-	-	-	-	-	-	668	**675**
Naval engineers	-	-	-	-	-	-	-	-	668	**668**
Environmental, sociological, marine/biology experts and fishers	7	609	-	-	-	-	-	-	-	**616**
Technicians	-	-	-	540	-	-	-	-	-	**540**
Physicists and weather data experts	7	-	-	135	-	-	-	-	-	**142**
Total (%as)	**48** (0.2%)	**2 591** (10.9%)	**1 728** (7.3%)	**2 160** (9.1%)	**5 185** (21.7%)	**48** (0.2%)	**48** (0.2%)	**8 012** (33.6%)	**4 008** (16.8%)	23 828

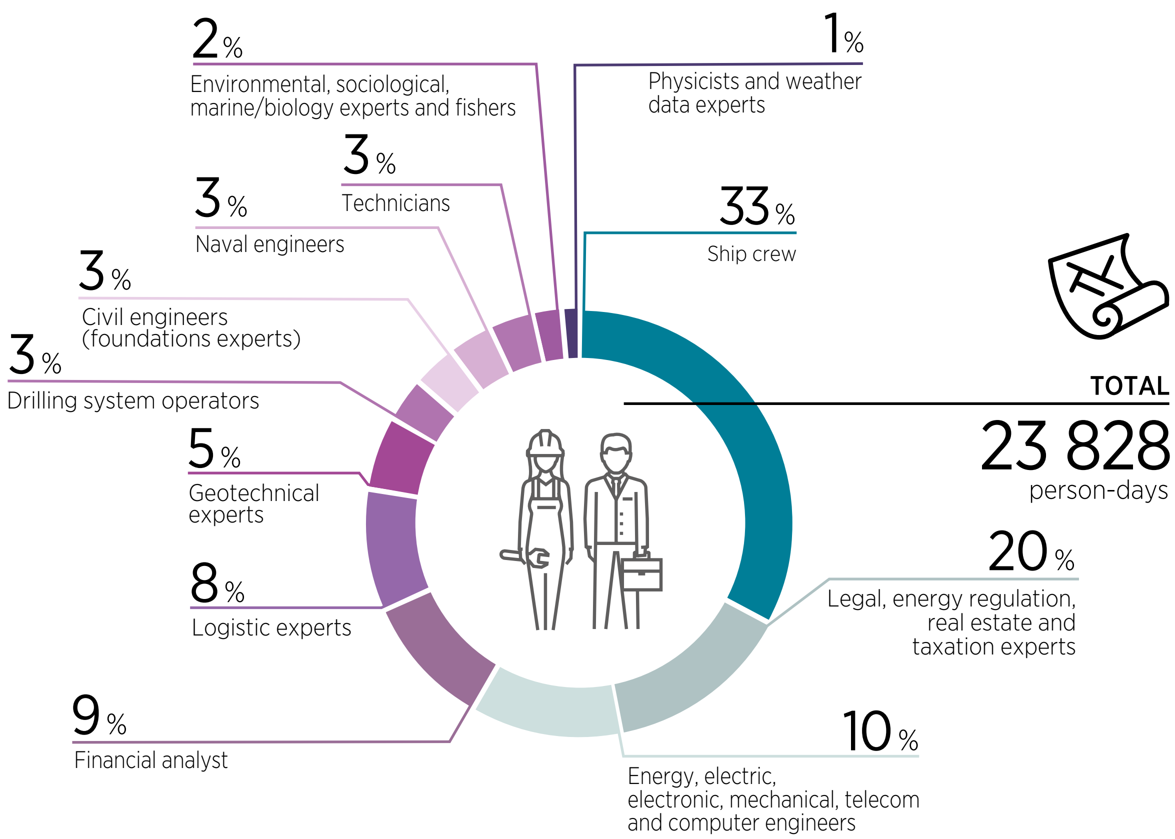
As for the skills needed (represented in Figure 3.1), the highest share – 33 percent of the total consists of **ship crew** for the boats required during the onshore, offshore and coastal surveys (7 932 person-days). Additionally, around 20 percent of the total (4 735 person-days) falls in the **'legal, energy regulation and taxation experts'** category, indicating the importance of knowledge of the offshore and local context.

Expertise for such activities is often transferred from completed projects, primarily in Europe. However, with the appropriate education and training, both the planning and permitting phases could potentially offer considerable opportunities for local employment.

Specialised engineers in different fields, including energy, electric, electronic, mechanical, telecommunications and computer engineers account for 10 percent of the total (2 389 person-days). Other engineers with civil and naval expertise are also required, accounting for 3 percent of the total (675 and 668 person-days, respectively).

Financial analysts and logistic experts required account for about 9 and 8 percent of the total, respectively. This is mostly needed during the project development phase, when it is decided whether to procure manufactured components domestically (if available) or to import them from foreign suppliers. The cost of technology and enabling conditions created by policies that support local manufacturing, such as taxes on imports or local content requirements, affect this decision. **Physicists**, including experts with wind data knowledge, and **geotechnical experts** together make up for around 6 percent of the total (142 and 1 266 person-days, respectively). This expertise can be hired from abroad or skills can be developed domestically through education and training policies designed to meet the future skills needed in the sector.

Figure 3.1 ■ **Distribution of human resources required for the project planning of a 500 MW offshore wind farm, by occupation**



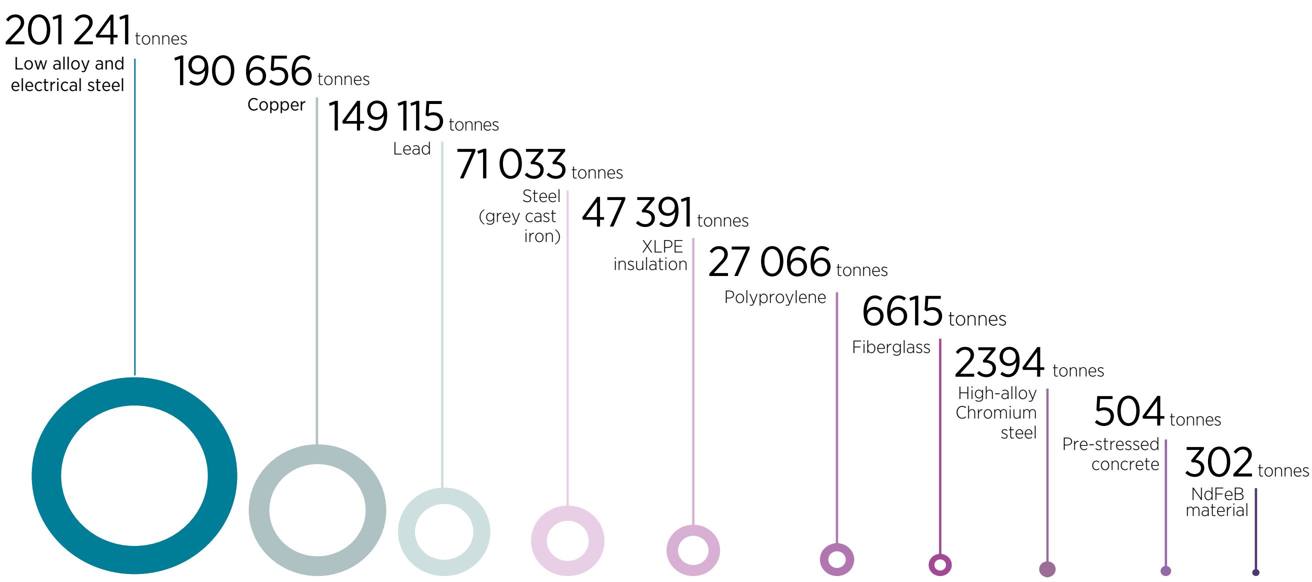
Project planning requires **equipment** to measure wind resources at the site selected, such as anemometers and wind vanes along with wind energy simulators and programmes to measure wind speeds and directions and to predict wind behaviour.[7] Sonar systems, seismic airguns, hydrophones and video cameras are used to map the seabed. Computers, radars and software to run simulations and produce feasibility analysis are also required. Vessels (both regular fishers' vessels and special vessels prepared to carry out geophysical analysis) are also often used.

Technical information is crucial to identify tidal and wave characteristics and climatic features at the site (such as the topography of the seabed, soil characteristics and information on marine life) that might affect a project's structural and operational requirements or impose limitations on it. Information about offshore rights, protected natural sea zones, bird migratory routes, impact on marine life and endangered species, policies and regulations related to support schemes for renewable energy, and grid connection is necessary to determine whether to proceed with the development of an offshore wind farm.

3.2 Procurement

Offshore wind projects require equipment, intermediary products and raw materials that could be procured domestically for maximum value creation. Materials used for the manufacturing and installation of an offshore farm are determined by taking into account factors such asa resistance to corrosion, strength of material, and weight and product specifications, tailored to the harsh conditions they will face: deep water, high salinity, wave impacts, etc. Procuring such inputs requires extensive work in developing specifications and assessing the local availability of materials. Figure 3.2 illustrates the quantities of materials needed to develop a 500 MW offshore wind farm.[8]

Figure 3.2 Materials needed to develop a 500 MW offshore wind farm (tonnes)



Note: NdFeB material (also known as neodymium magnet, NIB or Neo magnet), is a permanent magnet made from an alloy of neodymium, iron and boron.

7 Through its Global Atlas, IRENA in collaboration with the Danish Risø National Laboratory (DTU) now displays a global wind map that covers both continental areas and up to 30 km offshore.

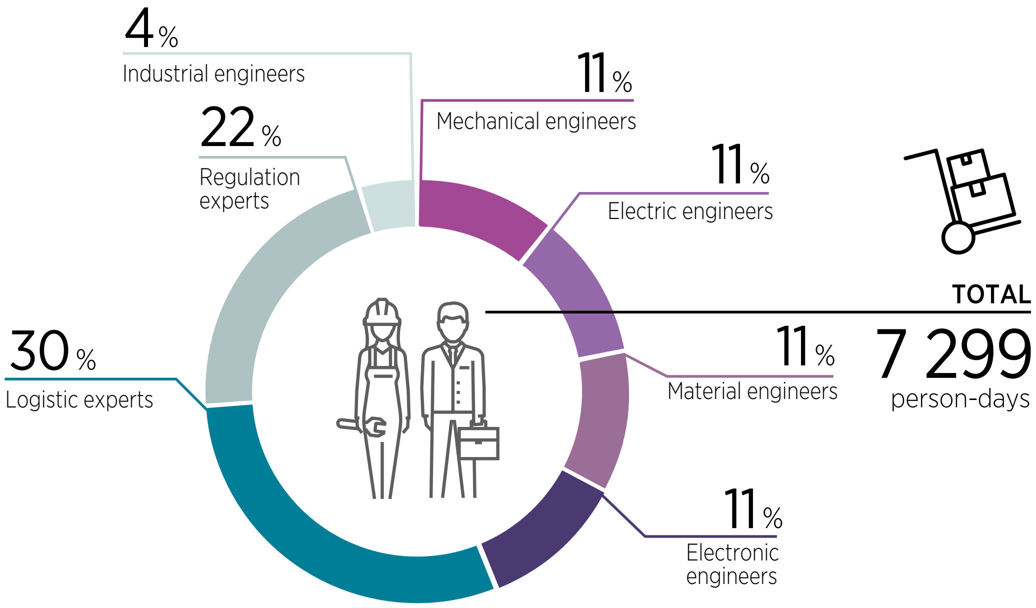
8 Materials used in an offshore wind farm vary vastly across projects. Total amounts differ depending on the models, the distance to the shore or the depth of the seabed. For this analysis, the offshore wind farm considered includes averaged weights for 63 direct-drive 8 MW turbines, 160 m diameter blades and 120 m height towers supported over a steel monopile foundation. Cables are included assuming 35 000 tonnes of inner array (33 kV) and 600 000 tonnes for export cables (132 kV). Onshore and offshore substations were not considered for the purpose of the analysis. Based on Birkeland (2011), Siemens (n.d.), The Crown Estate (n.d.), Dillinger Hütte GTS (n.d.) and Kaiser and Snyder (2012).

The selection of the most suitable suppliers of products and raw materials requires the services of **engineers**, who are able to evaluate the domestic availability of needed inputs and determine to what extent imports are required. **Regulation and logistics experts** are also required to identify any potential procurement barriers, such as import restrictions. As illustrated in Table 3.2, the definition of specifications and the availability of raw materials call for around 5 385 person-days (74 percent of the total procurement process). Once the requirements and specifications have been identified, transportation requirements should be analysed according to site location and project lead time. An average of 26 percent of the total procurement process (1 914 person-days) of **logistics and regulation experts** is required to ensure the appropriate and timely delivery of products to avoid overstock, which could lead to added costs and difficulties in storage (Figure 3.3).

Table 3.2 ■ Human resources required for the procurement of a 500 MW offshore wind farm (person-days) and breakdown by activity

TYPE OF HUMAN RESOURCE	Identification of specifications and raw materials	Logistics management	Total by occupation
Logistic experts	1 113	1 113	**2 226**
Regulation experts	801	801	**1 602**
Electric engineers	801	-	**801**
Electronic engineers	801	-	**801**
Material engineers	801	-	**801**
Mechanical engineers	801	-	**801**
Industrial engineers	267	-	**267**
Total (as %)	**5 385** (74%)	**1 914** (26%)	**7 299**

Figure 3.3 ■ **Distribution of human resources required for the procurement of a 500 MW offshore wind farm, by occupation**



3.3 Manufacturing

Decision makers may consider domestically manufacturing some of the main components of an offshore wind farm, such as the foundation and the substation, as well as the parts of the turbine (the nacelle and its subcomponents[9]) along with the blades, the tower and the monitoring and control system.

Decisions concerning the local manufacture of components will mainly depend on: 1) the level of expected local or regional demand for wind energy; 2) the existence of government policies to require or incentivise local value creation; 3) the availability of raw materials and presence of related domestic industries and 4) the ability to overcome high costs and logistical challenges related to transporting bulky equipment.

Additionally, existing onshore wind manufacturing facilities provide a unique opportunity to serve the offshore wind industry, as some components are comparable. However, for specific components (such as the gearbox), offshore wind energy technology has evolved and models are slightly different, requiring new production lines. Furthermore, oil and gas assets could be leveraged to support the deployment of offshore wind energy (Section 2.2), as the basic design of the foundations and substations for offshore wind turbines is essentially the same as that for platforms used in oil and gas fields. But individual projects involve differences with regard to size loading patterns and water depth, requiring manufacturers to tailor their production accordingly.

Manufacturing the main components of a 500 MW offshore plant requires 1.25 million person-days ***(around 59 percent of the total requirements along the value chain)***. The foundation requires most of the work (36 percent of the total), and the required workforce is mostly formed by **factory workers** who can generally be hired locally. This is followed by the nacelle and its subcomponents, accounting for 27 percent (340 581 person-days). The rotor requires 14 percent of the total, while the tower and the substation each account for about 10 percent share (over 120 000 person-days, each) (Table 3.3).

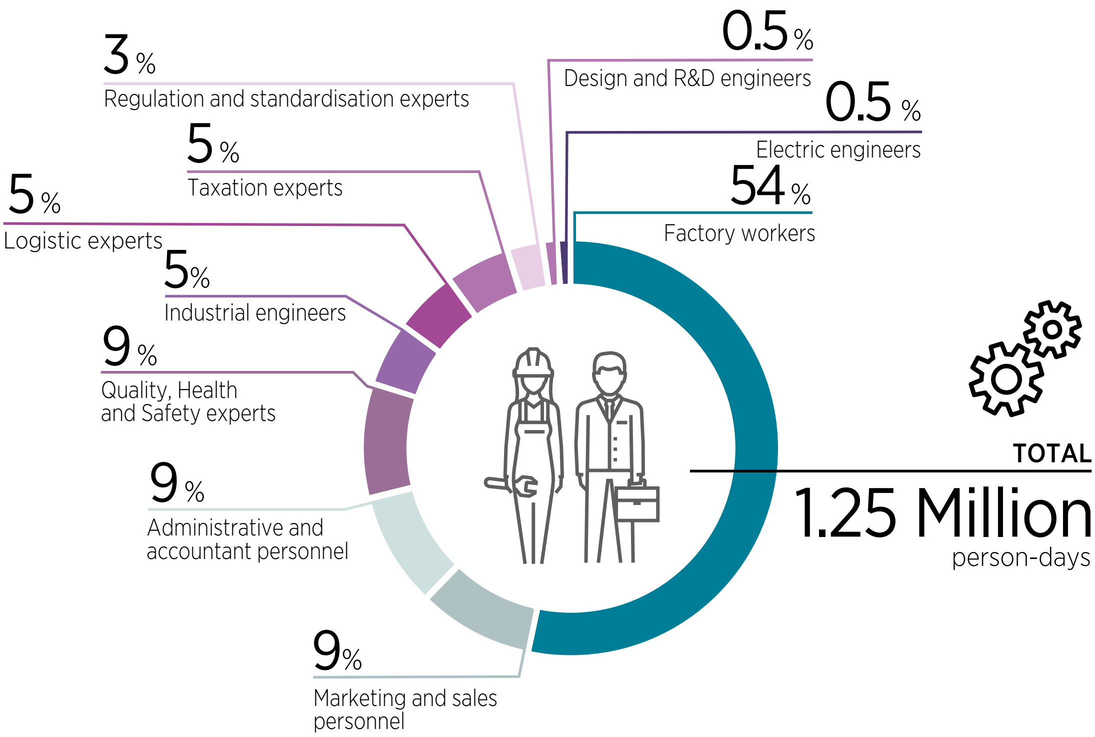
[9] Generator, gearbox, housing, bedplate, main shaft and transformer.

Table 3.3 **Human resources required to manufacture the main components of a 500 MW offshore wind farm (person-days) and breakdown by main component**

TYPE OF HUMAN RESOURCE	Nacelle	Rotor	Tower	Cabling	Foundation	Substation	Total by occupation
Factory workers	170 291	92 886	68 942	17 359	267 926	57 194	**674 598**
Marketing and sales personnel	34 058	15 481	10 606	2 671	41 219	11 439	**115 474**
Administrative and accountant personnel	34 058	15 481	10 606	2 671	41 219	11 439	**115 474**
Quality, Health and Safety experts	34 058	15 480	10 606	2 670	41 220	11 438	**115 472**
Industrial engineers	17 029	7 740	5 303	2 670	20 610	11 438	**64 790**
Logistic experts	17 029	7 740	5 303	1 335	20 610	5 719	**57 736**
Taxation experts	17 029	7 740	5 303	1 335	20 610	5 719	**57 736**
Regulation and standardisation experts	17 029	7 740	5 303	1 335	-	5 719	**37 126**
Electric engineers	-	-	-	1 335	-	5 719	**7 054**
Design and R&D engineers	-	-	-	1 335	-	5 719	**7 054**
Total (as %)	**340 581** (27%)	**170 288** (14%)	**121 972** (10%)	**34 716** (3%)	453 414 (36%)	**131 543** (10%)	1 252 514

Much of the labour needed to produce the main components involves low to medium skill sets, with **factory workers** accounting for 54 percent (almost 675 000 person-days). Those factory workers constructing foundations and substations (around 268 000 person-days and 57 000 person-days, respectively) may need to have some knowledge of offshore development. Workers with experience in the development and drilling of offshore oil rigs can be a natural fit for these positions. As for the turbine, the production of the technologically advanced subcomponents, such as the gearbox, the generator and the electronics, requires highly specialised skills that may not always be easy to source locally. Yet, governments could offer incentives for local manufacturing and support for supplier capacity development in order to localise these jobs. Figure 3.4 shows the distribution of human resources required to manufacture the main components of a 500 MW offshore wind farm, by occupation.

Figure 3.4 ■ **Distribution of human resources required to manufacture the main components of a 500 MW offshore wind farm, by occupation**



Although building a domestic manufacturing capacity for offshore wind components (including turbines, foundations, and substations) has the potential to create employment and income, this phase is very capital-intensive. it is most recommended where prospects are good for growing demand over an extended period of time. Other critical factors include adequate support for locally produced equipment, access to finance and skills, competitiveness in the regional and global market, and access to subcomponents and raw materials.

Maximising local value creation also depends on successfully leveraging existing expertise and capacities in other industries, such as aeronautics and construction or the oil and gas industry, that can provide expertise, raw **materials** and intermediary products such as steel, concrete, aluminium, copper, lead and fiberglass. Table 3.4 shows of the amounts of materials required for the main components for an 8 MW turbine and tower[10].

[10] The weight of each of the main turbine components, and thus the amount of materials needed, depends heavily on the technology used. This analysis is based on averaged weights for an 8 MW direct-drive turbine with a blade diameter of 110-130 m, and a tower 70-80 m high, supported over a monopile foundation.

Table 3.4 ■ Materials needed to manufacture the main components of a 8 MW offshore wind turbine[11] (tonnes)

<table>
<tr><th colspan="2">Materials needed for an 8 MW turbine (for conventional and direct-drive turbines)</th><th>Generator</th><th>Gearbox</th><th>Housing</th><th>Bedplate</th><th>Mainshaft</th><th>Transformer</th><th>3 blades (diameter 150-170 m)</th><th>Hub</th><th>Tower (120 m height)</th></tr>
<tr><td rowspan="2">Steel (grey cast iron)</td><td>Conventional</td><td rowspan="2">-</td><td>55-75</td><td rowspan="2">-</td><td>47-63</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">2</td><td rowspan="2">84</td><td rowspan="2">392</td></tr>
<tr><td>Direct-drive</td><td>-</td><td>42-57</td></tr>
<tr><td rowspan="2">High-alloy chromium steel</td><td>Conventional</td><td rowspan="2">-</td><td>55-75</td><td rowspan="2">-</td><td rowspan="2">-</td><td>36-48</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Direct-drive</td><td>-</td><td>32-44</td></tr>
<tr><td rowspan="2">Copper</td><td>Conventional</td><td>14-19</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td>10-14</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Direct-drive</td><td>8-11</td><td>9-13</td></tr>
<tr><td rowspan="2">Fiberglass</td><td>Conventional</td><td rowspan="2">-</td><td rowspan="2">-</td><td>14-19</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">90</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Direct-drive</td><td>13-17</td></tr>
<tr><td rowspan="2">Low alloy and electrical steel</td><td>Conventional</td><td>31-42</td><td rowspan="2">-</td><td rowspan="2">-</td><td>26-35</td><td>6-9</td><td>34-32</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Direct-drive</td><td>101-137</td><td>23-32</td><td>6-8</td><td>22-29</td></tr>
<tr><td rowspan="2">NdFeB material</td><td>Conventional</td><td>-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>Direct-drive</td><td>4.1-5.5</td></tr>
<tr><td colspan="2">Pre-stressed concrete</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>8</td></tr>
</table>

Based on Dillinger Hütte GTS, n.d.; Kaiser and Snyder, 2012.

Manufacturing the main components of a wind turbine requires specialised equipment as well as welding, lifting and painting machines that are used in other industries, such as construction and aeronautics. For the foundations, specialised equipment is also involved, including rolling drilling and welding machinery. Special vessels and cranes are used to move these big structures.

3.4 Transport

An 8 MW turbine can have a diameter of 150 to 170 m and weigh over 400 tonnes. Transportation of such bulky parts is one of the biggest challenges in the industry, especially over long distances. Some of the components can be manufactured close to the offshore wind farm site, but usually, similar to onshore wind, they are manufactured and then transported to a port (using specialised trucks) and then by sea to the final site (requiring specialised vessels).

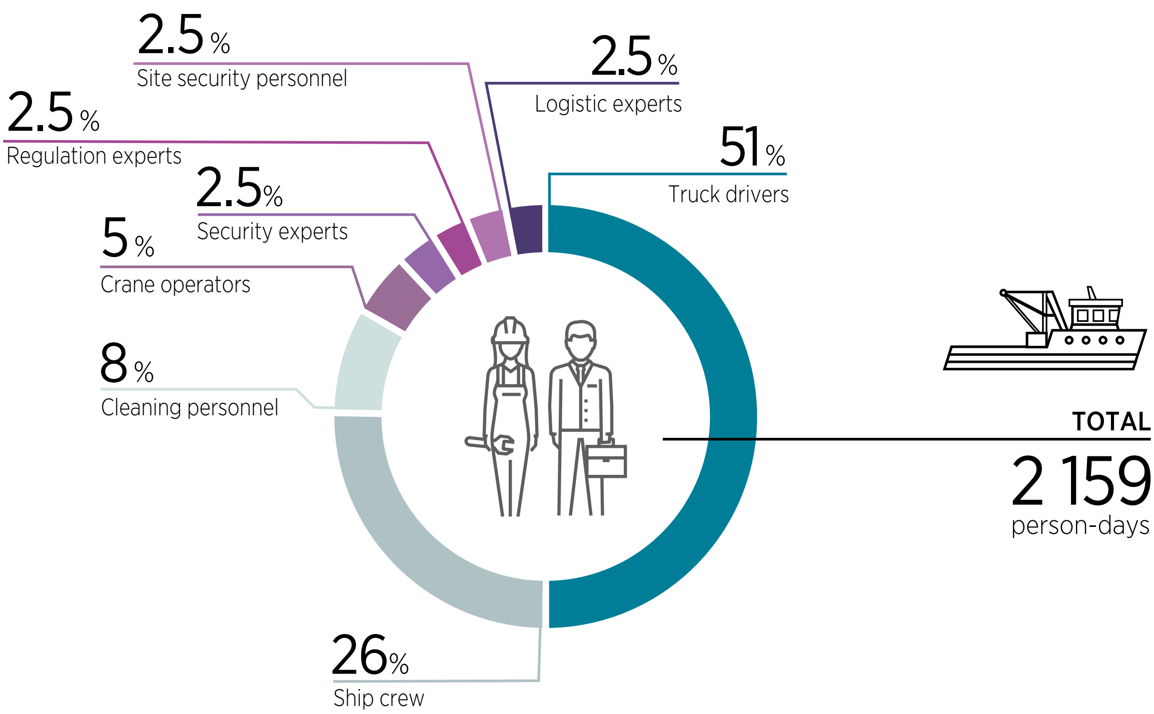
[11] While nearly all turbines that operate offshore or are currently being installed feature a conventional fast-speed geared drive system, direct-drive technology has been praised for its simpler design leading to easier operations and maintenance. The stigma of a bigger price tag and a heftier machine is still a burden to its deployment.

The foundations, platforms for the wind turbines and the substation are too heavy to be transported by land. For this reason, they are manufactured directly on the dock (similar to the manufacturing of boats) nearest to the planned site and transported to the offshore farm on completion.

An existing port can be modified to allow discharge and storage of turbine parts. However, a new port may be constructed if 1) the nearest available port is too distant, 2) the project is of a significant size, and 3) long-term operation and maintenance activity is expected to be based there. Typically, several ports will be involved on one project to carry out different activities (storage, O&M, training, manufacturing sites etc). In fact, is not just distance but the ability to provide adequate infrastructure, as well as superior services, the basis on what ports should be selected.

In summary, it takes about 2 159 person-days of labour to transport the main components of a 500 MW offshore wind farm ***(around 0.1 percent of the total requirements along the value chain).*** The distribution of human resources needed is shown in Figure 3.5. Of the total person-days of labour, specialised **truck drivers** account for more than half (1 108 person-days) to transport pieces such as blades and towers. **Ship crews** account for about 26 percent (554 person-days) of the total to carry out the transportation of components from dock to offshore. **Crane operators** to load and unload the pieces from boats and trucks account for 5 percent of the total. Both ship crew and crane operators, may require certified skills, but can generally be hired locally, drawing in part on the oil and gas industry workforce.

Figure 3.5 Distribution of human resources required to transport the components of a 500 MW offshore wind farm, by occupation



3.5 Installation and grid connection

The installation and grid connection of an offshore wind farm are a major cost component, representing about 19 percent of total installed costs. However, incremental opportunities to reduce the cost of installation and construction are expected by 2025 (IRENA, 2016d).

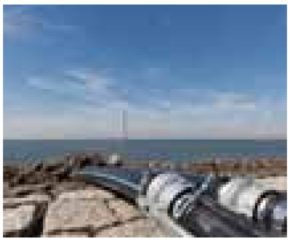
The installation and grid connection phases typically last about 24 months. During this phase, the foundations, substations and export cables are placed. Turbines are set on the foundations, electric connections are completed, and the grid connection of the offshore wind farm is finalised. Foundations installation, turbines erection and grid connection are activities carried out in parallel.This stage offers good opportunities for local value creation and for leveraging existing oil and gas industry equipment, labour and expertise.

Installing and connecting a 500 MW offshore wind farm takes about 237 250 person-days ***(an 11 percent of the total requirements along the value chain),*** as represented in Table 3.5. The most labour-intensive activity is installing the foundation (28 percent of the total), requiring around 50 000 person-days for both the **ship crew** and **crane operators** (IRENA, 2016d). The electrical installation of the array cables requires over 47 000 person-days (20 percent of the total) (Figure 3.6).

In terms of occupation, the **ship crew** accounts for more than 87 percent of the labour, with the rest distributed almost evenly among **technical personnel**, including **naval engineers, operators of remotely operated underwater trenching vehicle (ROV)** and **cable plough operators**.


Site preparation and civil works


Assembling equipment

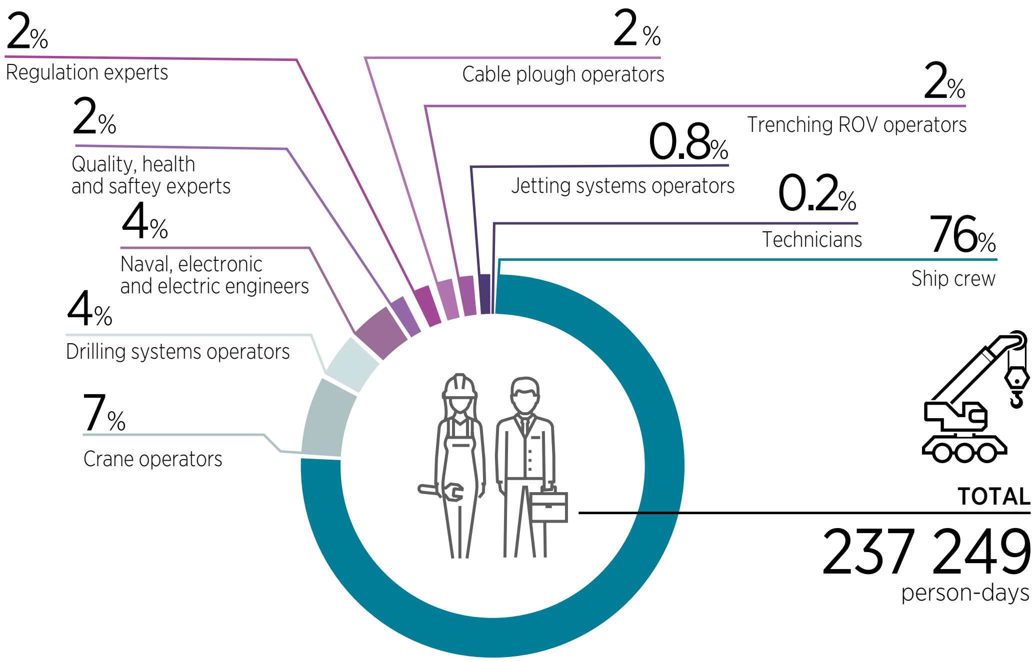

Cabling and grid connection


Commissioning

Table 3.5 Human resources required to install and connect of a 500 MW offshore wind farm (person-days) and breakdown by activity

TYPE OF HUMAN RESOURCE	Foundation	Substation	Cabling	Turbine	Array cable laying	Grid connection and commissioning	Total by occupation
Ship crew	39 996	13 951	43 210	40 826	40 826	615	**179 424**
Crane operators	9 999	3 488	-	4 083	-	61	**17 631**
Drilling systems operators	9 999	-	-	-	-	-	**9 999**
Naval, electric and electronic engineers	2 000	698	2 160	2 160	2 041	62	**9 121**
Quality, Health and Safety experts	2 000	698	-	2 160	-	62	**4 920**
Regulation experts	2 000	698	-	2 160	-	-	**4 858**
Cable plough operators	-	-	2 160	-	2 160	-	**4 320**
Trenching ROV operators	-	-	2 160	-	2 041	-	**4 201**
Jetting systems operators	-	-	2 160	-	-	-	**2 160**
Technicians	-	-	-	-	-	615	**615**
Total (as %)	**65 994** (27.5%)	**19 533** (8%)	**51 850** (22%)	**51 389** (22%)	**47 068** (20%)	**1 415** (0.5%)	**237 249**

Figure 3.6 Distribution of human resources required to install and connect a 500 MW offshore wind farm, by occupation



Equipment includes loaders, heavy-lift cranes (including floating cranes), high-tonnage trucks and vessels (including a cable-laying vessel to lay the cable in the sea bed). In addition, supervisory control and data acquisition (SCADA) equipment, electrical and electronic instrumentation, and control systems are used to receive information from the sensors installed in the turbines and relay it to the onshore control centre.

3.6 Operation and maintenance

The O&M phase of an offshore wind farm stretches over the expected lifetime of about 25 years. In many cases, platforms can be expected to exceed their design life, allowing the repowering of farms, and therefore increasing the total O&M jobs. Among the activities included are contract management, operations management, management of onshore facilities, wind turbine planned maintenance and unplanned service, balance-of-plant planned maintenance and unplanned service, and offshore logistics. Wind farms are operated automatically and are controlled in real time using a SCADA system or telemetry. These systems allow remote control of turbine operation and real-time gathering of data (*e.g.* wind direction, wind speed, vibrations and temperature of components of the nacelle).

These activities typically represent a quarter of the total lifecycle costs for offshore wind farms. Thanks to improvements in systems and procedures, it is estimated that annual O&M costs could be reduced around 44% by 2025 (IRENA, 2016c, 2016d).

Operating and maintaining a 500 MW offshore wind farm requires about 25 070 person-days during the first year. ***The total cumulative person-days over 25 years of project accounts for around 24 percent of the labour requirements along the value chain.***[12] Over a quarter of the total concerns operations (6 687 person-days per year) and the remainder, 73 percent is dedicated to maintenance (almost 18 386 person-days per year) (Table 3.6).

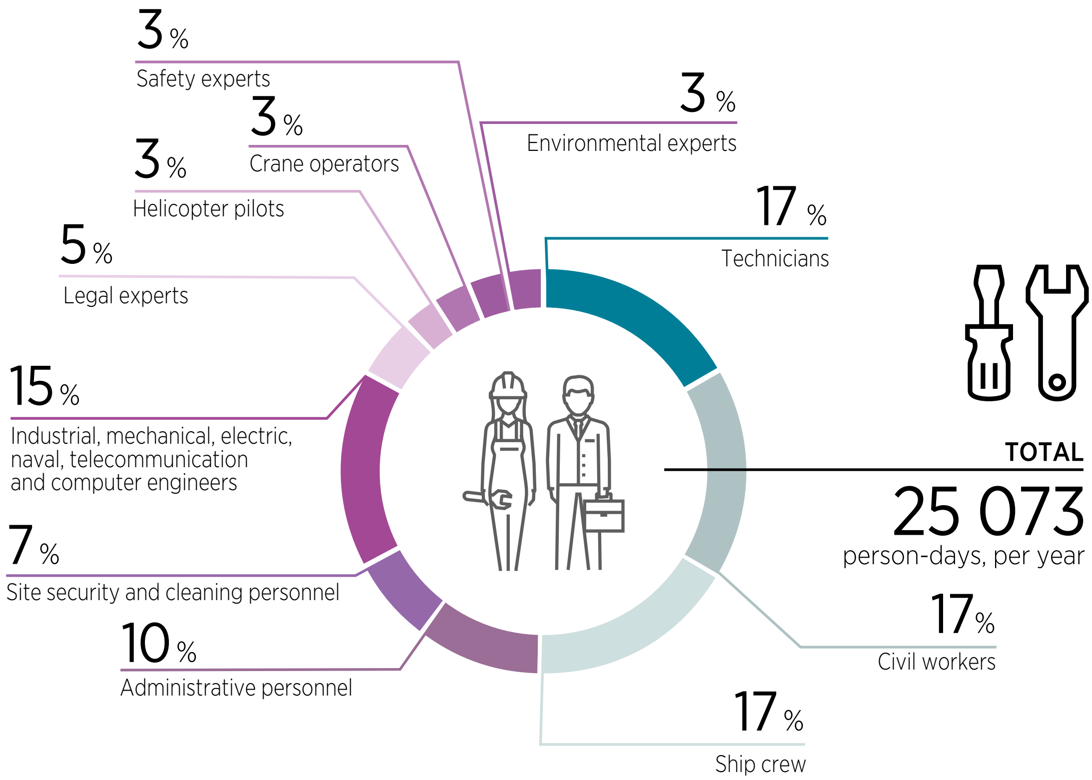
Table 3.6 Human resources required to operate and maintain a 500 MW offshore wind farm (person-days per year) and breakdown by activity

TYPE OF HUMAN RESOURCE	Operation	Maintenance	Total by occupation
Technicians	-	4 178	**4 178**
Civil workers	-	4 178	**4 178**
Ship crew	-	4 178	**4 178**
Administrative personnel	2 547	-	**2 547**
Industrial, mechanical and electric engineers	1 274	836	**2 110**
Site security and cleaning personnel	-	1 672	**1 672**
Telecommunication and computer engineers	955	418	**1 373**
Legal experts	1 274	-	**1 274**
Helicopter pilots	-	836	**836**
Crane operators	-	836	**836**
Safety experts	-	836	**836**
Environmental experts	637	-	**637**
Naval engineers	-	418	**418**
Total (as %)	**6 687** (27%)	**18 386** (73%)	25 073

[12] The number of person-days required for the first year of O&M is estimated to be 25 073. The total represents the cumulative person-days over 25 years of a project's lifetime, assuming average labour productivity improvements of 2 percent a year (Rutovitz, Dominish, and Downes, 2015). The current analysis does not include the O&M requirements for the repowering of the farm.

A highly skilled workforce with solid knowledge of different areas of engineering is required for both operations (a total of 2 229 person-days per year) and maintenance tasks (1 672 person-days per year) drawing on **industrial, mechanical, electric, telecommunications and computer engineers**. Altogether, engineers account for about 16 percent of total O&M labour requirements (Figure 3.7). Operation of the farm requires **personnel for administrative tasks** and **experts for legal and environmental** matters, together accounting for 4458 person-days per year (2 547, 1 274 and 637, respectively; this is equivalent to 10 percent, 5 percent and 3 percent of total O&M labour). **Ship crews, helicopter pilots** and **crane operator**s account for 5 849 person-days for maintenance duties every year (4 178, 836 and 836 person-days per year, respectively). This represents 32 percent of the maintenance workforce and is equivalent to 23 percent of total O&M labour. This labour force can easily draw on oil and gas industry workers.

Figure 3.7 Distribution of human resources required to operate and maintain a 500 MW offshore wind farm, by occupation



3.7 Decommissioning

Considering that offshore wind energy is a very recent technology and the average lifetime of projects is expected to be 25 years (even extending to longer periods after repowering[13]), measuring the labour needs for decommissioning a wind farm remains a theoretical exercise. It involves planning the needed activity, dismantling the project, recycling and disposing of the equipment, and clearing the site. These activities are likely to be carried out by local personnel.

Planning the decommissioning

Dismantling the project

Disposing/recycling the equipment

Clearing the site

13 Typically, following the construction of a wind farm, it is becoming more common to use the same site for the repowering and/or reinstallation of new facilities. Both "life extension" and "repowering/re-installation" programmes could have significant, positive impacts on local employment as they offer additional jobs or the extension/consolidation of existing O&M tasks over time.

It is estimated that it may take close to 100 000 person-days to decommission a 500 MW offshore wind farm ***(accounting for around a 5 percent of the total requirements along the full value chain)*** The most labour-intensive activity is dismantling the equipment, requiring 97 percent of the total (Table 3.7). Planning the decommissioning is thought to require close to 1 900 person-days (2 percent of the total), while clearing the site (disposing and recycling of materials and equipment) may take about 1 300 person-days (1 percent of the total).

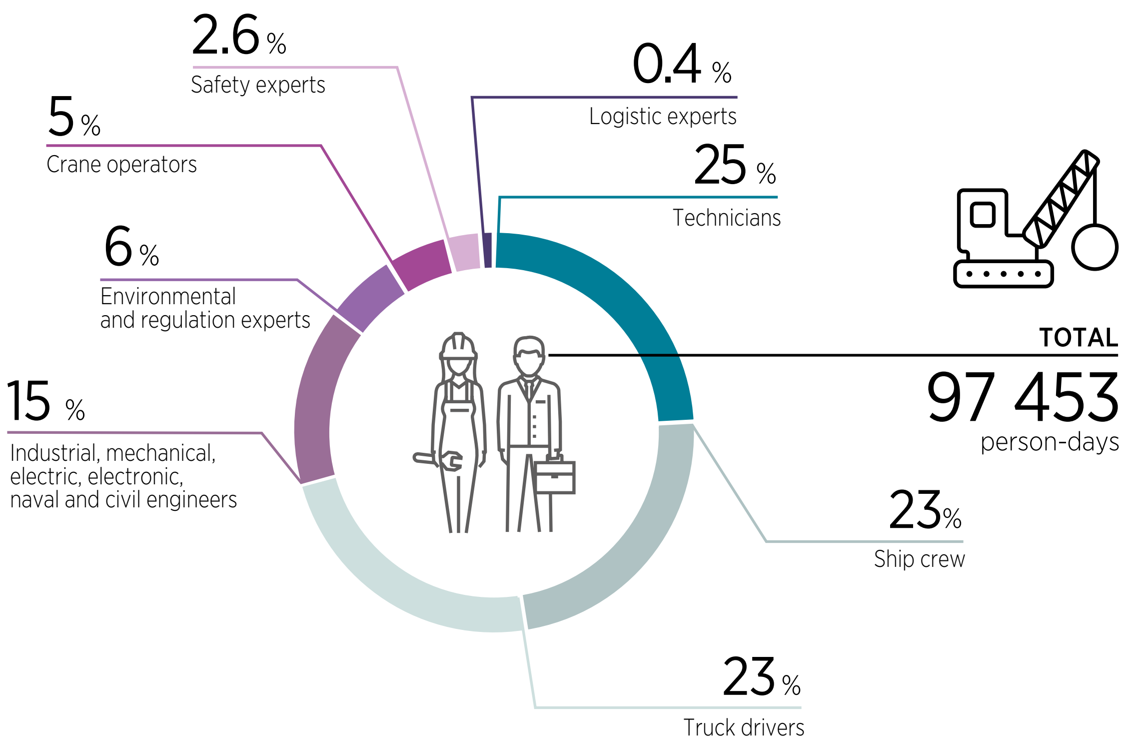
Table 3.7 Distribution of human resources required to decommission a 500 MW offshore wind farm, by activity

TYPE OF HUMAN RESOURCE	Planning	Dismantling	Recycling and disposal	Total by occupation
Technicians	-	22 994	997	**23 991**
Ship crew	-	22 994	-	**22 994**
Truck drivers	-	22 994	-	**22 994**
Industrial, mechanical, electric, electronic, naval and civil engineers	684	13 794	-	**14 478**
Environmental and regulation experts	686	4 598	100	**5 384**
Crane operators	-	4 599	-	**4 599**
Safety experts	171	2 299	100	**2 570**
Logistic experts	343	-	100	**443**
Total (% as)	**1 884** (2%)	**94 272** (97%)	**1 297** (1%)	**97 453**

Technicians, truck drivers and the **ships' crews** account for 73 percent of the required labour, almost evenly distributed (about 70 000 person-days in total), mostly during the dismantling phase. **Engineers** from different fields represent 15 percent (close to 14 500 person- days) (Figure 3.8).

The **equipment** needed for this purpose is similar to that required for construction and installation. Most of it is quite commonly available in countries with an active construction industry, and especially those with an existing oil and gas industry.

Figure 3.8 ■ **Distribution of human resources required to decommission a 500 MW offshore wind farm, by occupation**



4. CONCLUSIONS

The socio-economic benefits of renewable energy have become a key consideration in building the case for its wide deployment. Increasingly, governments understand that the expansion of renewable energy entails important co-benefits that go beyond the need to reconcile energy systems with environmental protection. Economic analysis underlines the fact that the switch to renewables supports economic growth, creates employment opportunities and enhances human welfare. Opportunities for domestic value creation can be created by leveraging and enhancing capabilities in existing industries (like oil and gas) along the value chain or planning to develop them.

To assess the case for domestic industry development in the offshore wind sector, policy makers need to analyse the labour, materials and equipment requirements of each segment of the value chain. Based on such an analysis, opportunities for leveraging local labour markets and existing industries can be identified to maximise domestic value. Regional and global market dynamics also strongly influence the decision to pursue domestic industry development.

The degree to which the transition to offshore wind and other renewables delivers significant socio-economic benefits depends on several factors. To navigate the transition successfully requires careful attention to a range of policies and a dedicated effort to ensure coherence among the different policy areas and the key actors and stakeholders in each of them. The main policy areas concern deployment measures in support of renewables, industrial policies to enhance capacities along the supply chain, education and training policies to ensure a well-trained and capable workforce, and a just transition policy to smooth the path forward and maximise the concomitant socio-economic benefits.

- On the deployment side, the level of national ambition towards the energy transition sets the overall pace for the deployment of offshore wind and other renewables. To provide a long-term perspective of the market's likely trajectory, it is necessary to set clear targets for renewable energy development. Targets are effective when accompanied by suitable deployment policies that provide a stable and predictable environment for attracting investments. The right mix of deployment policies depends on the particular circumstances and may entail feed-in tariffs, premium policies, auctions and other measures. It is the design of such policies (and the ability to retain a degree of flexibility to respond to evolving circumstances) that may matter more than the fundamental type of policy (IRENA, 2018e).

- Countries with well-developed relevant industries and service sectors will be able to build viable domestic supply chains for offshore wind more readily than countries which lack such capabilities and need to create them from scratch. But it is the task of industrial policy to build or strengthen such capacities. Measures in the industrial policy toolkit of governments are varied and include the provision of preferential access to credit, land and buildings for firms in the renewable energy sector. Other policies include the formation of economic incubators and industry clusters. Public investments in support of an emerging renewable energy industry are another option. To strengthen the industrial capability and competitiveness of domestic firms, various measures are needed such as industrial upgrading programmes, supplier development programmes, promotion of joint ventures, and investment promotion schemes.

- To ensure the full-fledged development of a nascent industry, policy support should be time-bound and include broader aspects beyond deployment, human resources and industrial development.

- To meet the human resource requirements associated with deployment targets, education and training policies need to consider the occupational and skills requirements of the offshore wind energy sector. Prospects for local employment improve to the extent that the provision of education and training/re-training sufficiently matches evolving skills needs.

- A particular challenge of the transition is to consider ways how workers released from a declining fossil fuel sector can be successfully retrained to take advantage of jobs and careers arising in renewables. Part of the task is to establish relevant occupational profiles to understand where skills requirements match or diverge. However, the jobs gained in the offshore wind sector may not necessarily be in geographic alignment or occur within the same time frame as jobs lost in fossil fuels. And because re-skilling and other such efforts take time and are not always certain to succeed, there is a need for additional just transition policies that provide interim support, such as unemployment insurance and other social protection measures, to affected workers and communities.

ANNEX A

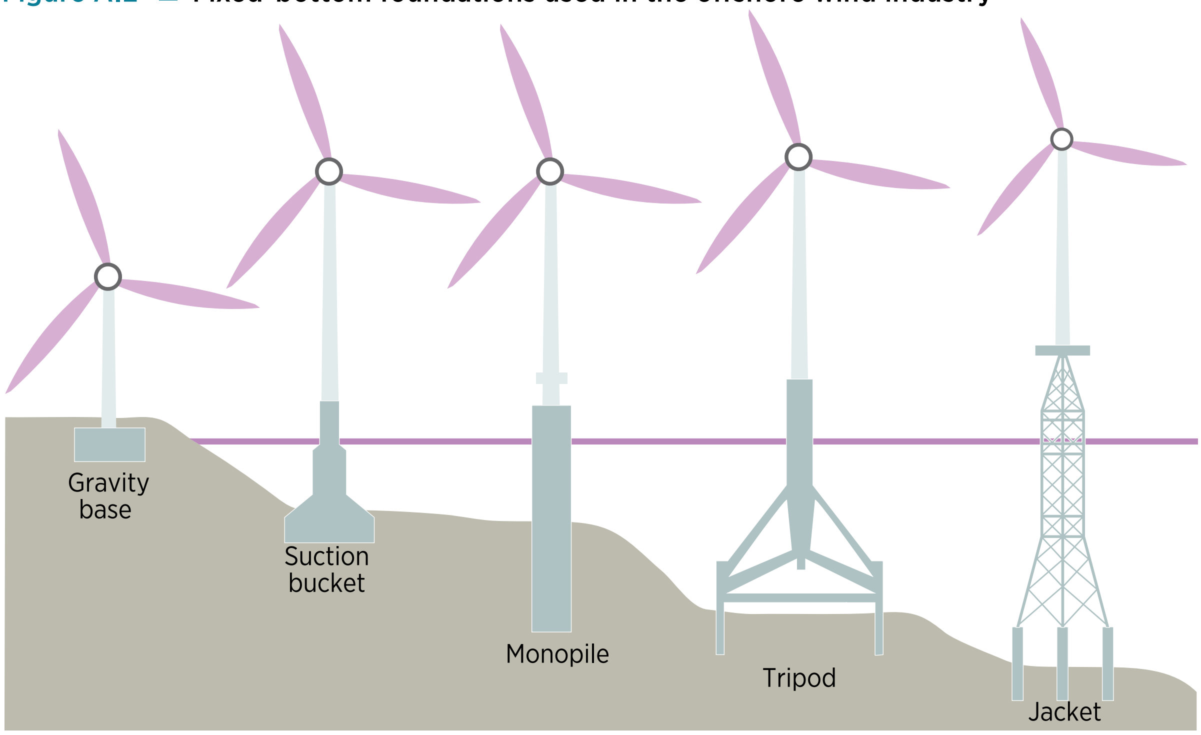
COMPONENTS OF AN OFFSHORE WIND FARM

The main components of an offshore wind turbine are very similar to those of an onshore wind turbine. They include the rotor (blades, hub casting, blade bearings, pitch, spinner, rotor auxiliary systems and fabricated steel components), the nacelle (bedplate, main bearing, main shaft, gearbox, generator, power system, control system, yaw drive, yaw brakes, yaw bearing, wind vane, nacelle auxiliary systems and cover, fasteners, and monitoring system), the tower and internal cabling. In addition, components of the offshore wind farm include the external cabling, the turbine foundation, and onshore and offshore substations. The subcomponents of the rotor, nacelle and tower are described in IRENA's analysis Leveraging Local Capacity of Onshore Wind (IRENA, 2017b).

Turbine foundation: The foundation is needed to support the wind turbine in offshore waters. A variety of designs have been developed, including monopiles, concrete gravity bases and jackets. In recent years, floating turbines have been developed for deeper water (more than 60 m deep), and in these cases a foundation is not needed. The foundation is connected to the tower with a transition piece, which extends to about 20 m above sea level. It includes a platform with guardrails and the crew access system, as well as the J tube, or the tube that routes the inter-array cable into the foundation and the turbine.

The most common foundations currently used in offshore wind projects are bottom-fixed (rooted to the seabed). While they are the most typically used structures, their use is restricted to waters less than 50 m deep. Bottom-fixed foundations can be classified as follows (presented in Figure A.1):

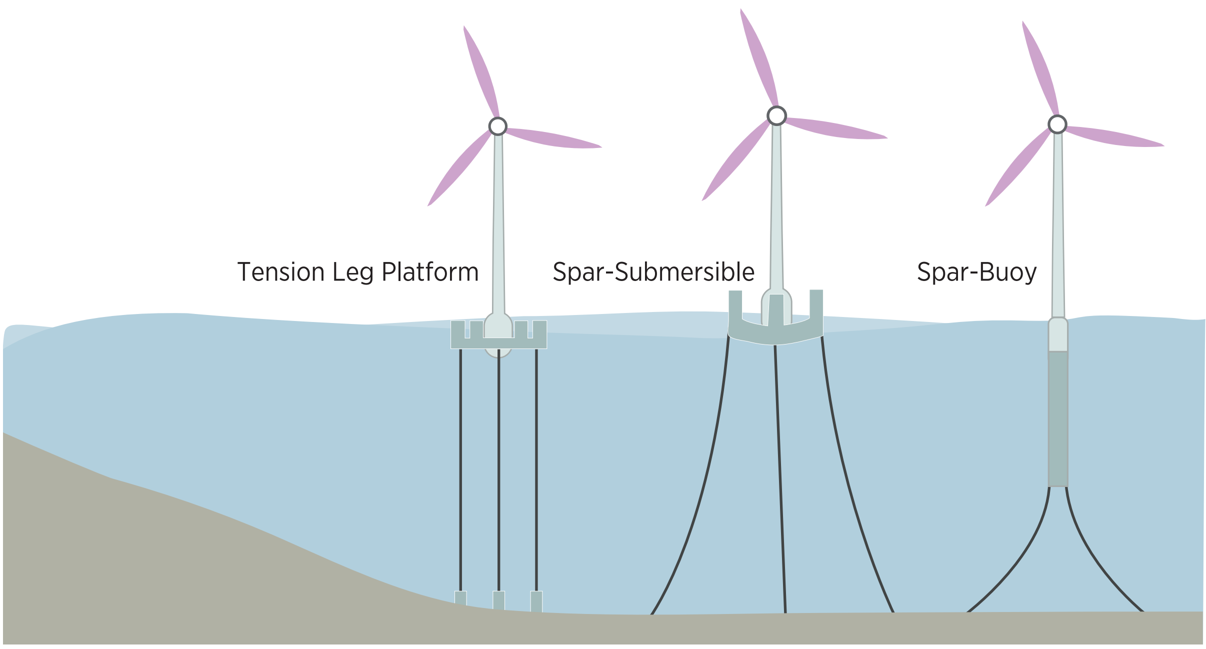
Figure A.1 ■ Fixed-bottom foundations used in the offshore wind industry



Source: Moulas *et al.*, 2017

- **Gravity base:** This consists of a large base constructed from either concrete or steel that rests on the seabed. The turbine is dependent on gravity to remain erect. This design is appropriate for shallow waters of 10 m depth and a plain seabed. In both cases (concrete and steel) rocks are placed around the edges of the base to prevent erosion. Currently, gravity base foundations comprise around 9 percent of the total market.
- **Suction bucket:** The structure is anchored by pumping water out of the bucket to reduce pressure inside the structure. The pressure, combined with the weight of the foundation, is able to keep the structure fixed in the seabed. This design is the least implemented in the current market, not even accounting for about a 2 percent of the total.
- **Monopile:** This foundation is typically used for water depths of no more than 30 m. A monopile consists of a steel pile with a diameter of 3.5 to 4.5 m. While it doesn't require the preparation of the seabed, it is installed by drilling, which makes it less suitable for rocky seabeds. These foundations account for more than 80 percent of the current market.
- **Tripod:** This technology is based on experiences from the oil and gas industry. The foundation consists of a steel pile below the turbine tower and a three-legged steel pile that is placed on the seabed. The tripod foundation does not require preparation of the soil bed before installation. It is not suitable for soil beds formed by hard rock or water depths lower than 6 to 7 m. Only around 3.6 percent of the currently used foundations, are tripods.
- **Jacket:** Although this technology was extensively used in the oil and gas industry, it has only recently been used for offshore wind facilities. A jacket is based on a three- or four-legged lattice structure consisting of corner piles interconnected with bracings with diameters of up to 2 m. These piles are driven into the soil bed to gain stability. The advantages of jacket foundations include wave resistance and suitability for large turbines and deep water. However, their construction costs are higher and transport is more difficult. Jacket foundations can be found in about 5.4 percent of the total market.

Figure A.2 ■ Offshore wind floating foundation



The areas with the largest potential for offshore wind are normally located in waters deeper than 50 m. A variety of floating designs have been developed to overcome the depth constraint and to take full advantage of wind resources while benefitting from less invasive activity on the seabed during installation. The three main concepts for floating foundations are spar-buoy, semi-submersible and tension leg platform (Figure A.2). Variants of these designs also exist, including the mounting of multiple turbines onto a single floating foundation (IRENA, 2016b; Vicente Negro *et al.*, 2017)

Offshore substation: Offshore substations are needed to stabilise and maximise the voltage of power generated offshore (from around 33 kilovolts [kV] to 132 kV), reduce potential electrical losses and transmit electricity to shore. A single substation can be used for around 500 MW of wind turbines, although in some cases there is more than one substation to increase security of export. Substations installed far from the coast can include facilities to provide refuge and accommodation for personnel, as well as fire and blast protection.

Onshore substation: The onshore substation is similar to the offshore substation described above and is used to increase voltage from 132 kV to grid voltage (*e.g.* 400 kV). If the power is sent in direct current from the offshore substation, a converter is needed to transform direct current into alternating current again.

Cabling: Cables transport the power output from the wind turbines to the grid. Subsea cables are made up of a stranded, profiled conductor with a combination of sealing layers, cross-linked polyethylene insulation and armouring. Cables are divided into small array and large array cables.

- **Small array cables** or inner cables, are the cables that connect the turbines to the offshore substation. Each turbine needs around 1 km of cable, depending on its size and space.
- **Export cables** connect the offshore and onshore substations.

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