Employment analysis (2019-2023) of various fields of activities in the Dutch offshore wind sector

Erik Knol (Qeam) and Erwin Coolen (ECHT)

July 2019
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Study commissioned by RVO (Netherlands Enterprise Agency) and TKI Wind op Zee (Top Consortium for Knowledge and Innovation Offshore Wind)

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Contractor: Centre of Expertise Water & Energy

Study performed by Erik Knol (Qeam) and Erwin Coolen (ECHT)


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Summary

Until today around 1 GW of offshore wind capacity has been realized in Dutch waters of the North Sea. For the near future the Dutch government has the policy to have five offshore wind farms of circa 700 MW each, realized as from 2019 until 2024. This is the so-called Roadmap 2023. Next, the ambition is to install around 6 GW in the period 2024-2030. This results in an expansion of the installed offshore wind power in the following years: from around 1 GW in 2019 to 10.6 GW in 2030.

Offshore wind energy contributes to a strengthening of the economic activities in the Netherlands and to reach the targets of the Dutch Climate Agreement (Dutch: Klimaatakkoord; MinEZK, 2019a). Therefore, it is relevant to have more in-depth information about employment developments in the Dutch offshore wind energy industry and insights regarding needed competencies. Available publications indicating employment (developments) in offshore wind in the Netherlands are not useful for human capital planning and education strategies. For this reason The Netherlands Enterprise Agency RVO and TKI Wind op Zee commissioned this study with the following objective: specify Roadmap 2023 employment in offshore wind at such a level of detail that the insights can be used to develop plans for education and inflow of future employees to the offshore wind sector. The request was to investigate certain fields of activities that are from employment and education perspectives relevant, namely: foundation supply, foundation and turbine installation, array cable installation, installation support, wind farm operations, turbine maintenance, structural inspection and maintenance, and maintenance and service logistics.

The study used a bottom-up approach to investigate employment developments: workload estimations on the level of specific fields of activities. Competencies were analysed by using the following framework: a) functional competencies, and b) foundational competencies. This study was done in close collaboration with key stakeholders from the Dutch offshore wind industry (e.g. Deutsche Windtechnik, Gemini, OutSmart, SeaZip, Siemens Gamesa Renewable Energy, SIF, Smulders, and Van Oord) via interviews, various iterations on employment figures, workshops, factory visits, and feedback on draft versions of this report.

Conclusions

Conclusion is that the (further) developed methodologies are well suited to come up with direct employment figures and competencies overviews able to support plans for education and inflow of future employees to the offshore wind sector.

Regarding direct employment generated by the execution of Roadmap 2023 the following conclusions can be drawn:

- The one-off cumulative direct employment over the coming 5 years due to the Roadmap 2023 execution is approx. 2,480 person-years when considering the 5 studied construction phase packages. Of this number around 1,290 person-years are related to foundation supply. Approx. 810 person-years relate to vessel crew.
- The yearly recurring direct employment with respect to studied operations and maintenance phase packages is around 320 FTE, as from 2023 when all Roadmap 2023 wind farms are in operation. Circa two-third of this yearly recurring direct employment consists of work for Dutch technicians.
- The employment estimations are in the upper side of the figures’ ranges, looking at developments in product and process innovations, economies of scale, and learning curves. It should be noted that the yearly outflow of professionals and export-related employment are not yet incorporated in the above-mentioned figures.

Regarding competencies the overall conclusion is that the created competency framework for this study is useful for industry and education institutes to discuss and align education and training options and needs the coming years.
Conclusion is that a substantial amount of the direct employment in the offshore wind industry is related to EQF (European qualifications framework) levels 1-5. In general, existing education programmes are serving the offshore wind industry when looking at the needed functional competencies. There is room for specialistic courses/trainings developed and organised in cooperation between education institutes and the industry.

It can be concluded that English reading, writing and conversation competencies are very important in the fast developing and international offshore wind sector, on all levels (VET, bachelor, and master level).

Career path information of professionals is not recorded by education institutes; this information could be useful to better align education strategies and yearly inflow of needed professionals.

**Recommendations for education institutes**
- Nationwide educational approach for offshore wind technicians and other staff categories. Address: synergies among education institutes, specializations, potentials of educating and training of foreign students and professionals, and the enabling potentials of industry-driven applied research for (future) education and training.
- Strong focus on English language skills.
- Align together with the industry who will facilitate the special courses and trainings needed.
- Stronger present together with the industry the offshore wind sector within education.

**Recommendations for industry**
- Develop a human capital plan: a) secure influx of students/professionals to the sector (among other factors by raising awareness among broader public about offshore wind sector careers), b) indicate career paths within the sector, and c) express education and training needs.
- Offer internship/apprenticeship programs with real-life assignments. Look for opportunities to involve students in the sector as early as possible during their education, not only for inspiration but also for perception management (qualified for offshore work: sea, heights etc.).
- Invest in applied research supporting the industry and enabling curriculum developments.
- Align together with the educational institutes who will facilitate what special courses and trainings that are needed.
- In-depth elaborations are needed to link more specific employment activities (e.g. on the level of scopes of work) to certain education levels.

**Recommendations regarding governmental policies**
- Specific barriers – e.g. elements of the Dutch Working Hours Act – should be in line with industry needs to facilitate the productivity of professionals in the sector.
- Facilitate bottom-up employment and competencies studies that support human capital and education strategies in offshore wind to generate detailed competencies overviews.
- Facilitate bottom-up employment and competencies studies on indirect employment and export-related employment in offshore wind.
- Facilitate investigations that could define the needed Dutch educational capacities needed considering the developments in offshore wind in the Netherlands and abroad, and the potentials to serve also students and professionals from abroad with education and training in the Netherlands.
- Looking at the dynamics within the offshore wind sector the upcoming years and beyond, it is recommended: a) to update of this study as presented in this report yearly, and b) to consider (online) approaches to collect data from offshore wind companies more easily.
Definitions and abbreviations

**Associate degree:** education programme – with in general a duration of 7 years - mostly offered by universities of applied sciences. This level of education is comparable with level 5 of the European qualifications framework.

**Bachelor education:** education mostly offered by universities of applied sciences and universities in the Netherlands. This level of education is comparable with level 6 of the European qualifications framework.

**CNC:** computer numerical control is the automated control of machining (and other) tools by means of a computer.

**Competencies:** cluster of related knowledge, skills, and abilities that affects a major part of one’s job (a role or responsibility), that correlates with performance on the job, that can be measured against well-accepted standards, and that can be improved through training, development, and experience.

**Crew:** standard marine manning for a vessel.

**CTV:** crew transfer vessel.

**Direct employment:** jobs that relate specifically to offshore wind activities.

**EQF:** European qualifications frameworks.

**Foundational competencies:** 'soft skills' and work readiness skills that most employers demand.

**FTE:** full-time equivalent; unit obtained by comparing an employee’s average number of hours worked to the average number of hours of a full-time worker. In this study the Dutch guidelines for a regular work week will be used as one FTE, namely 38 working hours a week.

**Functional competencies:** in general, job-related and relate to the ability to demonstrate performance to the standards required of employment in an offshore wind work context looking at packages, scopes of work, and job roles.

**GWO trainings:** safety trainings Global Wind Organisation.

**HBO:** Dutch label for higher professional education; in Dutch: hoger beroepsonderwijs. It is linked to the following European qualifications frameworks levels: 6 and 7.

**HEI:** higher education institute.

**HSEQ:** health, safety, environmental management, and quality.

**Indirect employment:** jobs outside of the offshore wind energy sector but which are part of the supply chain to the sector by supplying the inputs to offshore wind projects.

**Job roles:** work opportunities within each scope of work. Job roles are not considered in this study.

**Master education:** education mostly offered by universities of applied sciences and universities in the Netherlands. This level of education is comparable with level 7 of the European qualifications’ framework.

**MBO:** Dutch label for VET education in the Netherlands; in Dutch: middelbaar beroepsonderwijs. It is linked to the following European qualifications frameworks levels: 1, 2, 3, and 4.

**MP:** monopile.

**One-off activities:** in this study a cluster of activities that will be performed only once, e.g. in order to build up infrastructure during the construction phase of an offshore wind farm.

**Package:** bundle of activity clusters within an offshore wind phase. In this report the following packages related to the construction phase are studied: foundation supply, foundation installation, turbine installation, array cable installation, installation support. The following packages related to the operations and maintenance phase are studied: wind farm operations, turbine maintenance, structural inspection and maintenance, and maintenance and service logistics.

**Phases:** in the life cycle of an offshore wind farm four main stages can be recognised: development, construction, operations and maintenance, and decommissioning. This report focuses on certain fields of activities part of the construction phase and operations and maintenance phase.

**Predictive maintenance:** maintenance strategy focusing on predicting when device failure will occur and preventing that occurrence of failure with the help of monitoring.

**QC:** quality control.

**Recurring activities:** in this study a cluster of activities during the operation and maintenance phase with a repetitive character.
ROV: remotely operated vehicle.

Scopes of work: main activity clusters within each package.

SOV: service operations vessel.

Staff: pending the activity to be executed a specialised staff will be based on a vessel

STWC: international convention on Standards, Training and Watchkeeping for Seafarers.

TP: transition piece; part of the wind turbine foundation.

VCA certificate: Dutch certificate basic safety.

VET education: vocational education and training; prepares pupils for the professional practice or further study. It is linked to the following European qualifications frameworks levels: 1, 2, 3, and 4. See also MBO.

Weather window: period that wind and wave conditions are within construction criteria.

WTG: wind turbine generator.
1 Introduction

Background
Until today around 1 GW of offshore wind capacity has been realized in Dutch waters of the North Sea (Dutch Continental Shelf - DCS; in Dutch: Nederlands Continentaal Plat - NCP). For the near future the Dutch government has the policy to have five offshore wind farms of circa 700 MW each, realized as from 2019 until 2024. This is the so-called Roadmap 2023. Three of these wind farms have been tendered so far and the tendering process for the following offshore wind farms is in progress. The government has announced that it wants to increase the pace of deployment of offshore wind farms as from 2024. This is Roadmap 2030. The ambition is to install an average of at least 1 GW per year in the period 2024-2030. This results in a major expansion of the installed offshore wind power in the coming decade: from around 1 GW in 2019 to 10.6 GW in 2030 (MinEZK, 2018a, 2019b). This expansion supports the energy transition in the Netherlands substantially (MinEZK, 2019a).

Offshore wind energy contributes to a strengthening of the economic activities in the Netherlands. Both the domestic market for offshore wind energy and the export market bring a substantial amount of jobs for Dutch companies active on the national and international market. Therefore, it is relevant to have more in-depth information about employment developments in the Dutch offshore wind energy industry and insights regarding needed competencies in the industry. This information is relevant for policymaking (see e.g. CBS, 2018; SER, 2018), gives support in the offshore wind sector for appropriate labour market measures, and enables educational organisations to plan and provide training for future (and existing) offshore wind professionals. For these reasons the Dutch government wants to investigate specific employment developments for the coming years and needed competencies in the Dutch offshore wind energy sector.

Insights needed on the level of packages
Over the year several publications have become available regarding growth of employment in the Dutch offshore wind sector (e.g. Ecofys, 2014; EIB, 2016). On macro level these publications show the trends in employment. For several reasons these publications are not useful for human capital planning and education strategies. In the first place, some of the previous labour market scenarios were based on data of relatively small offshore wind farms (and based on employment indications per MW turbine capacity instead of employment indications per wind turbine, as used in this study) built in a period where the Dutch offshore wind sector was not mature yet. This has resulted in indications which are less well comparable with the characteristics of future Dutch offshore wind farms in terms of embedded product and process innovations (e.g. optimisation and automation in monopile supply and increase in single turbine capacity), economies of scale (e.g. larger wind farms), and learning curves (e.g. more efficient installation schedules, increase in operational excellence). Secondly, these previous labour market indications are mostly on the level of offshore wind farm phases (e.g. development, construction, operations and maintenance). To be more useful for the industry and education institutes to develop strategies to stimulate influx of professionals to the sector and to organise future-oriented training and education with appropriate capacities, insights on the level of packages - one level lower than phases - are needed. Packages are set of bundled activities mostly as contracts awarded by offshore wind farm developers. Examples of packages are: a) manufacturing of monopiles (part of construction phase), b) offshore installation of wind turbines (part of construction phase), and c) maintenance of wind turbines (part of operations and maintenance phase). Chapter 4 gives a more complete overview of the offshore wind packages and the set of packages under study.

This study focuses on Roadmap 2023 wind farms
The Netherlands Enterprise Agency RVO (Rijksdienst voor Ondernemend Nederland) and TKI Wind op Zee (Top Consortium for Knowledge and Innovation Offshore Wind) commissioned Centre of Expertise Water & Energy (CoE Water & Energy) to perform an analysis of labour market developments in terms of growth of direct employment related to Roadmap 2023 and needed competencies in a restricted number of packages in the Dutch offshore wind sector. These packages are: 1) foundation supply, 2) foundation installation, 3) turbine installation,
4) array cable installation, 5) installation support, 6) wind farm operations, 7) turbine maintenance, 8) structural inspection and maintenance, and 9) maintenance and service logistics. Most of these packages involve work for Dutch companies. Study of other packages - where Dutch companies are less involved or where the employment is relatively limited for Dutch companies and/or professionals from the Netherlands - was excluded in the Terms of Reference for this project (RVO, 2019). Chapter 4 gives an overview of offshore wind packages and the set of 9 packages under study.

The study is based on strong involvement of key stakeholders from the industry: interviews, various iterations on employment figures, workshop-like sessions, factory visits, and feedback on draft version(s) of the final report. Additionally, desk research was performed. Data is used that has been collected via more than 25 interviews1 by Atlas Professionals in the first phase of this study initiative. During the second phase of the study the available data was validated, and new data and insights were collected. During this second phase there was a strong involvement of several key stakeholders from the industry via several methods as indicated above.2 A supervisory committee - with members from the industry, research, education and representatives of the two principals – guarded the progress and quality of the study.

The purpose of this study is to deliver a deeper understanding of the nature and the development of the labour demand across installation and operations activities in the Dutch offshore wind industry for the coming 5 years. Therefore, this report offers information regarding employment and needed competencies in the sector, including conclusions and recommendations for government, industry and educational institutes.

Content of report
Chapter 2 gives details about the study objectives and the used methodologies. The next chapter indicates the offshore wind developments in the Netherlands and in the surrounding countries of the Netherlands. Detailed descriptions about the packages under study, including the various scopes of work related to the packages and high-level indications of involved employee categories per package are given in chapter 4. Employment figures related to Roadmap 2023 and based on industry consultations are given in chapter 5. In chapter 6 elaborations regarding needed competencies for the Dutch offshore wind industry are given, including a detailed competencies overview with respect to offshore wind turbine maintenance technicians. Chapter 7 reflects briefly on existing education programmes in the Netherlands relevant for the offshore wind industry. The last chapter gives the conclusions and recommendations.

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1 Various Dutch companies active in offshore wind, various education institutes focussing on offshore wind education and other relevant organisations.
2 Turbine manufacturers, monopile manufacturer, TP manufacturer, offshore wind farm operations, maritime and offshore wind installation company, and offshore shipping company (e.g. Deutsche Windtechnik, Gemini, OutSmart, SeaZip, Siemens Gamesa Renewable Energy, SIF, Smulders, and Van Oord).
2 Objectives and methodologies

2.1 Objectives of the study

This study has the following general and specific objectives as requested via the Terms of Reference by RVO (2019):

General objectives
General objective is to specify Roadmap 2023 employment in offshore wind at such a level of detail that the insights can be used to develop plans for education and inflow of future employees. Therefore the study focuses on 9 packages of offshore wind energy in the Netherlands: 1) foundation supply, 2) foundation installation, 3) turbine installation, 4) array cable installation, 5) installation support, 6) wind farm operations, 7) turbine maintenance, 8) structural inspection and maintenance, and 9) maintenance and service logistics. Within these packages the focus is on direct employment developments and needed competencies. Existing and future wind farms in the Dutch lake IJsselmeer are not included in this study. Definition and boundaries regarding packages and scopes of work are derived from e.g. Green Port Hull & BVG Associates (2017) and Knol & Baken (2018) (see definitions section and package descriptions in chapter 4).

Objectives related to employment analysis
A major objective is the indication of direct employment developments on the level of ‘scope of work’ in terms of volume of work (expressed in person-years or person-days) and/or full-time equivalent (FTE) jobs regarding existing and to be installed wind farms related to Roadmap 2023 (see chapter 3 and specifically table 2). An additional goal of the study is to indicate the amount of one-off employment (mostly related to activities during the construction phase of an offshore wind farm) and structural employment (mostly related to recurring activities in the phase of operations and maintenance). Related an estimation will be given to what degree employment could be filled with Dutch labour force. Offshore wind is an international sector, and in this study a first indicative estimation will be given of the employment potentials of export-related activities of offshore wind companies operating from the Netherlands in the surrounding countries of the Netherlands.

Objectives related to competencies
A major objective is to give results about: a) the distribution of employment within the packages in terms of the education levels VET, bachelor and master, and b) the most relevant competencies per package or scope of work.

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3 Aspects related to the level of job roles (a level deeper than the level of scopes of work) are not analysed in this study. Other segments or phases part of the Dutch offshore wind industry are excluded in this study. See also chapter 4.
2.2 Methodologies

Methodologies used for employment analysis

The core approach of this study is a (further developed) bottom-up approach: actual direct employment (workload) figures and estimates on the level of packages and scopes of work (see figure 1) related to existing Dutch offshore wind farms (e.g. Gemini) and forthcoming Dutch offshore wind farms (e.g. Borssele 3 and 4 wind farms). In this study direct employment figures and estimates are related to the number of WTGs instead of related to the (cumulative) power output of the WTGs. In the first phase of the study desk research is done on publications with offshore wind employment data and/or indications. Although offshore wind energy has become a rather mature sector publications regarding labour market developments in the Netherlands on the level of packages (and scope of work) are still scarce, as also noticed by Knol & Baken (2018).

Four phases:
- Development:
  - Site selection
  - Environmental impact assessments
  - Pre-construction activities (including site survey and environmental assessments)
  - Financial feasibility studies
  - Engineering design
  - Project development

- Construction:
  - Tower, nacelle, hub and blades supply
  - Foundation supply
  - Cable supply
  - Substation supply
  - Foundation installation
  - Turbine installation
  - Array cable installation
  - Substation installation
  - Substation foundation installation

- Operations & maintenance:
  - Wind farm operations
  - Turbine maintenance
  - Structural inspection & maintenance
  - Maintenance & service logistics
  - Maintenance & service logistics for substations

- Decommissioning:
  - Feasibility studies
  - Planning
  - Ports and logistics
  - Marine operations
  - Salvage and recycling
  - Project management

Packages
- Wind farm operations
- Turbine maintenance
- Structural inspection & maintenance
- Maintenance & service logistics
- Array cable inspection
- Export cable inspection
- Substation inspection & maintenance
- Maintenance & service logistics for substations

Scopes of work:
- a) Preventive maintenance
- b) Corrective maintenance

Job roles: * e.g.
- a) HV switching (HV responsible person)
- b) Trouble shooting (specialists - level 6-7)

Figure 1 - Bottom-up approach: investigating employment on the level of packages and scopes of work;
* This study is not focussing on employment indications of the level of job roles.

Besides the interview data, data is gathered via desk research and via workshop-like meetings with key stakeholders directly involved in the development and operations of Dutch offshore wind farms. This results in employment-related indicators based on or verified with ‘hard’ data from existing offshore wind farms projects and stable projections of forthcoming offshore projects. Next, these verified indicators are projected on the Dutch offshore wind farm roadmap (see table 2) leading to indications of developments in direct employment. These indications are verified by key stakeholders in the sector (e.g. via iterations on employment figures, workshop-like sessions, and feedback on version(s) of the report).

This study will give high-level reflections and first impressions regarding indirect employment (aspects) and export-related employment related to Dutch companies active in the offshore wind sector (and related sector like maritime services). In-depth reflections and elaborations on these topics were not possible during this study due to lack of appropriate data.

It should be noted that the number of WTGs for certain Roadmap 2023 wind farms is not available yet since these wind farms are in the development phase. For these wind farms estimations are made based on parameters of existing Dutch offshore wind farms, also
considering the future deployment of WTGs with single turbine capacities larger than 10 MW (see table 2 in chapter 3).

**Methodology used for competencies overviews**

For this study we created a competencies framework being a mix of several approaches and frameworks (e.g. Delamare Le Deist & Winterton, 2005; EC, 2008; IBM, 2015; US Dol, 2015; Hensen & Hippach-Schneider, 2016) (see figure 2): functional competencies and foundation competencies.\(^4\)

![Figure 2 - Competencies framework created for and used in this study.](image)

Regarding these two competencies categories elaborations on the level of packages and scopes of work are made. Input came from interviews, workshops, factory visits, publications (regarding competencies frameworks and competencies in offshore wind), and job descriptions received from the industry. Output of this study are high level competencies overviews on the level of packages, and one detailed competencies overview regarding maintenance technicians that can be seen as an example how to work-out competencies overviews on more detailed level for the packages and the scopes of work. More information from and elaborations together with the industry and education institutes are needed to develop more mature overviews of competencies.

Elaborations on the needed educational capacity, considering certain student dropout factors and outflow rates of professionals, could not be part of this study due to data unavailability. Regarding this topic more information from and elaborations together with the industry and education institutes are needed to define the needed educational capacities.

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\(^4\) Functional competencies are in general job-related and relate to the ability to demonstrate performance to the standards required of employment in an offshore wind work context looking at packages, scopes of work, and job roles (based on Delamare Le Deist & Winterton, 2005). Foundational competencies related to 'soft skills' and work readiness skills that most employers demand (based on US Dol, 2015). Social competence relates to the willingness and ability to experience and shape relationships, to identify and understand benefits and tensions, and to interact with others in a rational and conscientious way, including the development of social responsibility and solidarity (Delamare Le Deist & Winterton, 2005). Cognitive and meta competencies are primarily learned in a school setting and include cognitive functions and thinking styles. Meta-competencies are related to the ability to cope with uncertainty, as well as with learning and reflection (Delamare Le Deist & Winterton, 2005). Personal effective competencies are personal attributes essential for all life roles; these are generally learned in the home or community and honed at school and in the workplace (US Dol, 2015).
3 Offshore wind in the Netherlands

3.1 Global and European developments in offshore wind energy

The cumulative installed offshore wind energy capacity in the world was approximately 23.4 GW in 2018 (IRENA, 2019). Around 79% of this capacity was installed in Europe (18.5 GW; see table 1) and a little more than 19% in the People’s Republic of China (4.6 GW). Besides Europe and China, the offshore wind capacities in other countries and regions are still on a low level.

Nevertheless, large numbers of countries around the globe are catching up fast with offshore wind, like the US, India, South-Korea, Japan, Vietnam, and Taiwan. The US will build a substantial amount of offshore wind energy farms the coming years; a 2030 installed capacity indication is 22 GW (US DoE & Dol, 2016). It is estimated that the cumulative offshore wind capacity will be substantial in Asia in 2030, including the following estimations: China 30 GW, India 30 GW, South-Korea 13 GW, and Taiwan 10-17 GW (e.g. BNEF, 2018; IEEFA, 2019).

Within Europe the projection is to have installed more than 70 GW of offshore wind capacity in 2030 (WindEurope, 2017). A substantial part of this capacity is linked to the countries around the North Sea (see table 1). Estimates of the amount of offshore wind capacity that is needed in the North Sea by the year 2045 to meet the Paris Agreement climate change targets indicate that approximately 180 GW needs to be deployed (Ecofys, 2017).

The Netherlands is an attractive market for offshore wind, with a strong offshore supply chain, excellent ports, good wind resource, shallow waters (<40 m), easy soil conditions (sandy) and free from extreme weather conditions. It is for Dutch companies and research and education institutes highly interesting to serve the European and international market. This starts with good insights regarding offshore wind ambitions (in terms of capacities) in Europe and abroad.

<table>
<thead>
<tr>
<th>Offshore wind energy</th>
<th>2018 installed capacity (GW) *</th>
<th>2030 projections (GW) **</th>
<th>2050 scenarios (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global capacity</td>
<td>23.4</td>
<td>128 ****</td>
<td>520 ****</td>
</tr>
<tr>
<td>Europe</td>
<td>18.5</td>
<td>70 – 100 ****</td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>1.2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>1.4</td>
<td>4.8 – 5.4</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>0.0</td>
<td>6.2 – 7.0</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>6.4</td>
<td>15.0 – 17.0</td>
<td></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>1.1</td>
<td>10.6 – 18.5 ****</td>
<td>35 – 75 *****</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>8.3</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 - Offshore wind developments in Europe; * IRENA (2019) and WindEurope (2019a, 2019b); ** Various sources like WindEurope (2019b), PWC (2018) and BNEF (2018) regarding country specific figures; *** Renewable energy roadmaps of IRENA (2018a, 2018b); **** Central scenario and high scenario of WindEurope (2017); ***** 10.6 GW is the current ambition of the Dutch government; 18.5 GW is the 2GW scenario of NWEA; ****** PBL (2018) and SER & Secretariaat Klimaatakkoord (2019).

3.2 Offshore wind energy farms in the Netherlands

In the ’90 the first two offshore wind energy farms - with very modest capacities looking at the current norms - have been installed in lake IJsselmeer of the Netherlands: Lely of 2 MW (decommissioned in 2016) and wind farm Irene Vorrink of 17 MW. In 2006 the first projects on the North Sea were realised with respectively 120 MW and 108 MW capacities. And since a few years large wind energy farms were installed in the Dutch waters of the North Sea, with Gemini being an important milestone looking at its capacity: 600 MW. Currently, five offshore wind farms are operational on the North Sea, with in total 289 wind turbines (WTGs) and a total capacity of approximately around 1 GW (see table 2).
### Offshore wind energy farms in the Netherlands

<table>
<thead>
<tr>
<th>Existing large wind farms</th>
<th>Installation start year</th>
<th>Commissioning start year *</th>
<th>Total capacity (MW) **</th>
<th>Single turbine power (MW) ***</th>
<th>Total number of turbines ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAWP - Prinses Amalia</td>
<td>2006</td>
<td>2008</td>
<td>120</td>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td>OWEZ - Egmond aan Zee</td>
<td>2006</td>
<td>2007</td>
<td>108</td>
<td>3</td>
<td>36</td>
</tr>
<tr>
<td>Luchterduinen</td>
<td>2014</td>
<td>2015</td>
<td>129</td>
<td>3</td>
<td>43</td>
</tr>
<tr>
<td>Gemini</td>
<td>2015</td>
<td>2017</td>
<td>600</td>
<td>4</td>
<td>150</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>957 MW</strong></td>
<td></td>
<td><strong>289 WTGs</strong></td>
</tr>
</tbody>
</table>

**Roadmap 2023**

<table>
<thead>
<tr>
<th></th>
<th>Installation start year</th>
<th>Commissioning start year</th>
<th>Total capacity (MW) **</th>
<th>Single turbine power (MW) ***</th>
<th>Total number of turbines ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borssele 1 and 2</td>
<td>2019</td>
<td>2020</td>
<td>752</td>
<td>8</td>
<td>94</td>
</tr>
<tr>
<td>Borssele 3 and 4</td>
<td>2019</td>
<td>2020</td>
<td>732</td>
<td>9.5</td>
<td>77</td>
</tr>
<tr>
<td>Borssele 5 ****</td>
<td>2020</td>
<td>2020</td>
<td>19</td>
<td>9.5</td>
<td>2</td>
</tr>
<tr>
<td>Hollandse Kust South 1 and 2</td>
<td>2021</td>
<td>2022</td>
<td>760</td>
<td>10</td>
<td>76</td>
</tr>
<tr>
<td>Hollandse Kust South 3 and 4</td>
<td>2021</td>
<td>2022</td>
<td>700</td>
<td>11</td>
<td>64</td>
</tr>
<tr>
<td>Hollandse Kust North</td>
<td>2022</td>
<td>2023</td>
<td>700</td>
<td>12</td>
<td>59</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>3,663 MW</strong></td>
<td></td>
<td><strong>372 WTGs</strong></td>
</tr>
</tbody>
</table>

**Roadmap 2030**

<table>
<thead>
<tr>
<th></th>
<th>Installation start year</th>
<th>Commissioning start year</th>
<th>Total capacity (MW) **</th>
<th>Single turbine power (MW) ***</th>
<th>Total number of turbines ***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hollandse Kust West</td>
<td>2024</td>
<td>2024-2025</td>
<td>1,400</td>
<td>13</td>
<td>108</td>
</tr>
<tr>
<td>Ten noorden van de Waddeneilanden</td>
<td>2025</td>
<td>2026</td>
<td>700</td>
<td>14</td>
<td>50</td>
</tr>
<tr>
<td>IJmuiden Ver 1</td>
<td>2026</td>
<td>2027-2028</td>
<td>1,000</td>
<td>15</td>
<td>67</td>
</tr>
<tr>
<td>IJmuiden Ver 2</td>
<td>2027</td>
<td>2027-2028</td>
<td>1,000</td>
<td>15</td>
<td>67</td>
</tr>
<tr>
<td>IJmuiden Ver 3</td>
<td>2028</td>
<td>2029-2030</td>
<td>1,000</td>
<td>15</td>
<td>67</td>
</tr>
<tr>
<td>IJmuiden Ver 4</td>
<td>2029</td>
<td>2029-2030</td>
<td>1,000</td>
<td>15</td>
<td>67</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>6,100 MW</strong></td>
<td></td>
<td><strong>426 WTGs</strong></td>
</tr>
</tbody>
</table>

Table 2 - Existing and future Dutch wind farms based on sources like 4C Offshore (2018) and MinEZK (2018a, 2019b);
* Commissioning year of future wind farms is an indication based on information from various sources;
** Realised and projected capacities; rounded figures with no decimals;
*** Indication of single turbine capacity and total number of turbines of realised projects and future projects;
**** Borssele 5 is an innovation site.

As indicated currently and the coming years several large wind farms are and will be realised in the Dutch waters of the North Sea (circa 3.6 GW): Borssele 1 and 2 (approx. 750 MW), Borssele 3 and 4 (approx. 730 MW) and the three Hollandse Kust wind energy farms (respectively circa 760 MW, circa 700 MW and circa 700 MW). It should be noted that the forthcoming wind farm in lake IJsselmeer, Windpark Fryslân (capacity of approx. 383 MW and 89 WTGs), is excluded from in this study. Looking at the objectives of this study the main focus for analysis will be on the employment implications of the Roadmap 2023 projects (see table 2: grey rows).

As indicated earlier, the current ambition of the Dutch government is to install an average of at least 1 GW per year in the period 2024-2030. This is called Roadmap 2030 (circa 6.1 GW) with the projected farms Hollandse Kust West (approx. 1.4 GW), Ten noorden van de Waddeneilanden (around 0.7 GW) and IJmuiden Ver (around 4 GW in total). This will lead to an install base capacity of 10.6 GW in 2030. An additional capacity of 0.9 GW to the Roadmap 2030 is in consideration and therefore not part of this study. The Dutch offshore wind industry indicates to be ambitious and suggests with its so-called +2 GW Scenario to install instead of at least...
1 GW per year at least 2 GW per year in the period 2024-2030, leading to a cumulative offshore wind capacity of 18.5 GW in 2030 (NWEA, 2018).

For the longer-term scenarios indicate that around 2050 a combined capacity target of Dutch offshore wind farms could be around 60 GW (PBL, 2018). Which means an average installation of more than 2.5 GW yearly considering the first offshore wind farm decommissioning activities as from mid ’30s.

Regarding port distance, the Gemini site is relatively far located from the nearest port, namely 78 km. The upcoming projects Borssele and Hollandse Kust South and North are all situated much closer. The distance port – site has implications for the transit concept to be used during the operations and maintenance phase (see chapter 4).

The single turbine capacity of the Roadmap 2023 projects will be between 9.5 and 12 MW. This is a substantial enlargement looking at single turbine capacity of the Gemini wind farm, namely 4 MW. Although not fully clear yet, it is expected that the Roadmap 2030 projects will use turbines with single turbine capacity of 12 MW and more. For the moment the industry indicates that from current economical perspectives it is less clear if future turbines (within existing technology trajectory) with a single turbine capacity of more than 15 MW could become feasible. All Dutch sites as mentioned in table 2 have monopiles as foundation. The Gemini offshore wind farm has an infield voltage level of 33 kV; the forthcoming projects will use a voltage level of 66 kV for infield transport of electricity.

5 This does not exclude future wind turbines (within existing technology trajectory) of single turbine capacities of more than 15 MW. This does not exclude disruptive wind turbine concepts within new technology trajectories with single turbine capacities of more than 15 MW.
4 Packages

4.1 Introduction
In the life cycle of an offshore wind farm four main phases can be recognised.\(^6\)
- Development
- Construction
- Operations and maintenance
- Decommissioning

Within each of these phases several (sequential and parallel operating) packages are relevant. Figure 3 gives a high-level overview of most of these packages per phase. As requested by RVO (2019) this study focuses on a subset of these packages (see chapter 2) which are marked in figure 3.

![Diagram showing packages per phase](image)

- Site selection
- Environmental impact assessments
- Technical feasibility studies (including coastal, wind and seabed assessments)
- Financial feasibility studies
- Engineering design
- Project development
- Tower, nacelle, hub and blades supply
- Foundation substation supply
- Cable supply
- Substation supply
- Wind farm operations
- Turbine maintenance
- Structural inspection & maintenance
- Maintenance & service logistics
- Foundation supply
- Foundation installation
- Turbine installation
- Array cable installation
- Installation support
- Array cable inspection
- Export cable inspection
- Substation operations & maintenance
- Maintenance & service logistics for substations
- Export cable installation
- Substation foundation installation
- Substation installation
- Feasibility studies
- Planning
- Ports and logistics
- Marine operations
- Salvage and recycling
- Project management

Figure 3 - Indication of packages per phase; marked packages (dark orange and light orange) are under survey in this study.

In the following 2 paragraphs the packages under survey in this study are further described, also taking into account the Dutch offshore wind farm context for the coming years. These descriptions give first impressions regarding employment developments and competencies. In general, the duration of the construction phase is 1-2 years (in general one-off activities) and the operations and maintenance phase is 20-25 years (recurring/structural activities).

\(^6\) In some studies, the construction phase is presented via three phases: a) turbine manufacturing, b) balance of plant, and c) installation. Due to the fact the Dutch offshore sector doesn’t develop and manufacture offshore wind turbine systems this study has combined these three phases into one phase: construction.
4.2 Packages related to construction

4.2.1 Foundation supply
Foundation supply focuses on the manufacturing of foundations for the offshore wind turbines. Several types of foundations are being used, mostly depending on the depth of the water. Looking at the seabed and water depth of the Dutch part of the North Sea monopiles are used and will be used the current decade. Also, the manufacturing of the transition pieces is part of this packages.

Production of monopiles are currently done in 3 shifts during 5 working days a week (24/5). Due to larger turbines in the future the monopile diameters might increase to 12 m and weights to 2,000,000 kg and more. This will also influence the coating surface substantially. These larger dimensions will increase the number of manufacturing hours per monopile with more than 25%. Redesigns of the monopile lead to e.g. optimising diameter/thickness ratios of the steel segments. It is expected that over a few years the production efficiency of monopiles will be substantially increased (e.g. due to production automation). Among others, leading to higher labour productivities. Developments also suggests that transition pieces may become redundant (after 2023), also having implications for employment.

Relevant scopes of work of this package are:

a) Manufacturing of monopiles
b) Manufacturing of transition pieces

Regional stakeholders related to this package are e.g. SIF and Smulders.7

A large portion of the employment in this package is related to factory workers (EQF levels 1-3)8 with general expertise in (CNC) metal working (laser cutting, rolling, millers, welding, assembly) and coaters. Other employee categories are engineers, draftsmen, planners, shopkeepers, process operators, surveyors, logistic specialists, maintenance technicians, contract engineers, and QC professionals.

4.2.2 Foundation installation
The package foundation installation focuses on the installation of monopiles and transition pieces. In this study scour protection is not part of this package. For this installation specialist vessels and cranes are used. Vessels are manned with standard crew and pending the activities with a specialised staff.

Options for structural joints between foundation and transition piece are: 1) grout connection, 2) bolted connection, and 3) slip joints. Cost reduction scenarios focus more on slip joints and bolted connections, also leading to the possibility for all year installation. In comparison with a few years ago, it seems that the installation rate of foundations and transition pieces over a specific time period is increasing especially due to learning curves, redesigns and innovations, and the employable capacity (vessels, cranes, tooling, professionals etc.) to fulfil the installation work efficiently.

Several weather parameters are essential during offshore installation of foundations and turbines, like temperature, fog and visibility, tide variations, local swell and wave conditions. These parameters affect the weather window for offshore construction work in terms of safe operations of 1) vessel loading in the port, 2) vessel transit, 3) vessel positioning offshore, 4) jack-up/jack-down and 5) installation work. This weather window is in general larger in spring and summertime resulting in more efficient installation work than during the fall period. Developments indicate continuous installation schedules including the winter period.

An aspect of foundation installation is underwater noise reduction during piling (see e.g. Royal HaskoningDHV, 2015).

7 In each paragraph in this chapter relevant regional stakeholders (mostly companies) per package are mentioned, in alphabetic order.
8 European qualifications framework (EQF) levels are specified in chapter 7.
It is concluded that with respect to this study main scopes of work are:

a) Installation of monopiles
b) Installation of transition pieces

Regional stakeholders related to this package are e.g. Boskalis, DEME, and Van Oord.

On high-level, employment can be split in two categories: 1) crew members of vessels, and 2) offshore wind staff (e.g. offshore construction manager, drilling operators, superintendent, surveyors, riggers, lifting supervisors, bubble curtain operators, surveyors for geotechnical and geophysical and seismic investigation, QC and HSE professionals).

4.2.3 Turbine installation

During the turbine installation package the wind turbines are put in place on top of the foundation with large cranes in the following order: turbine towers are mounted, nacelles, rotors and blades are installed, and wind farm infield cables are connected to the power systems of the wind turbines. Turbines are usually installed using five lifts: tower fully assembled with internals, pre-assembled nacelle and hub, and 3x each blade separately. Over the years this offshore installation and assembly process has become rather efficient, mostly due to pre-assembling and prefab-like approaches and highly planned and controlled offshore activities. This leads to substantial reductions in installation hours and installation durations with respect to the forthcoming Roadmap 2023 wind farms. Developments indicate continuous installation schedules including the winter period.

This package consists of the following scopes of work:

a) Pre-assembling of towers and nacelles at harbour site
b) Offshore installation of towers, nacelles including hubs, and blades

Due to lack of data in this study the employment indications are only focused on offshore installation activities, thus excluding the pre-assembling activities.

Relevant stakeholders are the wind offshore wind turbine manufacturers like GE Renewable Energy, MHI Vestas, and Siemens Gamesa Renewable Energy, and installers like Van Oord.

On high-level the employment groups related to this package can be split: 1) technicians and service engineers for onshore pre-assemble, 2) offshore wind staff (e.g. offshore construction manager, superintendent, surveyor, lifting supervisor, riggers, site manager, WTG technicians and engineers, foreman, QC & HSE professionals, and riggers), and 3) crew members of vessels.

4.2.4 Array cable installation

In this study cable installation deals with the installation of the wind farm inter array cables. Activities related to export cabling are excluded in this study. Inter array cables laid and buried in the seabed with the aid of specialist cable vessels and special (plough) equipment. The total length of the inter array cables depends on the cable array design following the wind turbine farm layout and considering aspects like turbine type and size, number of turbines and power output, array voltage, number of infield connectors, foundation settings, and seabed settings.

This package consists of the following scopes of work:

a) Array cables laying
b) Array cables pulling and termination

Cable pulling and cable termination are excluded from this study due to lack of data. Employment indications are therefore only focussed on cables laying.

Regional stakeholders in this package are e.g. Acta Marine, Boskalis Subsea Cables & Flexibles, DEME, Van Oord, and Visser & Smit Hanab.

We have the following main groups of professionals: 1) vessel crew (e.g. dynamic positioning operators), 2) offshore wind staff for cable laying (e.g. offshore construction manager, superintendent, welder, bosun, deckhand, crane operator, cable operator, deck foreman, tower teams, ROV pilot, surveyors for depth of burial inspections and post & pre cable lay inspections, professionals in geotechnical works & seismic works), and 3) offshore wind staff for cables termination.
4.2.5 Installation support
Part of this package are various activities which support the developer, the wind turbine manufacturer and main installation contractors to complete installation activities efficiently and safely. Support services include unexploded ordnance (UXO) surveys and removal, the supply of guard vessels, oil-clean up services, the supply of fuel, and waste disposal. Some functions are provided by local companies, while others are supplied by highly specialist companies that work nationally and internationally (Green Port Hull & BVG Associates, 2017).

Crew vessel is the most important employee group regarding the above-mentioned employment focus within this package. From employment perspective this study has taken into account a subset of the vessels supporting the installation activities offshore (e.g. CTV, OSV, supply vessel, guard vessel, multipurpose vessel, survey vessel, and pre-lay grapnel run workboat, barges, general tugs, anchor handling tugs, platform supply vessel). Additional employment categories are related to marine management and marine coordination services, maritime pilot services, helicopter support, weather monitoring, and surveying with geotechnical, geophysical and seismic techniques.

Key regional stakeholders in this package are e.g. Acta Marine, Braveheart, C-Ventus, DEEP, DUC Marine, Fugro, MCS, Meteogroup, and SeaZip.

4.3 Packages related to wind farm operations and maintenance

4.3.1 Wind farm operations
This package deals with actions in order ensure maximum energy production of the offshore wind farm and ensuring the asset integrity during its lifetime of 20-25 years. Operations is remote management and can be done anywhere. Large operators have centralized, regional control centres. As Green Port Hull & BVG Associates (2017) indicate wind farm operations include day-to-day workflow management and the use of systems to store and analyse data, such as supervisory control and data acquisition (SCADA) systems and condition monitoring systems (CMS).

These systems allow the operators to organise the necessary spares, tools and technicians before (large) failures occurs, resulting in more efficient use of resources and reduced loss of energy production.

Wind farms operations is in general done by the owner-operator or via subcontractors of the owner-operator. There is a strong drive by the owner-operator and the involved turbine manufacturer to further optimise the operations and maintenance strategies with a mix of various methods and instruments like:

a) Standardisation of workflows and site organisation (roles and responsibilities)
b) Enhance performance culture within boundaries of health and safety risks and compliance
c) Data-based predictive maintenance/failures prediction

d) More centralised development and optimizations of maintenance plans
e) Optimisations in working shifts/working hours and transfers/logistics
f) Better weather and wave height forecasting
g) Innovative tooling to enhance offshore inspection and maintenance productivity
   (advanced bolt tightening tools, digital tools for technicians, blade inspection drones, blade maintenance via remotely operated robots, autonomous systems etc.)

For this study the following scopes of work are taken into account:

a) Commercial operations management
b) Technical operations management
c) HSEQ support

9 Innovations will come from machine learning/deep learning based on big data.
Stakeholders in this package are owners-operators of wind farms, turbine manufacturers, and operations service providers.

From employment perspective various groups can be observed: management, monitoring coordinators, data modelling and analysis, planning, engineers/technicians, administration, QC and HSE professionals.10

4.3.2 Turbine maintenance
Description of the package turbine maintenance
Turbine maintenance is split into: 1) preventive maintenance, 2) corrective maintenance in response to alarms/failures, and 3) major repairs.

Calendar-based preventive maintenance is mostly done during the months with acceptable weather conditions and involves offshore checks of various systems (hydraulics, mechanical, electrical, control etc.) and activities like filter changes, bolts tightening, and lubrication of mechanical parts. Condition-based preventive maintenance are service activities based on certain performance and wearing levels obtained via data of (sub)systems and components. Unplanned corrective maintenance could be related to a wide range of issues, from resetting of (sub)systems to replacing (large) (sub)systems. This last type of maintenance is mostly more intensive in the first production years of a wind farm and at the end of the production lifetime of a wind turbine.11 Most wind turbines need a major overhaul after 10 years, because not all main components last the lifetime of the turbine. Major repairs are mostly solved by specialist service technicians not stationed in the Netherlands. Therefore, this type of turbine maintenance is not further analysed in this study.

Typically, wind turbines are supplied with a five-year, ten-year or fifteen-year service agreement and wind turbine manufacturers provide full turbine maintenance services during this period. At the end of the service agreement, the wind farm owner may negotiate an extension, undertake the wind turbine maintenance itself or contract to a third-party services company (Green Port Hull & BVG Associates, 2017).

It should be noted that blades inspection and repair is not a large activity area within this package. Additionally, largescale blades overhaul and maintenance projects on wind farm level is in theory only done once during the lifetime of an offshore wind farm, and can be seen as a specific package due to the more one-off character of it. However, blade erosion is a challenge and some wind farms on the North Sea have blade repair campaigns after 5 years of operation.

For this study the following scopes of work are considered:

a) Preventive maintenance (calendar-based and condition-based)
b) Corrective maintenance

Regional stakeholders in this package are turbine manufacturers like GE Renewable Energy, MHI Vestas, and Siemens Gamesa Renewable Energy, and maintenance service providers like Deutsche Windtechnik.

In general, the employment in this package relates to offshore wind technicians (level 4-7). Level 4 and 5 technicians have general competencies in turbine inspection, maintenance, and repair. Level 6 and 7 technicians have more in-depth technical expertise for trouble shooting and team lead/coaching competencies. Other employment groups/professionals active for turbine maintenance are: site manager/coordinate, service manager, commercial project manager, stock keeper, project controller, and HSE manager.

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10 Small group of high educated professionals: a) technical backgrounds on bachelor and master level (mechanical engineering, electrical engineering, civil engineering, aerospace Engineering), and b) monitoring (coordination) professionals are mostly maritime officers.

11 Wind turbine failures follow a ‘bathtub curve’ during the production lifetime of the turbine: the first production years have relative high failures rate due to so-called early failures. During the next period the failure rate decreases and stays on a certain constant level. During the last years of the production period the failure rate increases, mostly due to wear-out failures.
Transfer strategies affect involvement of professionals
The service strategy and related management of logistics (transfer facilities, personnel, tooling and spare parts) are important aspects of wind farms maintenance. Type of transfer depends mainly on the distance of the wind farm to the port, but also on the nature of the visit (regular inspection, small repair/replacement activities, large repair/replacement activities etc.), and the business case for minimising downtime costs of turbine(s) in the case of sudden alarms/failures. Transport options for maintenance teams for existing and Roadmap 2023 wind farms are (see also ECN, 2016, 2018):

a) Crew transfer vessels (CTV) c) Helicopters
b) Service operation vessels (SOV) d) Combination of the previous options

Table 3 gives an indication of the default transit concept for preventive maintenance of Dutch offshore wind farms.\(^\text{12}\)

<table>
<thead>
<tr>
<th>Default transfer concept for preventive maintenance of Dutch offshore wind farms</th>
<th>CTV concept</th>
<th>SOV concept</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing wind farms</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gemini</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>All existing wind farms, excluding Gemini</td>
<td>● (indication)</td>
<td></td>
</tr>
<tr>
<td><strong>Roadmap 2023</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Borssele 3 and 4</td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>All roadmap 2023 wind farms, excluding Borssele 3 and 4</td>
<td>● (indication)</td>
<td></td>
</tr>
<tr>
<td><strong>Roadmap 2030</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All roadmap 2030 wind farms</td>
<td></td>
<td>● (indication)</td>
</tr>
</tbody>
</table>

Table 3 - Default transit concept for preventive maintenance of Dutch offshore wind farms.

Currently, Dutch wind farm Gemini uses helicopters for wind turbine troubleshooting and inspection/troubleshooting of offshore substations. It is expected that helicopters will be used for troubleshooting of large (+10MW) nearshore turbines during bad weather, because downtime costs are going up with the power size of the turbine.

The transit option has its implications on labour market indications and - more on tactical level - human resources planning: size and capabilities of technician teams, and nature of the shifts of the technicians. The CTV concept results in daily vessel transit (of a few hours) with less single person productive hours for inspection and maintenance at sea. The CTV concept is best suited for local workforce living nearby the port. The SOV concept offers shift work at sea resulting in higher labour productivities of technicians at sea. The SOV concept requires workforce that can adapt to working in shifts further afield.

CTV shifts in the Netherlands consists of 8 working hours per day (shifts of 5 working days and 2 weekend days) or 12 working hours per day (4-days shifts). SOV shifts have 12 workings hours per day (2-week shifts). Crew vessel member are seamen who fall under the working and resting hours regime of seafarers (see package 'Maintenance and service logistics'). Vessel passengers (mostly maintenance technicians) are falling under the Dutch Working Hours Act and cannot work as long as the vessel crew during a shift. A bottleneck is the current Dutch Working Hours Act (MinSZW & MinJ, 1995), especially due to the limitations of shifts longer than 12 hours and more flexible shift periods (e.g. 4-days SOV shifts or 1-week SOV shifts besides the current used 2-weeks SOV shifts).

\(^{12}\) A central artificial grid island in the North Sea - which is an idea of Tennet and currently in the orientation phase – could have its implications for maintenance service strategies when this island is used as service hub. A study of BLIX Consultancy (2019) indicates that for the moment this grid island will not be likely during the building period of the Roadmap 2030 wind farms.
4.3.3 Structural inspection and maintenance
This package is focused on the (subsea) inspection and maintenance of transition pieces, foundations, steel structures (boat landing systems, ladders, railings, and cranes), and scour (erosion of the seabed). Special focus is on the foundation since this part needs to be able to withstand significant stresses from currents and waves and is in constant contact with oxygen-rich surface water. Inspections are necessary due to the atmospheric, marine and biological influences on coatings and seals leading to corrosion damages. Preserving the integrity of the structures by preventing corrosion is crucial to the safety of the entire offshore wind turbine. These corrosion damages are difficult to repair, and repairs are expensive. Inspections can be done with the aid of e.g. divers and remotely operated vehicles (ROVs).

For this study the following scopes of work are considered:

a) Inspections and testing
b) Standard maintenance

Direct employment related to large scale maintenance activities are not included in this study.

Regional stakeholders in this package are e.g. Bluestream, C-Ventus, DEEP, Deutsche Windtechnik (mostly management of the works), Eneco (inhouse management), and Rana Works.

In general, the employment in this package relates to specialistiki inspection and maintenance technicians with e.g. diving certificates, and specialist engineers.

4.3.4 Maintenance and service logistics
Within this study the scope of the package maintenance and service logistics is limited to CTV and SOV vessel crew involvement. Most common in the Dutch waters are CTV and SOV.

Crew composition on these vessels:

a) CTV shift of 12 hours or less (e.g. 4-4-week rotation): one captain and one sailor
b) CTV shift of more than 12 hours: one captain, one maritime officer, and two sailors
c) SOV crew: 15 persons, including persons for deck handling, crane handling, and facilities

Currently, most of the vessel crew is non-Dutch.

For this study the following scopes of work are analysed:

a) CTV transport
b) SOV transfer
5 Employment Roadmap 2023 wind farms

This chapter focuses on Roadmap 2023 employment related to the 9 packages under survey:

a) Employment related to one-off activities linked to the construction phase of wind farms:
foundation supply, foundation installation, turbine installation, array cable installation, and installation support.
b) Employment related to recurring activities linked to the operations and maintenance:
wind farm operations, turbine maintenance, structural inspection and maintenance, and maintenance and service logistics.

The employment figures per packages in this chapter are positioned in the upper side of the range of these figures, mostly due to the fact that industry input was on the upper side of ranges looking at the current and forthcoming developments in the sector: a) product and process innovations (e.g. increase in single turbine capacity), b) economies of scale (e.g. larger wind farms), and c) learning curves (e.g. more efficient installation schedules, increase in operational excellence).

As mentioned in chapters 1 and 2 the employment figures – given in this chapter - are based on various consultations of and iterations with key stakeholders active in the Dutch offshore wind industry.

5.1 Direct employment related to construction

This paragraph focuses on direct employment related to the packages a) foundation supply, b) foundation installation, c) turbine installation, d) cable installation, and e) installation support.

These indications are restricted to the forthcoming Roadmap 2023 wind farms. With respect to the Roadmap 2023 projects around 370 wind turbines will be installed offshore the coming years, excluding Borssele 5 (see table 2).
5.1.1 Foundation supply

The tables below and on the next page give per scopes of work the employment figures.

<table>
<thead>
<tr>
<th>Direct employment for manufacturing of one monopile:</th>
<th>1.5 person-years per monopile *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative direct employment during 2019-2023 for 370 monopiles:</td>
<td>555 person-years for 370 monopiles **</td>
</tr>
</tbody>
</table>

* Included employee categories: factory workers (like welders and coaters), engineers, planners, process operators, maintenance technicians, and QA professionals. Conversion to person-years is based on 1,500 productive manufacturing hours per year per employee. No additional employment conversion factors are relevant like seasonality or production shifts factors. Influencing factors employment indication: included employee categories, robustness of retrieved data from industry, product specifications (e.g. type/dimensions of monopile, type of structural joint between monopile and transition piece), and ongoing increases in process efficiencies (production automation).

** Based on Roadmap 2023, excluding Borssele 5 (see table 2). In principle the employment concerns regular capacity within the industry with a yearly staff outflow of 5%-15% (not included in the figures). Therefore, the focus is on employee replacement demand for the coming years. Export-related direct employment is substantial; see paragraph 5.5, due to the usage of monopiles in non-Dutch offshore wind farms (e.g. US and Taiwan). Degree of direct employment in the Netherlands: > 90%. Degree employment could be filled with Dutch labour force: medium – low.

Table 4 - Direct employment for manufacturing of monopiles.
Direct employment for manufacturing of one TP: 2.0 person-years per TP *

Cumulative direct employment during 2019-2023 for 370 TPs: 740 person-years for 370 TPs **

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* Included employee categories: factory workers (like welders and coaters), engineers, planners, process operators, maintenance technicians, and QA professionals. Conversion to person-years is based on 1,500 productive manufacturing hours per year per employee. No additional employment conversion factors are relevant like seasonality or production shifts factors. Influencing factors employment indication: included employee categories, robustness of retrieved data from industry, product specifications (e.g. a) dimensions of TP, b) specifications of equipment in and around transition piece: LV and HV components, sensors etc., c) type of structural joint between monopile and transition piece), and ongoing progress in process efficiencies (production automation).

** Based on Roadmap 2023, excluding Borssele 5 (see table 2). In principle the employment concerns regular capacity within the industry with a yearly staff outflow of 5%-15% (not included in the figures). Therefore, the focus is on employee replacement demand for the coming years. Export-related direct employment is substantial; see paragraph 5.5. Degree of direct employment in the Netherlands: > 90%. Degree employment could be filled with Dutch labour force: medium – low.

Table 5 - Direct employment for manufacturing of TPs.
5.1.2 Foundation installation
The foundation installation workload is related to the installation of approximately 370 monopiles and 370 transition pieces during the years 2019-2023. In principle the installation is done during the so-called weather windows (see chapter 4.2). The table below give the employment for both scopes of work: installing MPs and installing TPs.

| Direct employment for installing foundation (MP and TP): | Staff: 0.25 person-years per foundation *  
Marine crew: 30 FTE fixed per project |
|----------------------------------------------------------|----------------------------------------------------------------------------------|
| Cumulative direct employment during 2019-2023 for 370 foundations: | Staff: 91 person-years for 370 foundations **  
Marine crew: 150 FTE fixed for 5 projects |

<table>
<thead>
<tr>
<th>Year</th>
<th>Person-years</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2022</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>2024</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

* Included employee categories: a) staff: offshore construction manager, drilling operators, superintendent, surveyors, riggers, lifting supervisors, QC and HSE professionals, and b) marine crew: master, 1st officer, 2nd officer, chief engineer, chief mate, electrician, jacking engineer, bosun, deckhands, stewards, camp boss, night cook. Approximately 2 client representatives and 2 warranty surveyors on board are excluded in the calculations. Conversion to person-years is based on 1,500 productive hours per year per employee. No additional employment conversion factors are relevant like seasonality or shifts factors. Marine crew employment is indicated in FTE (persons) per foundation project (mostly 1 offshore wind farm project). Influencing factors for both employment indications: included employee categories, robustness of retrieved data from industry, product and engineering specifications, vessels and cranes capabilities, ongoing progress in process efficiencies, and weather windows.

** Based on Roadmap 2023, excluding Borssele 5 (see table 2): 5 projects. In principle the employment concerns available capacity within the industry with a yearly staff outflow of 5%-15% (not included in the figures). Therefore, the focus is on employee replacement demand for the coming years. Export-related direct employment is substantial; see paragraph 5.5. Degree of direct employment in the Netherlands: > 75%. Degree employment could be filled with Dutch labour force: medium (staff) and low (crew).

Table 6 - Direct employment for installing foundations.
5.1.3 Turbine installation

The turbine installation workload is related to the installation of approximately 370 turbines during the years 2019-2023. In principle the installation is done during the so-called weather windows (see chapter 4.2). The table below gives the offshore turbine installation employment figures.

### Direct employment for turbine installation:

<table>
<thead>
<tr>
<th>Year</th>
<th>Staff: 0.38 person-years per WTG</th>
<th>Marine crew: 30 FTE fixed per project</th>
</tr>
</thead>
</table>

### Cumulative direct employment during 2019-2023 for 370 WTGs:

<table>
<thead>
<tr>
<th>Year</th>
<th>Staff: 139 person-years for 370 WTGs</th>
<th>Marine crew: 150 FTE fixed for 5 projects</th>
</tr>
</thead>
</table>

* Included employee categories: a) **staff installation contractor**: offshore construction manager, superintendent, surveyor, lifting supervisors, QA and HSE professionals, riggers, b) **staff WTG contractor**: site manager, foreman, WTG technicians and engineers, and riggers, and c) **marine crew**: master, 1st officer, 2nd officer, chief engineer, chief mate, electrician, jacking engineer, bosun, deckhands, stewards, camp boss, night cook. Approximately 2 client representatives and 2 warranty surveyors on board are excluded in the calculations. Conversion to person-years is based on 1,500 productive hours per year per employee. No additional employment conversion factors are relevant like seasonality or shifts factors. Marine crew employment is indicated in FTE (persons) per foundation project (mostly 1 offshore wind farm project). Influencing factors employment indication: included employee categories, robustness of retrieved data from industry, product and engineering specifications, vessels and cranes capabilities, ongoing progress in process efficiencies, and weather windows.

** Based on Roadmap 2023, excluding Borssele 5 (see table 2): 5 projects. In principle the employment concerns available capacity within the industry with a yearly staff outflow of 5%-15% (not included in the figures). Therefore, the focus is on employee replacement demand for the coming years. Export-related direct employment is substantial; see paragraph 5.5. Degree of direct employment in the Netherlands: > 75%. Degree employment could be filled with Dutch labour force: medium (staff) and low (crew).

* Table 7 - Direct employment for installing turbines.
5.1.4 Array cable installation

The table below gives the array cable laying employment figures.

| Direct employment for array cable laying: | Staff: 0.39 person-years per WTG *  
<table>
<thead>
<tr>
<th></th>
<th>Marine crew: 28 FTE fixed per project</th>
</tr>
</thead>
</table>
| Cumulative direct employment during 2019-2023 for 370 WTGs array cable laying (5 projects) excluding cable termination: | Staff: 144 person-years for 370 WTG **  
|  | Marine crew: 140 FTE fixed for 5 projects |

* Included employee categories: a) staff: offshore construction manager, superintendent, welder, bosun, deckhand, crane operator, cable operator, deck foreman, tower teams, ROV pilot, b) marine crew: captain, chief mates, 2nd mate, dynamic positioning operator, survey, chief engineer, 2nd engineer, rating engine room, 3rd engineer, electrician, cook, and c) CTV Crew. Approximately 2 client representatives and 2 warranty surveyors on board are excluded in the calculations. Conversion to person-years is based on 1,500 productive hours per year per employee. No additional employment conversion factors are relevant like seasonality or shifts factors. The marine crew employment figures (which include CTW crew employment figures) are indicated in FTE (persons) per foundation project (mostly 1 offshore wind farm project). Influencing factors employment indication: included employee categories, robustness of retrieved data from industry, cable plan, product and engineering specifications, vessels and plough capabilities, ongoing progress in process efficiencies, and weather windows.

** Based on Roadmap 2023, excluding Borssele 5 (see table 2): 5 projects. In principle the employment concerns available capacity within the industry with a yearly staff outflow of 5%-15% (not included in the figures). Therefore, the focus is on employee replacement demand for the coming years. Export-related direct employment is substantial; see paragraph 5.5. Degree of direct employment in the Netherlands: > 75%. Degree employment could be filled with Dutch labour force: medium (staff) and low (crew).

Table 8 - Direct employment for cable laying.
5.1.5 Installation support
The table below gives the installation support employment figures.

<table>
<thead>
<tr>
<th>Direct employment for installation support:</th>
<th>Marine crew: approx. 75 FTE per project *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative direct employment during 2019-2023 for 5 projects with in total 370 WTGs:</td>
<td>Marine crew: 375 FTE for 5 projects with in total 370 WTGs **</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FTE</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Included vessels (based on reference project): 2 x CTV (6 FTE), 1 x OSV supply vessel (5 FTE), 1 x guard vessel, 1 x multipurpose vessel (44 crew members + 6 client representatives), 1 x survey vessel, 1 x pre-lay grapnel run (PLGR) workboat (normal vessel crew, 2 x survey, 1 x client representative) = approximately 75 FTE. Marine crew employment is indicated in FTE (persons) per project (mostly 1 offshore wind farm project). Influencing factors employment indication: included employee categories, robustness of retrieved data from industry, product and engineering specifications, vessels capabilities, ongoing progress in process efficiencies, and weather windows.

** Based on Roadmap 2023, excluding Borssele 5 (see table 2): 5 projects. In principle the employment concerns available capacity within the industry with a yearly staff outflow of 5%-15% (not included in the figures). Therefore, the focus is on employee replacement demand for the coming years. Export-related direct employment is substantial; see paragraph 5.5. Degree of direct employment in the Netherlands: > 50%. Degree employment could be filled with Dutch labour force: low.

Table 9 - Direct employment for installation support.
5.2 Direct employment indications related to operations and maintenance

The current Dutch offshore wind farms on the North Sea have in total 289 wind turbines in operation (Q1 2019) (see table 2). Including the forthcoming Roadmap 2023 wind farms there will be in total around 661 offshore wind turbines producing electricity as from 2023.

This paragraph will further elaborate on the direct employment aspects of the operations and maintenance of only the Roadmap 2023 wind turbines (370 WTGs) which will be all in operation as from 2023. In general, all employment related to the phase of operations and maintenance has a recurring character. Therefore, in this paragraph the direct employment indications will be on an annually basis.

5.2.1 Wind farm operations

For this study the following scopes of work are taken into account:

a) Commercial operations management
b) Technical operations management
c) HSEQ support

The table below gives on package level Roadmap 2023 employment figures.

<table>
<thead>
<tr>
<th>Recurring direct employment per year for wind farms operations regarding one offshore wind farm:</th>
<th>Around 11.0 FTE per offshore wind farm *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurring direct employment per year for wind farms operations as from 2023 for all Roadmap 2023 wind farms:</td>
<td>Around 55 FTE for Roadmap 2023 wind farms **</td>
</tr>
</tbody>
</table>

* Included employee categories: management, monitoring and marine coordinators, technical specialists, data analysts, and administration. Capacity per employee category: management 1 FTE, maritime 2 FTE, and technical 8 FTE. Based on 1,500 productive hours per year per FTE. No (additional) employment conversion factors are relevant like seasonality or shifts factors. Influencing factors employment indication: robustness of retrieved data from industry, developments in economies of scale when multiple wind farms will be monitored from one operations base in the nearby future.

** Based on Roadmap 2023, and excluding Borsssele 5 wind farm, and considering the number of WTGs per wind farm (see table 2). The employment concerns a mix of: a) expansion capacity (incremental growth of employee capacity following the expansion rate of operational offshore WTGs), and b) replacement capacity: yearly staff outflow of 5%-10% (not included in the figures). Export-related direct employment: NA. Degree of direct employment in the Netherlands: > 90%. Degree employment could be filled with Dutch labour force: high.

Table 10 - Recurring direct employment per year for wind farms operations.
5.2.2 Turbine maintenance
The table below gives the employment figures for preventive and corrective maintenance.

| Recurring direct employment per year for preventive and corrective maintenance of one WTG based on SOV transfers: | Technicians: 0.27 FTE per WTG (SOV) * Other staff: 0.12 FTE per WTG (SOV) |
| Recurring direct employment per year for preventive and corrective maintenance as from 2023 for all Roadmap 2023 wind farms: | Technicians: 139 FTE for 370 WTGs (SOV/CTV) ** Other staff: 62 FTE for 370 WTGs (SOV/CTV) |

* Recurring employment indication per turbine per year: 200 effective preventive maintenance hours by technicians, independent of geographical distance of the wind farm to the nearest port and largely independent from the single turbine capacity (e.g. 3 MW turbine versus 9.5 MW turbine) as experienced in the Dutch offshore wind industry so far. Based on 1,200 productive hours per year per FTE. Included employee categories: technicians level 4 -7, and onshore (back office) professionals. Influencing factors employment indication: robustness of retrieved data from industry, specifications CTV concept (e.g. daily CTV transit time for technicians, shift duration; number of daily effective turbine hours; number of shift rotations per year), specifications SOV concept (e.g. shift duration, number of daily effective turbine hours, number of shift rotations per year), economies of scale when cross wind farm maintenance strategies are used, and weather windows.

** Based on Roadmap 2023, and excluding Borssele 5 wind farm (see table 2). Based on assumption that wind farm Borssele 3-4 will use the SOV concept (2-weeks shifts, 12 working hours per day during shift, two rotating shift teams). Based on CTV concept for all Roadmap 2023 wind farms excluding Borssele 3 and 4 (estimation of daily CTV transit of 1.5 hours; 8-12 working hours per day for technicians, including transit time). Conversion factor technicians FTE via SOV/CTS = 1/1.5. End of year 2023, the needed maintenance capacity related to Roadmap 2023 wind farms has reached its maximum for the remaining maintenance period till approx. 2043. The employment concerns a mix of: a) expansion capacity (incremental growth of employee capacity following the expansion rate of operational offshore WTGs), and b) replacement capacity: yearly staff outflow of 5%-10% (not included in the figures). Export-related direct employment: NA. Degree of direct employment in the Netherlands: > 90%. Degree employment could be filled with Dutch labour force: high.

Important note 1: The increase of single turbine capacity will hardly influence the number of hours for preventive maintenance per turbine per year.

Important note 2: Optimisation strategies regarding working hours for technicians offshore (CTV concept and SOV concept) are currently hindered by certain limitations of the Dutch Working Hours Act. Less restrictions/more exceptions for offshore work in this Act will positively influence the offshore labour productivity.

Table 11 - Recurring direct employment per year for preventive and corrective maintenance.
5.2.3 Structural inspection and maintenance
The table below gives the direct employment figures for the employment regarding inspection and standard maintenance. Direct employment regarding large scale maintenance is not included in this study.

<table>
<thead>
<tr>
<th>Recurring direct employment per year for structural inspection and standard maintenance of one foundation/WTG:</th>
<th>Technicians: approx. 0.09 FTE per foundation/WTG *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurring direct employment per year for structural inspection and standard maintenance of 370 foundations/WTGs as from 2023:</td>
<td>Technicians: 35 FTE for 370 foundations/WTGs **</td>
</tr>
</tbody>
</table>

* Recurring employment indication per year for inspection and standard maintenance. Based on 1,200 productive hours per year per FTE. Included employee categories: inspection and maintenance technicians. Influencing factors employment indication: robustness of retrieved data from industry, inspection and maintenance (needs) developments over time, amount of work related to large scale maintenance projects (currently not included in the figures), economies of scale when cross wind farm maintenance strategies are used, and weather windows.

** Based on Roadmap 2023, and excluding Borssele 5 wind farm (see table 2). End of year 2023, the needed inspection and standard maintenance capacity related to Roadmap 2023 wind farms has reached its maximum for the remaining operations period till approx. 2043. The employment concerns a mix of: a) expansion capacity (incremental growth of employee capacity following the expansion rate of operational offshore WTGs), and b) replacement capacity: yearly staff outflow of 5%-10% (not included in the figures). Export-related direct employment: NA. Degree of direct employment in the Netherlands: > 90%. Degree employment (inspection and standard maintenance) could be filled with Dutch labour force: high.

Table 12 - Recurring direct employment per year for structural inspection and maintenance.
5.2.4 Maintenance and service logistics

The table below gives the employment figures for maintenance and service logistics. As indicated in chapter 4 the employment focus of this package is on vessel crew of SOVs and CTVs.

<table>
<thead>
<tr>
<th>Recurring direct employment per year for maintenance and service logistics regarding one offshore wind farm:</th>
<th>Around 15.0 FTE per wind farm (SOV) *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recurring direct employment per year for maintenance and service logistics as from 2023 for all Roadmap 2023 wind farms:</td>
<td>Around 33 FTE (CTV and SOV mix) **</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>15</td>
</tr>
<tr>
<td>2020</td>
<td>20</td>
</tr>
<tr>
<td>2021</td>
<td>30</td>
</tr>
<tr>
<td>2022</td>
<td>35</td>
</tr>
<tr>
<td>2023</td>
<td>35</td>
</tr>
<tr>
<td>2024</td>
<td>35</td>
</tr>
<tr>
<td>2025</td>
<td>35</td>
</tr>
</tbody>
</table>

* Standard SOV crew is around 15 FTE and standard CTV crew is 2 FTE (12-hour shift). Based on 1,500 productive hours per year per FTE. Included employee categories: all vessel crew categories. Influencing factors employment indication: robustness of retrieved data from industry, specifications CTV concept, specifications SOV concept, economies of scale when cross wind farm maintenance strategies are used, and weather windows.

** Based on Roadmap 2023, and excluding Borssele 5 wind farm (see table 2). Based on assumption that wind farm Borssele 3-4 will use the SOV concept (2-weeks shifts, 12 working hours per day during shift, two rotating shift teams). Based on CTV concept for all Roadmap 2023 wind farms excluding Borssele 3 and 4 (estimation of 2 CTVs per shift). End of year 2023, the needed employment capacity related to Roadmap 2023 wind farms has reached its maximum for the remaining operations and maintenance period till approx. 2043. The employment concerns a mix of: a) expansion capacity (incremental growth of employee capacity following the expansion rate of operational offshore WTGs), and b) replacement capacity: yearly staff outflow of 5%-10% (not included in the figures). Export-related direct employment: NA. Degree of direct employment in the Netherlands: > 90%. Degree employment could be filled with Dutch labour force: low-medium.

Table 13 - Recurring direct employment for maintenance and service logistics per year.
5.3 Overview of direct employment regarding Roadmap 2023

The table below gives an overview of the direct employment regarding Roadmap 2023 offshore wind farms as presented in the above-mentioned paragraphs.

<table>
<thead>
<tr>
<th>Offshore wind farm packages under survey</th>
<th>Roadmap 2023 cumulative one-off direct employment 2019-2023 *</th>
<th>Roadmap 2023 recurring direct employment per year as from 2023 *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Person-years</td>
<td>FTE</td>
</tr>
<tr>
<td>Foundation supply</td>
<td>1,295</td>
<td>150 (marine crew)</td>
</tr>
<tr>
<td>Foundation installation</td>
<td>91</td>
<td>150 (marine crew)</td>
</tr>
<tr>
<td>Turbine installation</td>
<td>139</td>
<td>140 (marine crew)</td>
</tr>
<tr>
<td>Cable installation</td>
<td>144</td>
<td>375 (marine crew)</td>
</tr>
<tr>
<td>Installation support</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind farm operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbine maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural inspection and maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance and service logistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 14 - Overview of direct employment regarding Roadmap 2023;
* Not included in these figures are needed employment increasements to compensate yearly staff outflow; not included is a range indication of the figures.

Table 14 shows employment indications in person-years and FTEs. As indicated, the industry input regarding employment elaborations can be positioned in the upper part of the figure range. In order to add all employment figures, it would be needed to convert the person-years indications into FTEs or vice versa. However, for conversion of person-year figures into FTE figures it would be needed to have additional employment data: workloads (package level or scope of work level) for other projects than the projects related to Roadmap 2023 wind farms. Currently, this context information is not available. In order to give high-level employment insights this study makes a pragmatic move by converting FTEs figures into person-years figures based on a factor 1. This leads to the possibility to give an informative overview figure (see figure 4).

Figure 4 - Graphic overview of investigated employment figures.
5.4 Indirect employment

This paragraph focusses on indirect employment aspects. Indirect employment contains jobs outside of the offshore wind energy sector, but which are part of the supply chain to the sector. Table 15 shows the complexity of the supply chains of the packages under survey. Industry stakeholders active in foundation supply indicate that the degree of indirect employment strongly relates to business strategies: a) substantial inhouse manufacturing activities (e.g. regarding primary and secondary steel) versus b) as much as possible purchasing from and/or outsourcing to low-cost regions. Due to this supply chain (optimisation) complexity and the fact that no high-quality (supply chain input and output) data regarding indirect employment is available for this study or has become available via this study, this study is not able to elaborate on the size of the indirect employment regarding the packages under survey.

<table>
<thead>
<tr>
<th>Offshore wind farm packages under survey</th>
<th>Relative involvement of indirect employment supply chains (tier 1 level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production means for offshore wind industry</td>
<td></td>
</tr>
<tr>
<td>Initial supply</td>
<td>Spare parts/repairs</td>
</tr>
<tr>
<td>Foundation supply</td>
<td>●●● ○○○● ●●○</td>
</tr>
<tr>
<td>Foundation installation</td>
<td>●●○</td>
</tr>
<tr>
<td>Turbine installation</td>
<td>●●○</td>
</tr>
<tr>
<td>Cable installation</td>
<td>●●○</td>
</tr>
<tr>
<td>Installation support</td>
<td>○○○</td>
</tr>
<tr>
<td>Wind farm operations</td>
<td>○○○</td>
</tr>
<tr>
<td>Turbine maintenance</td>
<td>●●○</td>
</tr>
<tr>
<td>Structural inspection and maintenance</td>
<td>○○○</td>
</tr>
<tr>
<td>Maintenance and service logistics</td>
<td>○○○</td>
</tr>
</tbody>
</table>

Table 15 - Relative involvement of indirect employment supply chains;  
* E.g. vessels, cranes, manufacturing machines, tooling, warehouses, ports.

PWC (2018) indicates an indirect employment factor of 0.5 in relationship with direct employment on the level of the Dutch offshore wind industry sector. This figure is not based on an input-output study but based on figures from various studies about offshore wind in several European countries. Factor 0.75 is used in the publication of University of Hull (2017) regarding UK offshore wind on sector level. Employment studies of UMass Dartmouth (2017) shows a factor of around 0.35 which is more on phase level. Interview data don’t give clear directions regarding the balance between direct and indirect employment. In other words: the indirect employment factor variety is large and the specificity less clear (scope of supply chain activities embedded in the indirect employment factor). Therefore, it is less well possible to use these kinds of factor figures to suggest the indirect employment of the packages under study.

5.5 Indicative elaborations regarding export-related employment

Offshore wind developments outside the Netherlands (see e.g. table 1) offer relevant business opportunities for various Dutch companies active in offshore wind, maritime services, port facilities, and offshore logistics services (PWC, 2018). Therefore, it is relevant to investigate the export-related employment of Dutch companies. Important in the context of offshore wind in (North-West) Europe are the Dutch ports. These ports are characterized by their deep waterways, direct access to the sea and inland shipping, limited tides effects and good facilities such as reinforced quays, long quays, heavy (mobile) cranes, assembly facilities, and helicopter

13 Ports of Amsterdam and IJmuiden, Port of Den Helder, Port of Eemshaven (Groningen Seaports), Port of Harlingen, Port of Rotterdam, and Ports of Vlissingen and Terneuzen (Zeeland Seaports).
platforms (NFIA, 2014; RVO, 2016; RVO, 2017; PWC, 2018). These ports are highly suitable to serve offshore wind projects.

Unfortunately, data is very limited available to give sound indications of Dutch employment potentials related to export in the offshore wind sector. In order to give some food for thought this paragraph gives high-level elaborations regarding export-related employment directions for Dutch offshore wind companies with respect to a selected number of European countries. In general export-potentials are linked to Dutch companies active in the development and constructions phases of offshore wind farms. Dutch companies active in operations and maintenance have limited export-related employment potentials.

For the coming years the neighbouring countries in the Netherlands have to ambition to add to their installed base in the period of 2019-2030 the following capacities (based on table 1): Belgium 2.8 GW, Denmark 3.4 – 4 GW, France 6.2 – 7 GW, Germany 8.6 – 10.6 GW, and UK 21.7 GW. In total between 39.9 and 43.3 GW will be installed, leading to the offshore installation of around 3,500 WTGs in these countries (2019-2030) considering an average single turbine capacity of 12 MW. The assumption that each offshore wind farm has a capacity of 1 GW leads to the indication that around 40 offshore wind farms will be built in the mentioned countries during the period of 2019-2030. Transforming the above-mentioned figures to the period of 2019-2023 gives:

- Number of WTGs to be installed offshore: approx. 1,250 WTGs
- Number of offshore wind farms to be installed: approx. 15 projects

There is lack of valid data regarding export-potentials of Dutch companies on package level, although Roland Berger (2015), RVO (2016), and WindEurope (2017a, 2019a) gave some indications and elaborations which are not fully up to date anymore. Therefore, it is suggested to use the following indications and logic for this moment:

- **Cumulative direct employment regarding the 5 construction phase packages** under survey for the period 2019-2023 to install 370 WTGs in the Dutch part of the North Sea is around 2,480 FTEs (see paragraph 5.3).
- Extrapolation of this above-mentioned employment figure to the installation of 1,250 WTGs in the mentioned neighbouring countries leads to a cumulative direct employment indication of approx. 8,400 FTEs with respect to the 5 construction phase packages and for the period 2019-2023. This figure should be seen as a very rough indication, not considering the specific parameters of the offshore wind farm projects in these countries.
- Percentage range of the 1,250 WTGs installations that could be realized with (more than) substantial involvement of Dutch companies seen on construction phase level: 10% - 30%.\(^{14}\)

This results in the cumulative export-related direct employment indication range for Dutch companies: 840 FTE – 2,520 FTE for the period 2019-2023 regarding activities in the 5 studied construction phase packages in the mentioned neighbouring countries. No data is available to convert these indications into employment estimations on the level of persons (FTE) who live and work in the Netherlands and/or work from the Netherlands abroad. It should be noted that large numbers of non-Dutch professionals are working in or for Dutch offshore companies with activities in the Netherlands and abroad.

Besides the offshore wind markets of the mentioned 5 European countries, it should be noted that within certain packages export potentials are substantial to regions like Europe (e.g. Norway, Baltic area, Ireland, and Spain), US, and Asia (e.g. Taiwan, South-Korea, and Vietnam).

Conclusion is that the export-related direct employment of Dutch companies active in or for the offshore wind sector is potentially substantial when considering the international offshore wind developments, the international ambitions and potentials of Dutch companies, and also the Dutch ports that are suitable to serve offshore wind projects (in the North Sea region).

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\(^{14}\) These percentages are indicative and research is needed to come up with precise percentage ranges, preferably per package. It should be noted that the involvement of Dutch companies differs per package. E.g. involvement of Dutch companies in the foundation supply could be relatively high in comparison with certain activities within the package of installation support. According to WindEurope (2019a) the monopole market share of Dutch company SIF in offshore wind in Europe was 29% in 2018.
6 Competencies

The focus of this chapter is to indicate the most relevant functional and foundational competencies per package or scope of work (see also paragraph 2.2 and figure 2). In-depth competencies overviews for all packages and scope of work are out of scope of this study. However, this chapter will give for one scope of work a detailed overview of the functional and foundational competencies.

6.1 Detailed competencies overview related to turbine maintenance

Table 16 gives a detailed overview of the functional and competencies related to the scopes of work preventive and corrective maintenance and the employee category technicians (maintenance and repair expertise levels 4-7). The level of details in this table is an example to work-out competencies overview for other packages and scopes of work.

<table>
<thead>
<tr>
<th>Package: Wind farm operations</th>
<th>Scope(s) of work: Preventive and corrective maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee category: Technicians (level 4-7)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Functional competencies</th>
<th>Job roles level competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HV switching (HV responsible person)</td>
</tr>
<tr>
<td></td>
<td>Major/advanced technical repairs (specialistic technicians – level 6-7)</td>
</tr>
<tr>
<td></td>
<td>Trouble shooting (specialistic technicians – level 6-7)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scope of work level competencies and requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWO (safety trainings Global Wind Organisation)</td>
</tr>
<tr>
<td>HSE (advanced/offshore)</td>
</tr>
<tr>
<td>Non-major technical repairs</td>
</tr>
<tr>
<td>Technical maintenance (mechanical, electrical, electronics, digital)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Package level competencies and requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSE (general)</td>
</tr>
<tr>
<td>Operations and maintenance (general principles)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foundational competencies</th>
<th>Social competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coaching and leadership (depending on job role)</td>
</tr>
<tr>
<td></td>
<td>Communication, interpersonal skills</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cognitive and meta competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer skills</td>
</tr>
<tr>
<td>Critical and analytical thinking</td>
</tr>
<tr>
<td>English reading and writing</td>
</tr>
<tr>
<td>Lifelong learning</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Personal effectiveness competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptability and flexibility</td>
</tr>
<tr>
<td>Dependability and reliability</td>
</tr>
<tr>
<td>Duty awareness</td>
</tr>
<tr>
<td>Integrity</td>
</tr>
</tbody>
</table>

Table 16 - Example of detailed competencies overview: turbine maintenance technicians; Note: the competencies and requirements are ordered alphabetically.

37/51
The relationship between the competencies and the types of education and training is giving in table 17. It shows per competencies domain/level what kind of education and/or training could be relevant regarding service and maintenance technicians. Again, this is an example how on more detailed level the connection between education and training categories and competencies can be shown.

<table>
<thead>
<tr>
<th>Package: Scope(s) of work</th>
<th>Wind farm operations</th>
<th>Types of education and training (excluded: training on the job)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preventive and corrective maintenance Technicians (level 4-7)</td>
<td>- Special training being part of specialistic minor(s) of education institutes (levels VET, associate degree, and/or bachelor)</td>
</tr>
<tr>
<td>Functional competencies</td>
<td>Job roles level competencies</td>
<td>- E.g. special training for high voltage</td>
</tr>
<tr>
<td></td>
<td>Scope of work level competencies and requirements</td>
<td>- WTG supplier trainings (specialistic training regarding trouble shooting or digital systems of WTGs)</td>
</tr>
<tr>
<td></td>
<td>Package level competencies and requirements</td>
<td>- General offshore wind minor(s) and specialistic minor(s) of education institutes (levels VET and associate degree)</td>
</tr>
<tr>
<td></td>
<td>Social competencies</td>
<td>- Specialist trainings for offshore working (e.g. GWO) and regarding HSE</td>
</tr>
<tr>
<td>Foundational competencies</td>
<td>Cognitive and meta competencies</td>
<td>- Regular VET education programmes: MBO electrical engineering, MBO mechanical engineering, MBO industrial engineering/ all-round operational technician (AOT)</td>
</tr>
<tr>
<td></td>
<td>Personal effectiveness competencies</td>
<td>- Special training regarding teamwork and communication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Regular education programmes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Part of specialistic trainings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Regular education programmes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Part of specialistic trainings</td>
</tr>
</tbody>
</table>

Table 17 - Example of linkages between competencies to types of education and training: turbine maintenance technicians.
6.2 Introductory overviews of competencies on package level

This paragraph gives introductory competencies overviews on package level of the packages under study. These are inspirational. More elaborations among industry parties and between industry and education institutes are needed to make progress in working out of these competencies overviews, not only being relevant for the human capital activities within the Dutch offshore wind sector, but also for education and training institutes serving the sector.

<table>
<thead>
<tr>
<th>Package:</th>
<th>Foundation supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope(s) of work:</td>
<td>Manufacturing of monopiles and TPs</td>
</tr>
</tbody>
</table>
| Functional competencies | Coating  
Electrical engineering  
(LV/HV-packages in TP)  
Electrical engineering (TP)  
Logistics management  
Manufacturing management and production automation | Metal works manufacturing  
Modelling, simulation, engineering  
QC  
VCA |
| Foundational competencies | Coaching and leadership  
Communication  
Dependability and reliability  
Dependability and reliability  
Duty awareness  
Flexibility (working in shifts) | Interpersonal skill  
Mathematics, science and technology to express ideas and solve problems  
Personal development  
Professionalism  
Results drive |

Table 18 - Introductory overview of competencies regarding the manufacturing of monopiles and TPs;  
Note: competencies and requirements are ordered alphabetically, like in the rest of the tables in paragraph 6.2.

<table>
<thead>
<tr>
<th>Package:</th>
<th>Foundation installation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope(s) of work:</td>
<td>Installation of monopiles and TPs</td>
</tr>
</tbody>
</table>
| Functional competencies | GWO  
HSE  
Installation of MPs  
Jack-up/jack-down  
Mounting TPs | Positioning of MPs  
QC  
VCA  
Working at sea |
| Foundational competencies | Coaching and leadership (depending on job role)  
Communication  
Dependability and reliability  
Duty awareness  
English speaking  
Interpersonal skill | Mathematics, science and technology to express ideas and solve problems  
Professionalism  
Results drive  
Team living  
Teamwork |

Table 19 - Introductory overview of competencies regarding installation of foundations
### Package: Turbine installation

**Scope(s) of work:** -

<table>
<thead>
<tr>
<th>Functional competencies</th>
<th>Turbine installation</th>
<th>Foundational competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolting towers</td>
<td>Installation of nacelles</td>
<td></td>
</tr>
<tr>
<td>Commissioning of various turbine systems (electrical, hydraulic, digital etc.)</td>
<td>Jack-up/jack-down</td>
<td></td>
</tr>
<tr>
<td>GWO</td>
<td>QC</td>
<td></td>
</tr>
<tr>
<td>HSE</td>
<td>Termination of electrical system</td>
<td></td>
</tr>
<tr>
<td>Installation of blades</td>
<td>VCA</td>
<td></td>
</tr>
<tr>
<td>Installation of hubs</td>
<td>Working at sea</td>
<td></td>
</tr>
</tbody>
</table>

Table 20 - Introductory overview of competencies regarding installation of turbines.

### Package: Array cable installation

**Scope(s) of work:** -

<table>
<thead>
<tr>
<th>Functional competencies</th>
<th>Array cable installation</th>
<th>Foundational competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Array cables laying</td>
<td>GWO</td>
<td></td>
</tr>
<tr>
<td>Array cables termination</td>
<td>HSE</td>
<td></td>
</tr>
<tr>
<td>Burial inspection</td>
<td>QC</td>
<td></td>
</tr>
<tr>
<td>Commissioning of array cables</td>
<td>VCA</td>
<td></td>
</tr>
<tr>
<td>Geotechnical and seismic works</td>
<td>Working at sea</td>
<td></td>
</tr>
</tbody>
</table>

Table 21 - Introductory overview of competencies regarding array cable laying.

### Package: Installation support

**Scope(s) of work:** -

<table>
<thead>
<tr>
<th>Functional competencies</th>
<th>Installation support</th>
<th>Foundational competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordination of vessel support</td>
<td>Planning</td>
<td></td>
</tr>
<tr>
<td>HSE</td>
<td>Working at sea</td>
<td></td>
</tr>
<tr>
<td>Operational excellence in supporting key offshore activities like foundation, turbine and cable installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adaptability and flexibility</td>
<td>Interpersonal skill</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>Professionalism</td>
<td></td>
</tr>
<tr>
<td>Dependability and reliability</td>
<td>Team living</td>
<td></td>
</tr>
<tr>
<td>Duty awareness</td>
<td>Teamwork</td>
<td></td>
</tr>
</tbody>
</table>

Table 22 - Introductory overview of competencies regarding installation support.
### Package: Wind farm operations

**Scope(s) of work:**
- Wind farm operations

<table>
<thead>
<tr>
<th>Functional competencies</th>
<th>Foundation competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business management</td>
<td>Marine monitoring and coordination</td>
</tr>
<tr>
<td>Commercial operations management</td>
<td>Operational excellence</td>
</tr>
<tr>
<td>Data modelling and analysis</td>
<td>Planning</td>
</tr>
<tr>
<td>Energy output optimisation</td>
<td>QC</td>
</tr>
<tr>
<td>HSEQ support</td>
<td>Technical operations management</td>
</tr>
<tr>
<td></td>
<td>Coaching and leadership</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
</tr>
<tr>
<td></td>
<td>Duty awareness</td>
</tr>
<tr>
<td></td>
<td>Mathematics, science and technology to express ideas and solve problems</td>
</tr>
<tr>
<td></td>
<td>Professionalism</td>
</tr>
<tr>
<td></td>
<td>Reflectivity</td>
</tr>
<tr>
<td></td>
<td>Results drive</td>
</tr>
<tr>
<td></td>
<td>Teamwork</td>
</tr>
</tbody>
</table>

Table 23 - Introductory overview of competencies regarding wind farm operations.

### Package: Structural inspection and maintenance

**Scope(s) of work:**
- Structural inspection and maintenance

<table>
<thead>
<tr>
<th>Functional competencies</th>
<th>Foundation competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWO</td>
<td>Structural inspection (methods, guidelines: transition pieces, foundations, steel structures, and scour</td>
</tr>
<tr>
<td>HSE</td>
<td>VCA certificate (Dutch certificate basic safety)</td>
</tr>
<tr>
<td>Operations and maintenance (general principles)</td>
<td>Working subsea and at height</td>
</tr>
<tr>
<td>QC</td>
<td></td>
</tr>
<tr>
<td>Standard maintenance (methods, guidelines: transition pieces, foundations, and steel structures, bolted connections)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adaptability and flexibility</td>
</tr>
<tr>
<td></td>
<td>Coaching and leadership (depending on job role)</td>
</tr>
<tr>
<td></td>
<td>Dependability and reliability</td>
</tr>
<tr>
<td></td>
<td>Duty awareness</td>
</tr>
<tr>
<td></td>
<td>Integrity</td>
</tr>
<tr>
<td></td>
<td>Interpersonal skill</td>
</tr>
<tr>
<td></td>
<td>Mathematics, science and technology to express ideas and solve problems</td>
</tr>
<tr>
<td></td>
<td>Personal development</td>
</tr>
<tr>
<td></td>
<td>Professionalism</td>
</tr>
<tr>
<td></td>
<td>Results drive</td>
</tr>
<tr>
<td></td>
<td>Team living</td>
</tr>
<tr>
<td></td>
<td>Teamwork</td>
</tr>
</tbody>
</table>

Table 24 - Introductory overview of competencies regarding structural inspection and maintenance.

### Package: Maintenance and service logistics

**Scope(s) of work:**
- Maintenance and service logistics

<table>
<thead>
<tr>
<th>Functional competencies</th>
<th>Foundation competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>GWO</td>
<td>Safe transfer: personnel, spare parts, tooling etc.</td>
</tr>
<tr>
<td>HSE</td>
<td>STWC (International Convention on Standards, Training, and Watchkeeping for Seafarers)</td>
</tr>
<tr>
<td>Logistics management</td>
<td>VCA</td>
</tr>
<tr>
<td>QC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adaptability and flexibility</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
</tr>
<tr>
<td></td>
<td>Dependability and reliability</td>
</tr>
<tr>
<td></td>
<td>Duty awareness</td>
</tr>
<tr>
<td></td>
<td>Interpersonal skill</td>
</tr>
<tr>
<td></td>
<td>Professionalism</td>
</tr>
<tr>
<td></td>
<td>Teamwork</td>
</tr>
</tbody>
</table>

Table 25 - Introductory overview of competencies regarding maintenance and service logistics.
7 Education

The previous chapters have given insights on Roadmap 2023 employment developments per package, and (first overviews of) competencies relevant per package. The focus of this chapter is on the following:

a) Overview of the Dutch education system
b) Overview of education levels related to the employment character within the packages
c) Indicative overview of offshore wind relevant education programmes

7.1 Overview of the Dutch education system

Information in this section is based on information of Nuffic (2018). The Dutch education system is made up of primary education, secondary education and higher education. Primary education lasts 8 years (groups 1-8) and is offered at primary schools and special needs primary schools. On secondary education level there are 3 pathways: a) general education (VMBO-t, HAVO, and VWO), b) pre-vocational secondary education (VMBO-basic, VMBO-kader, and VMBO-gl), and c) senior vocational education (MBO – levels 1-4). Learning pathways of VMBO are tracks that lead to senior secondary vocational education (MBO). Secondary education is intended for children aged 12 through 16, 17 or 18 depending on the education route/level. Table 26 positions the levels of these different education routes in the European qualifications framework (EQF).

Senior secondary vocational education and training (MBO) prepares students for the professional practice or further study, and its duration will depend on the chosen qualification/level. The MBO students can choose between 2 learning pathways. The first one is the school-based pathway (called BOL) whereby students spend at least 20% and no more than 60% of their study programme working in the professional practice. The other one is the work-based pathway (called BBL) whereby students spend at least 60% of their study programme working in the professional practice.

Dutch education qualifications | European qualifications framework (EQF) level
--- | ---
Master and doctor * | 7 + 8
Bachelor * | 6
Associate degree | 5
MBO – level 4 | HAVO and VWO
MBO – level 3 | 4
MBO – level 2 | VMBO-kader, VMBO-gl and VMBO-t **
MBO – level 1 | VMBO-basic **

Table 26 - Position of Dutch education qualifications in the European qualifications framework (EQF);
* Includes bachelor and master programmes of universities of applied science and (technical) universities.
** VMBO education programmes are

The Dutch higher education system distinguishes research-oriented higher education (universities and technical universities) and higher professional education (universities of applied sciences). These 2 types of education each have their own admission requirements, duration and official titles. Universities of applied sciences offer both bachelor degree programmes and associate degree programmes. However, since the introduction of the bachelor - master degree structure, universities of applied sciences have also been allowed to offer master programmes.

---

15 VMBO-kader: pre-vocational training with a large share of practical training; VMBO-t: pre-vocational training with a large share of theoretical education; VMBO-gl: mix of VMBO-kader and VMBO-t looking at share of practical training and share of theoretical education.
Higher professional education is mostly organised in 2 stages: a 4-year bachelor degree programme and a master degree programme (1 or 2 year(s) depending on the specialisation). Associate degree programmes, offered by universities of applied sciences, have a duration of 2 years and are mainly designed to prepare students for the labour market in a shorter period of time than a regular 4-year bachelor programme. Research-oriented higher education programmes are divided into 2 stages: a 3-year bachelor degree programme and a master degree programme (1, 2 or 3 year(s) depending on the specialisation).

### 7.2 Education levels in relation with employment character within packages

The table below indicates the relative weight of four levels of grouped education levels in relationship with the employment character within the packages under survey. This information gives a very general overview, and more in-depth elaborations are needed to link more specific employment activities (e.g. on the level of scopes of work) to certain education levels.

<table>
<thead>
<tr>
<th>Offshore wind farm packages under survey</th>
<th>Relative weight of education levels when looking at employment character within packages</th>
</tr>
</thead>
<tbody>
<tr>
<td>VET education level (EQF 1+2)</td>
<td>VET education level (EQF 3-5)</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Foundation supply</td>
<td>●●●●</td>
</tr>
<tr>
<td>Installation: foundations, turbines and cables</td>
<td></td>
</tr>
<tr>
<td>- Staff offshore wind</td>
<td>●●○○</td>
</tr>
<tr>
<td>- Vessel crew</td>
<td>●●●●</td>
</tr>
<tr>
<td>Installation support</td>
<td>●●●●</td>
</tr>
<tr>
<td>Wind farm operations</td>
<td></td>
</tr>
<tr>
<td>Turbine maintenance</td>
<td>●○○○</td>
</tr>
<tr>
<td>Structural inspection and maintenance</td>
<td>●○○○</td>
</tr>
<tr>
<td>Maintenance and service logistics</td>
<td>●●●●</td>
</tr>
</tbody>
</table>

Table 27 - Relative weight of education levels when looking at employment character within packages.

Table 27 shows that a substantial amount of the employment in the offshore wind industry is related to the EQF levels 3-5:

a) Staff involved in the offshore installation of foundations, turbines, and array cables (planners, supervisors, and technicians)

b) Turbine maintenance technicians (various maintenance and repair expertise levels) and professionals to support maintenance planning and logistics

c) Inspectors and technicians for foundation inspection and maintenance

d) Crew of vessels used during construction phase and the operations and maintenance phase

Also, a substantial amount of the professionals working in the industry can be linked to the EQF levels 1+2, especially factory workers (foundation supply) and marine crew on the vessels. Bachelor and master level competencies are especially relevant in wind farms operations (business management, marine coordination and planning, and engineering), but also relevant for coordination, planning and engineering related to offshore installation activities. Master level competencies are relatively limited needed within the studied packages, besides foundation supply (modelling/simulation, design, engineering), and wind farm operations and turbine maintenance (e.g. business management, operational excellence, data-based predictive maintenance modelling, data analytics, weather forecasts).
7.3 Indicative overview of offshore wind relevant education programmes

This paragraph gives an overview of education programmes and related aspects that have (to a certain degree) connections with the current situation and future developments and innovations in offshore wind:

- VET and relevant minors on VET level\(^{16}\)
- Bachelor and master programmes of universities and universities of applied sciences
- Associate degree programmes of universities of applied sciences
- Bachelor level minors\(^{17}\) of universities of applied sciences

It should be noted that the information in the tables below is a snapshot of what is currently available (see also Collette, 2019) and/or communicated (by education institutes), without giving the suggestion to be complete with the information.

In the Netherlands universities of applied sciences have set up applied research groups (in Dutch: lectoraten) over the last 10 years. A substantial number of research groups can be linked to topics relevant for offshore winds (e.g. materials, engineering, energy, operational excellence). This applied research is relevant for the industry (development of innovations) as well for education institutes (e.g. enhancing the content of curricula).\(^{18}\) It is outside the scope of this study to give a detailed overview of these groups.

<table>
<thead>
<tr>
<th>Indicative overview of relevant VET level education offered by Dutch VET colleges *</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VET programmes</strong></td>
</tr>
<tr>
<td>E.g. Electrical engineering, Mechanical engineering (mechanic, welder, pipe fitter etc.), Industrial engineering/All-round operational technician (AOT), Maritime officer.</td>
</tr>
<tr>
<td><strong>Relevant minors linked to VET programmes</strong></td>
</tr>
</tbody>
</table>

Table 28 - Indicative overview of relevant VET level education offered by Dutch VET colleges;
* Education programmes are ordered alphabetically.

---

\(^{16}\) VET level minor gives VET students the opportunity to broaden and/or specialize his/her knowledge.

\(^{17}\) Bachelor level minor is a coherent package of courses, usually about 3 to 6 courses spread over the academic year that a bachelor student (of a university of applied sciences) can follow to broaden and/or specialize his/her knowledge. Minors can be related to the bachelor programmes a student follows, but a student can in principle also choose and follow one or more minors from another university of applied science or university.

\(^{18}\) It is perceived that these applied research groups in collaboration with industry partners and – when possible - VET colleges play highly relevant roles in knowledge generation and knowledge sharing. These well-focused collaborations (e.g. in the field of offshore wind) – also being labelled as learning communities - are well suited to support ambitions of the so-called national multi-annual mission-driven innovation programs (MMIPs; in Dutch: meerjarige missiedreven innovatieprogramma’s) (MinEZK, 2018b) stimulating the energy transition in the Netherlands (Kool & Velzing, 2019).
Conclusion is that regarding needed competencies on the level of packages and scopes of work in the Netherlands more than appropriate education programmes are available, looking at the aboveShown tables in relation with table 27 (relative weight of education levels when looking at employment character within packages) and the competencies indications as given in chapter 6. Regarding job role specific competencies there is room for specialistic courses developed and organised in cooperation between education institutes and industry.
8 Conclusions and recommendations

8.1 Conclusions

Methodologies well suited
The study is based on two further developed methodologies: 1) bottom-up workload elaborations based on iterations with key stakeholders from the industry (bringing in workload insights of existing and forthcoming offshore wind farms) for direct employment indications (related to the number of WTGs instead of related to the amount of wind turbine power), and 2) analysis of needed competencies from the perspectives of functional competencies and foundational competencies. Conclusion is that these methodologies are well suited to come up with direct employment figures and competencies overviews able to support plans for education and inflow of future employees to the offshore wind sector. The study shows that useful data on indirect employment and export-related employment in offshore wind is not available. Input to generate detailed competencies overviews is limited.

Direct employment generated by the execution of Roadmap 2023
The offshore wind market is developing considerably in the Netherlands, in Europe, and outside Europe. Therefore, adequate employment development figures are highly relevant, especially to support the processes of industries and education institutes to stimulate influx of qualified professionals to the sector and to optimize the content and capacities of education and training programmes. This is needed, not only when looking at the market developments in the Netherlands but also when looking at the growing foreign markets for the international operating Dutch offshore wind companies.

Conclusions regarding Roadmap 2023 direct employment are focused on the nine fields of activities that are put central in this study, namely a) construction phase activities: foundation supply, foundation installation, turbine installation, array cable installation, and installation support, and b) operations and maintenance phase activities: wind farm operations, turbine maintenance, structural inspection and maintenance, and maintenance and service logistics. Construction phase activities are mostly one-off activities; operations and maintenance phase activities are largely recurring activities.

The one-off cumulative direct employment over the coming 5 years due to the Roadmap 2023 execution is approx. 2,480 person-years when considering the 5 studied construction phase packages. Of this number around 1,290 person-years are related to foundation supply: manufacturing of monopoles and transition pieces. Approx. 810 person-years relate to vessel crew for foundation installation, turbine installation, and installation support.

The yearly recurring direct employment with respect to operations and maintenance phase (packages: wind farm operations, turbine maintenance, structural inspection and maintenance, and maintenance and service logistics) is around 320 FTE, as from 2023 when all Roadmap 2023 wind farms are in operation. In principle this employment will stay on this level till the end of the operating period of the Roadmap 2023 wind farms (around 2043). Circa two-third of this yearly recurring direct employment consists of work for Dutch technicians. The current Dutch Working Hours Act is hindering more optimized strategies for working shifts in offshore wind, especially during the operations and maintenance phase.

Conclusion is that the export-related direct employment of Dutch companies active in or for the offshore wind sector is potentially substantial when considering the international offshore wind developments, the international ambitions and potentials of Dutch companies, and also the Dutch ports that are suitable to serve offshore wind projects in mostly the North Sea region.

The employment estimations are in the upper side of the figures’ ranges, looking at developments in product and process innovations (e.g. optimisation and automation of monopile supply and increase in single turbine capacity), economies of scale (e.g. larger wind farms), and learning curves (e.g. more efficient installation schedules, increase in operational excellence).

It should be noted that the yearly outflow of professionals is not yet incorporated in the mentioned
figures. The figures presented in this report can support human capital and education strategies by companies and education institutes the coming period.

**Competencies overviews**

Overall conclusion is that the created competency framework for this study is useful for industry and education institutes to discuss and align education and training options and needs the coming years.

In this report a detailed competencies overview is worked-out regarding wind turbine maintenance technicians, taking into account functional competencies (divided in job roles level competencies, scope of work level competencies and requirements, and package level competencies and requirements) and foundational competencies (divided in social competencies, cognitive and meta competencies, and personal effectiveness competencies). Introductory competencies overviews are created for the studied packages on package level.

The study shows that a substantial amount of the employment in the offshore wind industry is related to the EQF levels 3-5. Also, a substantial amount of the professionals working in the industry can be linked to the EQF levels 1+2, especially factory workers (foundation supply) and marine crew on the vessels.

Elaborations lead to the conclusion that a large part of the functional competencies on package level and (to a lesser extend) scopes of work level are dealt with during the regular education programmes. In other words: in general, the existing education programmes are serving the offshore wind industry when looking at the needed functional competencies. Competencies on job roles level are in principle more developed ‘on the job’ or via special trainings/courses. This counts also for a large group of acknowledged foundational competencies. There is room for specialist courses/trainings developed and organised in cooperation between education institutes and the industry.

It can be concluded that English reading, writing and conversation competencies are very important in the fast developing and international offshore wind sector, on all levels (VET, bachelor, and master level).

Career path information of professionals is not recorded by education institutes; this information could be useful to better align education strategies and yearly influx of needed professionals.

**8.2 Recommendations**

**Recommendations for education institutes**

Nationwide educational approach for offshore wind technicians and other staff categories. Address: synergies among education institutes, specializations, potentials of educating and training of foreign students and professionals, and the enabling potentials of industry-driven applied research for (future) education and training.

Strong focus on English language skills.

Align together with the industry who will facilitate the special courses and trainings needed.

Stronger present together with the industry the offshore wind sector within education.

**Recommendations for the industry**

Develop a human capital plan: a) secure influx of students/professionals to the sector (among other factors by raising awareness among broader public about offshore wind sector careers), b) indicate career paths within the sector, and c) express education and training needs.

Offer internship/apprenticeship programs with real-life assignments. Look for opportunities to involve students in the sector as early as possible during their education, not only for inspiration but also for perception management (qualified for offshore work: sea, heights etc.).

Invest in industry-driven applied research supporting the industry and enabling curriculum developments.
Align together with the educational institutes who will facilitate what special courses and trainings that are needed.

In-depth elaborations are needed to link more specific employment activities (e.g. on the level of scopes of work) to certain education levels.

**Recommendations regarding governmental policies**

Specific barriers – e.g. elements of the Dutch Working Hours Act – should be in line with industry needs to facilitate the productivity of professionals in the sector.

Facilitate bottom-up employment and competencies studies that support human capital and education strategies in offshore wind to generate detailed competencies overviews.

Facilitate bottom-up employment and competencies studies on indirect employment and export-related employment in offshore wind.

Facilitate investigations that could define the Dutch educational capacities needed considering the development in offshore wind in the Netherlands and abroad, and the potentials to serve students and professionals from abroad with education and training in the Netherlands.

Looking at the dynamics within the offshore wind sector the upcoming years and beyond, it is recommended: a) to update of this study as presented in this report yearly, and b) to consider (online) approaches to collect data from offshore wind companies more easily.
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