MASTER'S THESIS

Professional competences to support transformative change towards a largescale application of 5GHDC

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Professional competences to support transformative change towards a largescale application of 5GHDC

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Professional competences to support transformative change towards a largescale application of 5GHDC

Professionele competenties ter ondersteuning van transformatie naar een grootschalige toepassing van 5GHDC

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Summary

Making the heating sector sustainable is crucial to limit greenhouse gas emissions. The fifth-generation district heating and cooling (5GDHC) can be applied for making the heating sector more sustainable. Recent research on 5GDHC focuses on the large-scale application and implementation of 5GDHC networks. An area that has not been adequately studied is the knowledge and skills required by workers involved in 5GDHC networks. The aim of this master's thesis research is to gain insight into the knowledge and skills required by workers involved in 5GDHC systems to perform their job successfully. This insight can serve as input for the development of a training program. By creating a competence framework, the knowledge and skills required by workers involved in the construction of 5GDHC networks are mapped out systematically.

To gain insight into the positions on 5GDHC projects and the skills and knowledge required by workers, surveys have been conducted among employees working on 5GDHC projects. A literature review has been carried out on the criteria for a competency framework and on existing competency frameworks for similar positions. Based on the survey results and literature review, a competence framework for the positions on the 5GDHC project locations is developed. The European Skill, Competence, Qualification and Occupations database is used to define the competences.

The survey conducted to identify the positions on 5GDHC projects has led to the identification of 26 positions. The survey to map out the competencies has been fully completed by 24 respondents. The competence framework has been developed for 13 positions that are present on one or more projects. The framework is based on NEN-EN 16234-1, the e-CF for ICT professionals. The framework consists of 12 main areas of competence, which are further subdivided into competences and knowledge and skills.

For the positions of engineers in specific fields, competences related to those fields and general engineering competences are particularly important. For other positions, such as project managers, competences related to those fields are also important, but to a lesser extent. Competences related to project management are crucial for this type of position. For all positions, social competencies are more or less important, especially working in a team and dealing with stakeholders. Several special technical 5GHDC competences were found, but these do not apply for all positions. Each position in the framework is linked to an EQF level.

Future research should focus on obtaining a broader picture of how demand for competences is distributed across different project sites and how demand for competencies is related to the stage a 5GDHC project is in.

The main conclusion of this research is that, some unique 5GDHC competences were found and that in addition to technical competences, social competences such as communication skills and working in a team are also important for working on 5GDHC projects. These competences are not unique for 5GDHC.

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Samenvatting

Het duurzaam maken van de warmte sector is cruciaal om de uitstoot van broeikasgassen te beperken. Hiervoor kan de vijfde generatie stadsverwarming en -koeling (5GDHC) worden toegepast. Recent onderzoek naar 5GDHC is gericht op grootschalige toepassing en implementatie van 5GDHC-netwerken. Een aandachtspunt dat nog onvoldoende bestudeerd is, is de kennis en vaardigheden die werknemers die aan 5GDHC-netwerken werken, nodig hebben. Het doel van dit master afstudeeronderzoek is inzicht te krijgen in de kennis en vaardigheden die de werknemers die aan 5GDHC systemen werken nodig hebben om hun beroep succesvol uit te oefenen. Dit inzicht kan als input dienen voor het samenstellen van een training voor medewerkers op de 5GDHC projecten. Door een competentie framework te maken, wordt die kennis en vaardigheden overzichtelijk in kaart gebracht.
Om inzicht te krijgen in de functies op de 5GDHC projecten en in de vaardigheden en kennis die de werknemers nodig hebben, zijn enquêtes uitgevoerd onder medewerkers op de 5GDHC projecten. Een literatuurstudie is uitgevoerd naar de criteria voor een competentie framework en naar bestaande competentie frameworks voor vergelijkbare functies. Met de resultaten van de enquête en de resultaten van de literatuurstudie, is het competentie framework voor de functies op de 5GDHC-project locaties gemaakt. Voor de definities van competenties is gebruik gemaakt van de European skill, competence, qualification and occupations database.
De enquête voor de inventarisatie van de posities op de 5GHDC projecten heeft tot de identificatie van 26 posities geleid. De enquête voor het in kaart brengen van de competenties is volledig ingevuld door 24 respondenten. Het competentie framework is opgesteld voor 13 posities die aanwezig zijn op één of meerdere projecten. Het framework is gebaseerd op het NEN-EN 16234-1, het e-CF voor ICT-professionals en is opgebouwd uit 12 main areas of competence, welke onderverdeeld zijn in competenties die op hun beurt onderverdeeld zijn in kennis en vaardigheden. Voor de posities van de engineers uit de specifieke vakgebieden zijn met name de competenties gericht op die vakgebieden en algemene engineeringscompetenties van belang. Voor andere posities, zoals die van projectmanager, zijn competenties gericht op die vakgebieden ook van belang, maar in mindere mate. Competenties gericht op het beheersen van het project zijn voor dit type posities belangrijk. Voor alle posities geldt dat sociale competenties in meer of mindere mate van belang zijn. Vooral de samenwerking binnen het team en de omgang met stakeholders is van belang. Speciale technische 5GDHC vaardigheden werden voor een aantal functies gevonden. In het framework is er een EQF-level aan iedere positie gekoppeld.
Toekomstig onderzoek zal gericht moet zijn op het verkrijgen van een breder beeld op hoe de vraag naar de competenties verdeeld is over de diverse project locaties en hoe deze vraag naar de competenties samenhangt met de fase waarin een 5GHDC project zich bevindt.
De voornaamste conclusie in dit onderzoek is dat er speciale 5GDHC competenties zijn en dat behalve de technische vaardigheden ook sociale competenties zoals communicatieve vaardigheden en samenwerken van belang zijn voor het werken op de 5GDHC projecten. Deze vaardigheden zijn niet uniek voor 5GDHC.

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Glossary

5GDHC	Fifth generation district heating and cooling, a bi-directional district heating and cooling systems in which the participants exchange heat and cold (Boesten et al., 2019)
5GDHC project site	Location where a 5GDHC system for D2Grids is realised
Attitude	How people deal with certain situations
Competence	'"*The proven ability to use knowledge, skills and personal, social and/or methodological abilities in work or study situations, and in professional and personal development"* (European Commission, n.d.-a)
Competence framework	A tool in the form of an overview of the competences that practitioners in a given position must master for proper performance in their profession (Megahed, 2018)
D2Grids	Demand Driven Grids, the aim of the D2Grids projects is to accelerate the implementation of 5GDHC grids in Europe
EQF	European Qualification framework, the common European reference framework with the purpose to make qualifications more readable and understandable across different countries and systems within the European Union (Cedefop, 2022)
ESCO	European skills, competences, qualifications and occupations
Knowledge	*´the body of facts, principles, theories and practices that is related to a field of work or study. Knowledge is described as theoretical and/or factual, and is the outcome of the assimilation of information through learning'* (European Commission, n.d.-c)
KSA	Knowledge, skills and attitude
Level	The accuracy and the speed at which a task is performed (Cedefop, 2022)
Skill	"*The ability to apply knowledge and use know-how to complete tasks and solve problems*"(European Commission, n.d.-d)

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1 Problem definition and research questions

1.1 Problem definition

1.1.1 Green jobs

The aim of limiting the temperature rise to 2°C due to climate change can create about 18 million green jobs worldwide (Czako & European Commission. Joint Research Centre., n.d.). In the energy sector the total number of jobs (green and non-green) will increase from 10.3 million in 2017 to 23.6 million in 2030 and 28.8 million in 2050 to transform the energy use and the kind of energy used in the sector (European Commission, 2016). According to the International Labour Organisation (ILO) green jobs are "*jobs that reduce the environmental impact of enterprises and economic sectors, ultimately to levels that are sustainable"* (Gregg et al., 2015).
To accomplish this transformative change, the education and training of the workers for the jobs are essential to avoid skill-gaps. Surveys among workers in industry in the EU that are conducted to collect data about the competences that are needed for green jobs in industry, have highlighted the general need for technicians and engineers with skills in science, technology, engineering and mechanics (STEM) and the need for trainers and teachers in those skills (EUREC, n.d.). To prepare for green jobs in the energy sector, EUREC made some general recommendations:

- Education in STEM should be improved and adapted to the demands of the market of the energy sector.
- STEM education should become more visible, perceived wider and incentivised.
- The availability of programs of reskilling and upskilling and apprenticeship should be increased.

A limited or inadequately skilled workforce might be the bottleneck for the new green deal as the technological adaptations needed to realise the energy transition demand a skilled workforce (Czako & European Commission. Joint Research Centre., n.d.).
In the first initial phases of the development of greening technologies, most jobs will be in the high educated roles (Lewney et al., 2019). As the greening process continues, more and more of these jobs are expected to be for employees who are educated on the lower and medium vocational education levels. A European Qualification Scheme for the medium and low vocational level might soon be necessary.

1.1.2 Decarbonising the heating sector

About 50% of the energy in the European Union was used for heating and cooling (European Union, n.d.). In 2023, 23% of the energy used for heating and cooling in the EU is based on renewable energy. To achieve the COP 21 target of limiting the temperature rise to 2°C before the end of the 21st century, the use of fossil fuels must be replaced by the use of renewable energy (UNFCCC, n.d.). District heating and cooling can be used to decarbonise the heating and cooling sector as a large-scale expansion of district heating combined with improving the energy efficiency of buildings could reduce CO_2 emissions in the European Union in 2050 with 80% compared to 1990 levels (Allen et al., 2020). Spread over Europe there are about 6000 district heating systems in operation, covering 12% of the total heat demand of 2017 (Buffa et al., 2019). In addition, there are 115 dedicated district cooling networks in operation.

1.1.3 History of district heating

In a traditional district heating and cooling system, heat and cold is transferred from a central point or multiple decentral points to the building through pipes (Lund et al., 2014). In most cases water at a temperature of 70°C or more is used as medium. In traditional district heating there is also a return flow from the buildings to the heat supply.
The use of district heating has evolved in several distinctive generations. The first generation of district heating used steam produced in a central heating point (CHP) using fossil fuels as heating medium (Lund et al., 2014). The second generation used pressurised hot water of more than 100 °C as heat carrier for the district heating. The hot water was also produced at a central heating point. In both the first and second generation of district heating, there are high heat losses and low efficiencies due to the high temperatures.
The third generation makes use of pressurised water between 80 °C and 100 °C (Sorknæs et al., 2020). Although decreased due to the lower temperatures, the heat losses are generally still around 20%.
For cooling a comparable subdivision in generations can be made (von Rhein et al., 2019). In the fourth generation district heating and cooling (4GDHC) the heating and cooling is combined in one system. For heating purposes, a

lower temperature for the medium is used, usually 50 °C or lower, and renewable energy sources and waste heat from thermal processes e.g. in industry are used (Sorknæs et al., 2020). In combined heating and cooling grids, a four-pipe system is used. A warm pipe and its return pipe and a cold pipe and its return pipe.

1.1.4 Fifth generation district heating

The current state of the art is the fifth generation district heat and cold (5GDHC) systems (Buffa et al., 2019). 5GDHC is different from other generations of district heating systems due to their bi-directional, two-pipe system with a low temperature difference between the hot and cold pipes of about 5 °C to 10 °C allowing high efficiencies to be reached (Caputo et al., 2021). The low temperature difference between the medium and the ground causes very low thermal losses and allows low temperature excess heat as heat source for the system, e.g., from datacentres, which can be discharged directly in the warm pipe (Wirtz et al., 2020a). A heat pump at the location of the end-user is needed to boost the temperature to a value that is suitable for heating or cooling (Boesten et al., 2019).
In 5GDHC systems the consumers of heat produce cold, and the consumers of cold produce heat. The participants in the network are therefore called “prosumers” (Buffa et al., 2019; Gross et al., 2021; Sulzer et al., 2021).
Boesten et al., (2019) give five features to which a 5GDHC system has to comply:

- The system has to be bi-directional
- The temperature of the medium has to be close to ground temperature
- There should be seasonal storage of heat
- The system is decentralised and demand driven
- For closing the gap between supply and demand, renewable energy sources are used

When the heating and cooling demands are balanced, the system is self-sufficient. In case of a gap, renewable sources such as geothermal or solar heat but also other sources as water from the sea or rivers can be used (Buffa et al., 2019). Surplus heat can be temporarily stored by raising the temperature in the hot pipe or in seasonal storage, for example in summer surplus heat can be stored in mine water or ground water (Boesten et al., 2019).
When the 5GDHC systems are compared to individual heating and cooling systems for buildings there is a substantial reduction in costs (-42% on average) and reduction in CO_2 emissions (-56% in average) (Wirtz et al., 2020a).

For 5GDHC two kinds of topologies for the network are possible (von Rhein et al., 2019).

- In a ring topology, the main pipe is a closed loop to which the prosumers are connected.
- In a meshed network, interconnections are made in the ring. A meshed network has the highest security of supply, can be extended easily, but has the highest investment costs.

The 5GDHC systems are still in an early development stage (Buffa et al., 2019). In Europe 40 5GDHC systems are in operation so far, most of them in Germany and Switzerland. These 5GDHC systems are mainly part of pilot projects. Buffa et al. do not specify if all of these 40 5GDHC systems comply to all five features as stated by Boesten et al. (2019).

1.1.5 Challenges for the large-scale application of 5GHDC

Research on district heating has evolved over time, with a focus on technical characteristics in the 1980s, operational optimization in the 1990s, and GHG emission reduction in the 21st century (Mazhar et al., 2018). Recently, the focus is on the large-scale application of low temperature district heating and cooling and much research to the modelling of the 5GDHC systems is performed. Models are used to optimize the balance between supply and demand, the topology, and pipe diameters (Ho et al., 2021).
Most models do not address all three purposes, but only one or two purposes, mostly the balancing and pipe diameters (Ho et al., 2021). On top of that, most models do not incorporate the full complexity of the 5GDHC systems.

Because the system has to be balanced, the system has to be designed as a whole with the heat and cooling demands optimised (Bilardo et al., 2021; Gross et al., 2021; Wirtz et al., 2020a, 2020b, 2021). The prediction of the

behaviour of the prosumers (Dong et al., 2021; Gross et al., 2021) and rejected waste heat from processes is crucial (Abdalla et al., 2021).
Fluctuating heat demand of the prosumers has to be taken into account (Sayegh et al., 2017) to reduce energy needs and reduce GHG emissions (Abdalla et al., 2021).
Models are also used to simulate and optimise the systems, to calculate losses, optimise pipe diameters and optimise the interconnection of the prosumers to minimise losses (von Rhein et al., 2019) or to optimise the design of the prosumer's substation where the heat pump or chiller is located (Abdalla et al., 2021).
Much research is conducted on the incorporation of renewable energy sources to close the gap between heat demand and heat supply (Meibodi & Loveridge, 2021, Quirosa, Torres, & Chacartegui, 2022).
Many researchers sum up challenges for the large-scale application of 5GDHC systems. The most are summarised as "gaining more knowledge." More specifically, the challenges mentioned are:

- Improvement of the availability of data and expansion of the data, especially of the heat demand by prosumers (García et al., 2019).
- Reduce the investment costs as the investment costs are a major barrier for implementing 5GDHC systems (Allen et al., 2020; Edtmayer et al., 2021; Gudmundsson et al., 2022). Improvement of the economy of scale by making components modular and standardised may reduce these investment costs (Gudmundsson et al., 2022).
- The development of more models suitable for large scale systems as most existing models are limited to case studies or pilot projects (Bilardo et al., 2021).
- The modelling for the best topologies for the systems (von Rhein et al., 2019).
- Adapting the operation of the systems to the energy sectors (Quirosa, Torres, Soltero, et al., 2022) and incorporating renewable energy resources into the system (Quirosa, Torres, & Chacartegui, 2022)
- The billing of the heat (Caputo et al., 2021). The challenge is that the prosumers consume but also supply.
- Training and education to design, build and operate low temperature district heating and cooling systems (Mathiesen in: (Caputo et al., 2021); European Technology Platform on Renewable Heating and Cooling & Institute for Environment and Sustainability, 2011; Millar et al., 2020).

Training and education are important for the large-scale implementation of district heating systems as mentioned by Mathiesen in: Caputo et al. (2021); European Technology Platform on Renewable Heating and Cooling & Institute for Environment and Sustainability, (2011) and Millar et al. (2020). The research on skills needed for the construction of DHC systems is limited to a summation of what should be, for example, by stating that knowledge of DHC should be standard in the curricula of education at all levels, that the accessibility of the vocational training programs for DHC should be enhanced and that the latest knowledge about DHC should be shared.
The expertise about district heating and cooling is of a high level among researchers and professionals in the energy sector (Romanov & Holler, 2021). Property owners of buildings, municipalities and investors have little knowledge of district heating and cooling. To make engineering students more aware of the interdependencies between the different aspects and stakeholders Romanov and Holler developed the REWARD Heat Serious Game. By using this game students learn how to develop strategies for a successful development of a low temperature district heating system of a fictional town. In the REWARD Heat Serious Game, game elements are used to improve the experience and engagement of the user. The complex business relations are simulated and simplified in order to explain the basic techniques and to demonstrate the basic techniques. It helps the students to develop the technical understanding and to test the effects of management decisions. The game does not teach the students how to design a DHC system or what the construction of it includes. Also, the REWARD Heat Serious Game is not specifically based on 5GDHC.
The recommendation of the European Commission (2016b) named earlier to improve and adapt the STEM education to the demands of the market of the energy sector is related to the training and education challenge of the large-scale implementation of 5GDHC systems.

The knowledge gap this research focuses on concerns the competences that practitioners at 5GDHC project sites need to have in order to fulfil their job. The aim of the research is to gain that insight into the competences in order to put together a curriculum for a training course for 5GDHC practitioners. The competences will be organised in a competence framework.

1.2 Research questions

First central research question in this research is:

1 What knowledge and skills are needed by position and vocational level to work on the 5GDHC systems as a practitioner?

Sub questions for this central research question are:

1.1 What different positions are needed to implement 5GDHC systems?

1.2 What knowledge and skills are needed for the most common positions in 5GDHC systems?

1.3 How can the level of knowledge and skills be described?

1.4 At what level are the knowledge and skills needed for the most common positions?

1.5 How do these levels on the knowledge and skills relate to the levels on the European qualification framework (EQF)?

Second central research question in this research is:

2 How can a competence framework be compiled that describes knowledge and skills needed to work on 5GDHC systems?

Sub questions for this central research question are:

2.1 What are the criteria for compiling a competence framework?

2.2 Are there competence frameworks available that are useful for describing the knowledge, skills and levels needed for positions in 5GDHC systems?

The last sub question is subdivided in the sub questions:

2.2.1 What competence frameworks are there?

2.2.2 Which of the found competence frameworks can be used for describing the knowledge and skills needed for working on the 5GDHC systems?

2.2.3 Does a general international competence framework apply to work on the 5GHDC systems, or do different requirements in the different countries require a different set of competences?

1.3 Reading guide

In chapter two, first is explained what the D2Grids project is and what competence frameworks are. Then the methodology of this research and the ethical considerations are described. Chapter three describes the results of all research activities performed to answer the research questions. In chapter four the results are discussed in relation to the research questions. In the fifth chapter the answers to the research questions are summarised and recommendations for further research are given.

2 Methodology

An overview of the steps taken during the research are given in figure 1. Steps that are or can be taken in parallel are drawn in columns next to each other. The steps taken for the analysis of the survey results, are shown in figure 2 in section 2.3.

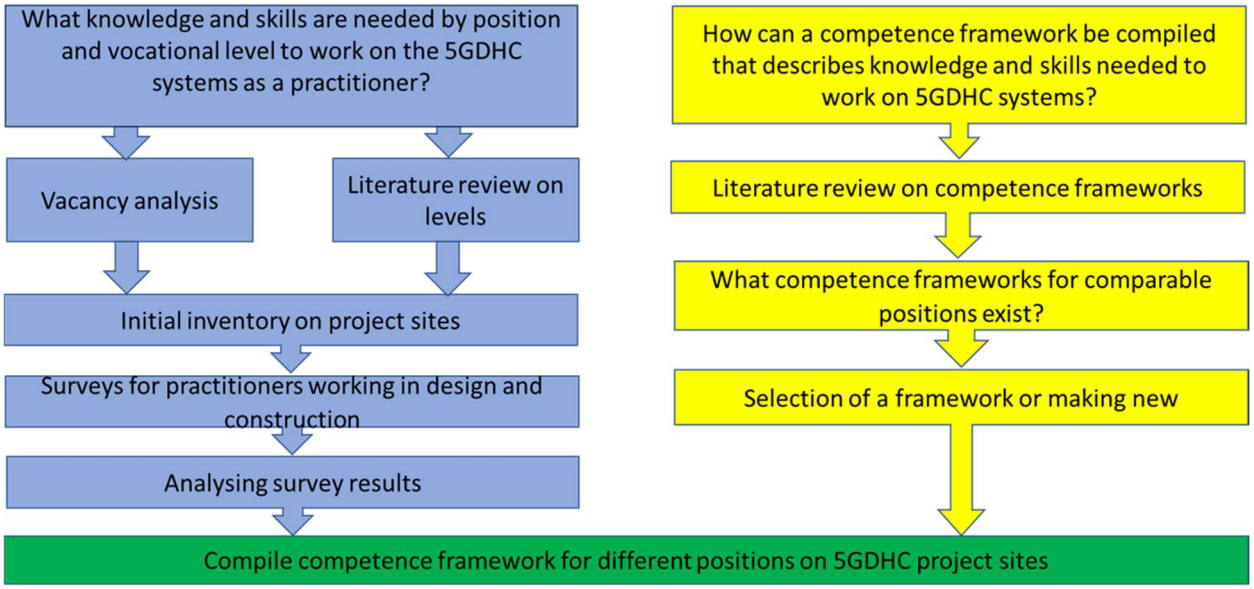

Figure 1 Overview of the research steps taken in this study. The columns represent that the steps in the different columns can be taken in parallel.

2.1 The D2Grids Project

For the study on the competences required to work on 5GHDC projects, competences were surveyed among employees at 5GDHC project sites of D2Grids. D2Grids develops five 5GDHC pilot projects (Interreg NWE, 2019). D2Grids stands for Demand Driven Grids. The aim of the D2Grids project is to accelerate the implementation of 5GDHC systems in Europe. Open Universiteit Nederland (OUNL) is the science-partner in the D2Grids project. An important task for OUNL in this project is to bring in their expertise in postgraduate and digital learning to the training and education of specialists.
Each of the five D2Grids pilot plant is in a different developmental stage. A brief description of each of the plants is given in the next sections.

1.1.1.1 Paris-Saclay

At the 5GDHC site of Paris-Saclay is situated at the Paris-Saclay urban campus (D2Grids Project, 2022e; *La Réseau d'échange de Chaleur et de Froid de Paris-Saclay*, n.d.). Boreholes of 700 meters deep are used to exchange heat with the Albien underground water table. Water of 30°C is pumped from the Albien and reinjected after the heat exchange has taken place. The 5GDHC system in Paris-Saclay is in full operation (D2Grids Project, 2022d), but the recovery of heat from other heat producers is still being studied. Possible producers are the Jean Zay supercomputer and the Synchrotron Soleil, a particle accelerator located in Paris-Saclay (*La Réseau d'échange de Chaleur et de Froid de Paris-Saclay*, n.d.).
Housing association Seqens has joined the project by connecting their new housing stock to the 5GDHC system (D2Grids Project, 2022e). The electricity demand is provided by photovoltaic electricity production on the roofs. In part, the generated electricity is used for the tenants, the other part is sold to the operator of the 5GDHC system. An intelligent management system allows to adapt the production of heat closely to the needs of connected buildings, so local energy sources are optimally utilised (*La Réseau d'échange de Chaleur et de Froid de Paris-Saclay*, n.d.). For the intelligent management system, an digital infrastructure that is capable of collecting and processing more than 5,000 data in real time is created.

To smooth out peaks in the heat consumption, some of the student residences are equipped with an advanced energy demand management system.

1.1.1.2 Bochum

The Bochum project is in the construction phase. In February 2022 and May 2022, boreholes of respectively 340 meters and 820 meters were drilled to reach the MARK 51°7 (D2Grids Project, 2022c). Mine water from the MARK 51°7 is pumped up. For covering the heat demand, water of 30°C is pumped up and further heated to 45°C using heat pumps. Then the heated water is pumped into the network. For covering the cold demand, water of 18°C is pumped up from a different underground layer.
About 75% of the heat and cold demand can be supplied using the mine water. The other heat demand will be supplied by a existing conventional district heating system. Additional cold demand are supplied by conventional cooling systems (D2Grids Project, 2022c).

1.1.1.3 Brunssum

In the 5GDHC project of Brunssum, about 200 homes in the residential complexes of housing cooperation of Weller B.V. are heated and cooled using a 5GDHC system (D2Grids Project, 2022a). For the heating and cooling, multiple renewable resources and sources of waste heat in combination with underground energy cellars is used. The underground energy cellars are used to store and exchange energy between the three residential complexes.

1.1.1.4 Glasgow

In Dalmarnock, Glasgow Clyde Gateway and its partners have installed a 5GDHC system that provides 48 homes and the new offices with heat (Clyde Gateway, 2022). In the coming years connections for over 300 homes and commercial buildings are planned.
Waste heat from the Dalmarnock waste water treatment will be supplied to the ambient loop and serve as a heat source for heat pumps (Clyde Gateway, 2022).

1.1.1.5 Plymouth

In Plymouth the latest project site of D2Grids is under development (Capgras, 2022; D2Grids Project, 2022b). The 5GDHC project site will be built using the previous project: Heatnet NWE Project. For Plymouth a concept design is made and test drillings are performed. The aim of the project is to supply a number of public buildings, a commercial area and a theatre with low carbon heat with the possibility to transit to zero carbon emission.

2.2 Inventory of positions on 5GDHC sites

To gain insight in the jobs and the competences that might be applicable for the construction of 5GDHC systems, a vacancy analysis was performed. In the vacancy analysis, vacancies for positions in the construction and engineering of district heating systems and jobs for positions as heat pump or air conditioning technician were collected and analyzed.
Vacancies were collected for the countries where the D2Grids projects are located, namely in the Netherlands, Germany, France and the United Kingdom.
For finding the vacancies, the search terms “vacancy” in combination with “district heating” or “heat pump” in the national language was used in Google.
This has led to the combinations of search termsas shown in table 1.

Table 1 Search terms for vacancy analysis

County	Language	Search terms	
The Netherlands	Dutch	Vacature + stadsverwarming	Vacature+ warmte pomp
Germany	German	Vakante stelle + Fernwärme	Vakante Stelle+ Wärmepumpe
France	French	Poste vacante+ chauffage urbain	Poste vacante + thermopompe
United Kingdom	English	Vacancy + district heating	Vacancy + heat pump

Search terms containing a job title are not included, as this may distort the search results. If job titles were used, one consequence could be that more vacancies not related to district heating would be found for that type of job.

The vacancies found were written in the national languages. The British vacancies were written in English and the Dutch, French and German vacancies were translated in English by means of Google Translate. Because one vacancy can be pasted on multiple vacancy websites, the unique vacancies were filtered comparing texts of the content of the vacancy and by comparing texts about the principal when it concerned a vacancy of a secondment company.
To test the outcomes of the vacancy analysis, an inventory of positions on the sites of the D2Grids project was held. In that inventory, the site construction managers were asked to list the positions that are present on their project sites. The site construction managers were approached by email by Anna Bronzes, OU research tutor in this research. The survey is attached in appendix 2.

2.3 Inventory of competences needed on 5GHDC site

The vacancy analysis conducted for the positions was also used to gain insight in the competences practitioners might need on 5GDHC sites. The competences that were found to be needed according to the vacancies were arranged by position. The aim was to make a first overview of the competences needed for each position, this as a basis for further research into the competences needed at the 5GDHC project sites.
The occupations found in the analysis of the positions at the 5GDHC sites were used to extract the list of competences from the ESCO database. The ESCO database is a standardized classification system developed by the European Union to describe and classify occupations, skills, qualifications and other relevant job-related information across different sectors and countries in Europe (European Commission, n.d.-b). More information about the ESCO database is provided in chapter 3.6.
Based on the findings of the vacancy analysis and the list extracted from the ESCO database, a survey is developed. The aim of the survey was to identify the competences that are needed for each position on the 5GDHC project sites. The surveys in the four different languages are attached in appendix 7.
The survey was structured as follows:

- Introduction and informed consent;
- Two general questions about what location the respondent works at and what position he/she holds;
- Six open-ended questions in which the respondents were asked to write an imaginary job advert for a new colleague in their own position. The respondents were asked to describe what tasks the new colleague has to perform, what skills the new colleague must master (the new colleague should be able to…), what knowledge the new colleague should possess (the new colleague should have knowledge of…) and what attitude the new colleague should have. Also was asked what skills or knowledge are, in the view of the respondent, unique for working on a 5GDHC project site and what challenges they faced when they started working on a 5GDHC project site;
- A list of competences that might be needed by the new colleague was presented. The list was derived from the ESCO database for similar positions. The respondent was asked to what extend the presented competences are needed in their positions.
- In the end of the survey the respondent was asked if he or she would like to add anything on the list and if he or she has anything to comment on.

The respondents of the survey were practitioners working on the D2Grids project sites. All employees working on the project sites in the D2Grids project in the positions as found in the inventory for positions were requested to complete the survey. The respondents were employees of the D2Grids partners. The link to the survey was send to the contact persons of the partner organisations with the request to distribute the survey among their employees.
The surveys were translated into the language of the countries where the project sites are located. For the translations the translator DeepL was used to translate the survey from English to Dutch, French and German. The result of the translation in DeepL was corrected by a native speaker of the relevant language.
The results of the open-ended questions of the non-English surveys were first translated into English using DeepL. Then the surveys were grouped per position. For each position, the answers to the open-ended questions were coded using the ESCO competences. Most of the competences mentioned in the responses could be directly coded to one of the ESCO competencies. When the competence of concern could not directly be coded into one of the ESCO competences the procedure was as follows:

1. It was checked whether the listed competence appears in the ESCO database under another name. For example, frequently named in the responses was the competence to “be flexible” or just “flexibility” was given as answer. In the ESCO database the competence “adapt to change” is included.

2. If no synonym was given in the database, a related competence was searched, the listed competency was defined on that basis. For example, for the specific 5GDHC competences, the competences of conventional district heating from the ESCO database were adapted for a definition which includes 5GDHC.
3. Some competences were defined by the respondents in their answers. In that case, the first check was whether the description matched a definition in the ESCO database. If not, the definition was kept and a short name for the competence was made-up by the researcher.
4. When no related competence was found and the respondent had not given a definition, the researcher defined the competence using an online dictionary. This was especially the case for attitudes named in the responses. For example, “being diligent” was named, but not found in the ESCO database.

The coding of the responses of the surveys resulted in a list of competences for each position of which completed surveys were received. The competences on the list are divided into categories according to the classification of the ESCO database. Also, distinguishment between skills, knowledge and attitude is made.
The process of the analysis of the responses is shown in figure 2.

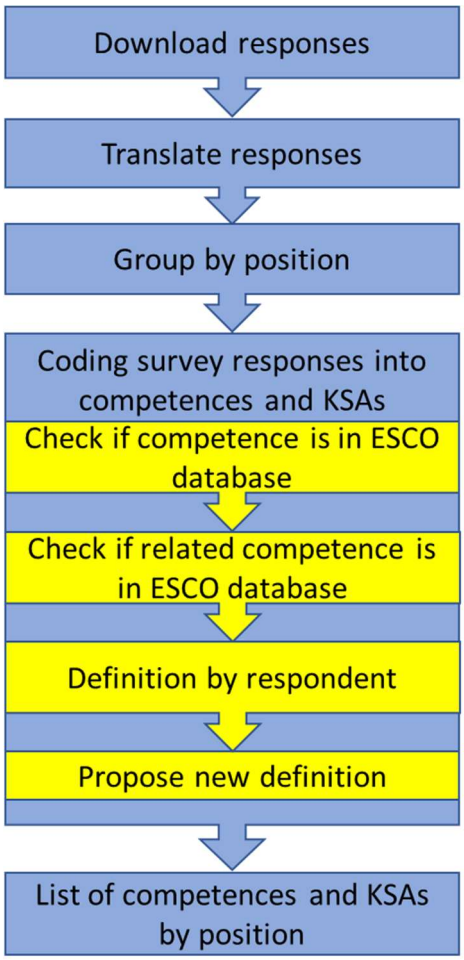

Figure 2 Overview of the steps taken in the analysis of the survey results. Yellow indicates the steps taken in coding the responses

2.4 Levels of skills and knowledge

The direct measurement of levels of skills and knowledge via the survey was not possible as it would make the survey too long. The general level of the position was established from the description of the tasks which were given in one of the open-ended questions of the survey. For each task the respondent gave in the survey, the EQF level was derived on the basis of general task descriptions the EQF gives for each level. EQF is described in section 3.4.

2.5 Competence framework

A competence framework is a structured model that outlines the essential skills, knowledge, and behaviours required for a specific role or profession (Delamare Le Deist & Winterton, 2005; Lester, 2014). It provides a clear understanding of the requirements of the job and can include technical skills, soft skills, and personal attributes, and may also incorporate levels of proficiency or proficiency scales. From section 3.5 on, competence frameworks are explained in more detail.
First, an overview of criteria for constructing a competency framework is provided through desk research.
For the selection of an existing competence framework, an inventory of existing competence frameworks has been conducted. Competence frameworks used for similar applications are listed and characteristics were noted. For selecting what competence framework is used for describing the skills and knowledge needed for working on a 5GDHC project site, the criteria found in the desk research were used. The competence framework that complied to all or complied to the most criteria was selected.
When all positions of which a competence framework had to be made, knowledge, skills and levels were clear, the data was fitted into the selected competence framework.

2.6 Ethical statement

For performing this research data about the positions of informants had to be gathered. Ethical issues concerning the personal data of the informants and the secure storage of data might rise. Informants who participated in this study by completing surveys were informed in the accompanying introduction letter about the storage and use of the data they entered in the survey and that participation to the survey is voluntary and anonymous and that the respondent may discontinue participation at any time. Before starting the survey, the respondents were asked for approval of the declaration of consent for using and storing the data. The respondent gave approval by filling in the date of entering of the survey.
For conducting the surveys Limesurvey was used. The link to the survey was distributed by email to the contact persons on the D2Grids project sites by Anna Bronzes, OU research tutor in this research. No email addresses of other employees of the D2Grids project sites are known by the researcher.
The data from de surveys is stored on the PW-secured surf-drive folder. To Elize Stoel only anonymous data were provided. Only the final general results will be shared within the D2Grids consortium on the joint and two-way password secured online working environment in Nextcloud.
For this research cETO approval has been applied for on June 13th, 2022. Approval has been given by cETO on July 21st, 2022.

3 Results

As a first step in the research, a vacancy analysis was conducted. The vacancy analysis did not contribute to answering the research questions, but did contribute to the making of the survey for the inventory of positions. The results of the vacancy analysis are shown in annex 1.

3.1 Occupations on 5GDHC project sites.

Of the five surveys sent to the project sites, all were returned. A total of 25 different positions across the five 5GDHC project sites were identified during the inventory. The result of the survey shows that not all project sites have the same positions. Positions that are present on all five sites concern the positions as technician heat pumps, heating engineer, project coordinator, project manager, installer for the 5GDHC pipework and pipeline engineer. Other positions are found at a number of project sites, e.g. the position of drilling engineer is found on four project sites, the position of geothermal engineer is found on three project sites and the position of hydrologist is found on two project sites. Twelve positions were reported at only one of the project sites. These include among others the positions of financial manager and financial analyst, civil engineer, expert approval procedures and maintenance engineer. The summary of the positions at the 5GDHC project sites is shown in table 2. In the second survey, four additional positions were found, these are indicated by an asterix.

Table 2 Summary of positions per D2Grids 5GDHC project sites as demonstrated by the inventory on the project sites. The additional positions found in the second survey are indicated by an asterix.

Position	UK: Glasgow	UK: Plymouth	France: Paris	Germany: Bochum	Netherlands: Brunssum
Architect*	X				
Building construction	X	X		X	X
Business manager *	X				
Civil- structural engineer	X				
Customer engagement	X				
Data analyst			X		
Drilling engineer		X	X	X	X
Electrical engineer*	X				
Energy consultant*	X				
Expert approval procedures				X	
Financial manager				X	
Financial specialists		X			
Geothermal engineer		X	X	X	
Geothermal technician		X	X	X	
Ground survey		X			
Groundwork specialists		X			
Heat pump technician	X	X	X	X	X
Hydrologist		X	X		
Maintenance manager					X
Mechanical engineer:					
Heating engineer	X	X	X	X	X
Smart grid control	X	X		X	
Operation and Maintenance technician	X				
Pipeline engineer	X	X	X	X	X
Pipeworker DHC system -Loop installation	X	X	X	X	X
Pipeworker inside building	X	X		X	X
Planning consultants		X			
Project co-ordinator	X	X	X	X	X
Project manager	X	X	X	X	X
Reliability engineer					X

3.2 Survey to determine knowledge and skills on the 5GDHC project sites

In the databases of the surveys, 51 registrations of a click on the survey link are made. 15 respondents did not agree with the informed consent and quitted the survey. In 12 responses, only the work location and the position of the respondent were entered. 24 responses were fully completed. It was then decided to send the survey to another 5GDHC plant that is not affiliated with D2Grids. This did not result in any extra responses.
When the responses to the surveys were returned, it turned out that the responses to the lists of competences had not been stored in the database. The wrong question type had been used for the lists of competences. Only the answers to the open questions were stored in the database.

An overview of all responses from the first and second survey is shown in appendix 3. The overview shows by location which positions were indicated in the first survey, how many complete responses were received and how many partial responses were received.
In appendix 4, the full responses from the respondents are shown. The Dutch, French and German responses were translated to English.
For some positions that were mentioned in the first survey, no responses were received, but for positions that were not indicated in the first survey, responses were received. That was the case for four positions: architect, business manager, electrical engineer and energy consultant. For the architect, the response was not completed. Looking at the tasks and skills, the energy consultant might be categorised as a heating engineer as many tasks and skills overlap with the other heating engineers. The extra remaining positions are than the electrical engineer and business manager.
The original intention was to make a competence framework for the positions that were present on at least 3 of 5 project sites. This resulted initially in the following 10 positions:

- Drilling engineer
- Geothermal engineer
- Geothermal technician
- Heat pump technician
- Heating engineer- smart grid engineer- energy consultant
- Pipeline engineer
- Pipeworker DHC system
- Pipeworker inside building
- Project coordinator
- Project manager

For the geothermal technician, pipeline engineer and the pipeworker inside buildings, no information contributing to the compilation of the framework was returned, which makes seven positions for making the framework.

Extra positions for which at least one full response is received are:

- Business manager
- Customer engagement/ sales
- Electrical engineer
- Expert approval procedures
- Financial specialist
- PV- specialist

For in total 13 positions the competence frameworks can then be made.
Translation and coding of the responses resulted in 328 KSAs and competences. In the surveys, there were separated questions for knowledge, skills and attitudes. Respondents appeared to mention knowledge, skills and attitudes interchangeably in the various questions. Some respondents mentioned KSAs multiple times in the various questions, sometimes in slightly different wording.
The KSAs and competences were coded into the terms of the ESCO database. The classification of KSAs in the framework and the required KSAs per position are discussed in section 3.7 of this chapter.

3.3 Description of levels per competence

According to Cedefop (2022), the level of a skill refers to the accuracy and speed with which a task is performed. However, much research on the level of skills and knowledge, however, is referred to the acquisition of the skills and learning processes for acquiring knowledge.
Cedefop refers to the five-stage model of skill acquisition of Dreyfus and Dreyfus (1980) as the model most commonly used to describe skill acquisition.
Dreyfus and Dreyfus developed a five-stage model of skill acquisition through training. According to this model, the student learns to acquire full proficiency over a skill in five stages. Successively, the stages are novice, competent, proficient, expert and master. In table 3, the five stage of skill acquisition and the mental activities per stage are given.

Table 3 Five stages of skill acquiring according to the Dreyfus and Dreyfus five-stage model of skill acquisition, adapted from (Dreyfus & Dreyfus, 1980)

Skill level	Novice	Competent	Proficient	Expert	Master
Mental function					
Recollection	Non- situational	Situational	Situational	Situational	Situational
Recognition	Decomposed	Decomposed	Holistic	Holistic	Holistic
Decision	Analytical	Analytical	Analytical	Intuitive	Intuitive
Awareness	Monitoring	Monitoring	Monitoring	Monitoring	Absorbed

In the progressive stages the recollection of the actions needed, range from non-situational in the novice stage to situational in the other stages. The recognition ranges from decomposed in the novice and competent stage to holistic in the other stages. Decision making ranges from analytical in the stages novice, competent and proficient to intuitive in the other two stages. The awareness of the skill is absorbed in the master stage and monitoring in the preceding stages.

Other models are used to describe the acquisition of knowledge. Webb's depth of knowledge describes the process of acquiring knowledge in four phases which are called levels by Webb (Webb, 2002).

- Level one is based on recalling and reproducing knowledge. Facts and definitions are known, simple procedures can be followed.
- Level two requires some mental processing that goes beyond habitual responses. Some decision making is required at this level.
- In level three, the cognitive demands are more complex and abstract. It requires strategic thinking, i.e., reasoning, planning, using evidence and explain their own thinking.
- In level four, the reasoning is very complex and the cognitive demands are very high.

Bloom's taxonomy is similar to Webb's depth of knowledge, but assumes six levels for the process of the acquisition of knowledge (Forehand, 2011). The levels of the acquisition according to Bloom's taxonomy is shown in table 4.

Table 4 Levels of the acquisition of knowledge according to Bloom's taxonomy, adapted from (Forehand, 2011)

Level		Examples
Level 1:	Remember	Recall and memorize
Level 2:	Understand	Organise in simple frameworks, illustrate obvious differences, summarize plot of simple story
Level 3:	Apply	Use a formula to solve a problem, select a design to meet a purpose
Level 4:	Analyse	Identify and explain
Level 5:	Evaluate	Judge, interpret and illustrate
Level 6:	Create	Put elements together and create a new pattern

The Dreyfus and Dreyfus model, levels of Webb's depth of knowledge and the levels of Bloom's taxonomy are useful to describe the required level of skills and knowledge. The levels can be used to indicate the degree to which automation of a skill should be present or the degree to which the practitioner should be able to use knowledge.

3.4 Levels according to the European Qualification Framework

The European Qualification Framework (EQF) is a European reference framework with which national education levels can be compared (Cedefop, 2022). The EQF can also be used to indicate a general level of work and thinking required to perform a job successfully.
The EQF consists of eight education levels, ranging from primary education to PhD. The characterisation of the levels that are applicable for 5GDHC project sites according to the EQF are:

- EQF level 3 is characterised by a repetitive application of most knowledge and skills. Tasks are carried out under direct supervision. Responsibility can be taken for completion of their own tasks.
- Practitioners performing on EQF level 4 can work independently on tasks and can apply their technical knowledge and skills in a broad context. The practitioners are able to use experience in common and exceptional situations and are able to solve problems. The routine work of others can be supervised.
- At EQF level 5 the practitioner can deal with complex situations and has experience in a wide range of professional situations. The practitioner has comprehensive and specialised knowledge about the field of study and has the skills that are required to solve abstract problems.
- At EQF level 6 the practitioner can work autonomous and can take responsibilities for the design, management, decision making and administration for unpredictable or complex work situations. The practitioner has advanced knowledge and the skills allow innovation to solve complex problems.
- At EQF level 7 the practitioner can manage work in contexts that require special strategies. The practitioner has highly specialised knowledge and specialised problem-solving skills. The practitioner can take responsibility for the strategic performance of teams.

The level of functioning for each position on the project was determined from the responses on the question in the survey about the main tasks to be performed by the job incumbents in the concerning position. These task descriptions were coded to the EQF descriptions as described above.
If the task descriptions lead to multiple EQF levels per position, the highest level is retained because this is the level at which practitioners should be able to function.

3.4.1 Levels per position

In table 5 the various tasks and responsibilities per position are described. For each task an EQF level is indicated. In the last column the overall EQF level for the position is indicated.
An unequivocal EQF level cannot be determined for every position from the job descriptions because the descriptions given by some respondents were not sufficient for this purpose.
The financial analyst, for example, gives a limited description of the tasks, but when asked what knowledge is required for the position, having an excellent knowledge of business administration is mentioned, which is in line with EQF level 6 or 7. That is why this has been assigned as an EQF level to the position of financial analyst.
The same goes for the technician DHC systems. No responsibilities other than assembly duties are mentioned, but competences for coordination and supervision tasks are named as KSAs in the survey. Level 4 of the EQF therefore seems to correspond the most.
The drilling engineer did not mention tasks other than resource planning, plant and staff. Since "manage staff" is mentioned, an EQF level 6 seems most obvious.
The sales engineer has tasks such as competent exchange with designers and architects, providing technical support, performing business analysis and negotiating contracts. The EQF level is difficult to determine from these descriptions, nor do responses to the other questions offer any clues. The most plausible is level 6.

Table 5 EQF levels per position

Position	Main tasks	Level	Overall Level
Business manager	• Collaborating and negotiating with stakeholders	7	7
	• Coordinating financial aspects of the project	7	
	• Responsible for the project as a whole	7	
Financial analyst	• Project control	6	6/7
	• Checking offers and invoices	-	
	• Calculating returns	-	
Regulatory, financial and legal affairs manager	• Reviewing assumptions made in terms of law and regulations, technical application and finance	6/7	6/7
	• Coordinating the quotation process between various departments	6	
	• Defining the starting points for the quotations	6	
Sales engineer	• Competent exchange with designers and architects	6	6
	• Providing technical support	-	
	• Performing business analysis	6	
	• Negotiating contracts	-	
Project manager	• Managing people	6	6
	• Communicating well	-	
	• Dealing with conflict	6	
	• Coordinating multiple disciplines	6	
	• Solving problems in engineering and construction	6	
Project coordinator	• Managing people	6	6
	• Communicating well	-	
	• Dealing with conflict	6	
	• Solving problems in engineering and construction	6	
Heating engineer	• Designing and specifying the installation of the 5GDHC system	5/6	5/6
	• Designing and specifying the installation of ventilation systems	5/6	
	• Maintaining contact with customers	5	
	• Acting as an advisor or expert on questions from both customers and subcontractors	6	
	• Coordinating implementation work	6	
	• Managing the team	6	
Geothermal engineer	• Design of the concept	6	7
	• Scientific approach to the project	7	
Drilling engineer	• Resource planning	6	6
	• Manage staff	6	
Electrical engineer	• Design and specification of electrical equipment	5/6	5/6
	• Performing electrical calculations	5/6	
	• Coordinating electrical connections with other disciplines	6	
PV design engineer	• Design of PV systems and wind turbines	5/6	5/6
	• Connecting the systems to the power grid	5/6	
	• Educate customers about energy consumption and energy saving measures	5	
Heat pump technician	• Assembling fittings and brackets	3	3
	• Doing pressure testing	3	
Technician DHC systems	• Assembling fittings and brackets	3	4
	• Doing pressure testing	3	

3.5 Criteria for compilation of a competence framework

There are multiple definitions of what a competence framework is and what criteria it should fulfil.
According to Lester (2014), a competence framework provides an overview of what competences professionals need to perform an occupational role. According to Delamare-Le Deist and Winterton (2005), a competence framework is a descriptive tool that identifies the skills, knowledge and personal characteristics and behaviours needed to effectively perform a role in the organisation and help the business meet its strategic objectives. A competence framework should enclose a combination of knowledge, skills and attitudes (Delamare Le Deist & Winterton, 2005).
Megahed (2018) uses the term competency model instead of competence framework. Megahed uses the definition "*a competency model are those competences that are required for satisfactory or exemplary job performance within the context of a person's job role, responsibilities and relationships within an organisation"* (Megahed, 2018, p.105). The competency model is built up by competences that are the predictors for successful performance on a certain job.
In literature about research to competences, there are two main perspectives on competence (Delamare Le Deist & Winterton, 2005; Lester, 2014; Winterton et al., 2006). The first perspective is the internal and attribute-based perspective on competencies. In this perspective, internal and individual properties of a person enables that person to act competently in a situation. This perspective is mainly the dominant perspective in the USA. The attribute-based perspective is effective for the development of training and education programs and for the assessment of potential. In the social, external and activity or outcome-based perspective, the behaviour what a person does to produce a competent result is described (Lester, 2014). There is more focus on actions that contribute to being able of reaching the result than on skills or attributes. The outcome-based perspective is mainly dominant in the UK and to an extend in Europe.
In the European Union, the competence frameworks follow the structure of the European Qualification Framework (EQF) and include skills, knowledge and activity-based competences (Lester, 2014). In the EQF, the definition of competence is "proven ability to use knowledge, skill and personal, social and/or methodological abilities to work or study situations and in professional and personal development."
Lester (2014) studied 40 competence frameworks. 35 of which were used for admission to a qualified or licensed status of a profession. All 40 competence frameworks were used in the UK. The study led to the following list of common practices in the compilation of competence frameworks:

- The majority of the frameworks had a hierarchical structure divided into areas which in turn were divided into sub areas and which in turn were divided into statements about competences. Typically, there were two or three levels of detail. 33 of the competence frameworks referred to a single professional level. When there were multiple levels present, the standards for each level were specified.
- 35 of the 40 competence frameworks were activity-based. 30 of the 40 competence frameworks had a section with general statements about profession principles. 3 of the 40 competence frameworks were based on the understanding and application of knowledge.
- Most competence frameworks were written in the third person in sentences like: "the professional must be able to" or "the professional must have knowledge of."
- Most competence frameworks provide descriptions of these competences, but do not provide "pass" points for when a competence is mastered.
- The content of the competence framework can be focussed on processes such as analysis or planning or can be focussed on specific areas of the profession such as knowledge about standards or technologies. Of the 35 activity-based competence frameworks of the research of Lester, all had profession specific components and 34 had also common factors as management, communication and the ability to identify and pursue opportunities for own personal and professional development as well as for others.

According to Megahed (2018) competence frameworks should consist of 12 core competences maximum; the competences should consist of measurable components and the definitions of each competence should be given. When multiple levels are applicable, an example for each level should be given. One should make sure that the competency model does not become a 'wish list' of competences for an outstanding performance (Megahed, 2018). Rather, the competences should describe competent job behaviour. The competences should therefore be described in behavioural terms. For each level behavioural descriptors should be defined. Also, the minimum level of acceptable performance should be described.

The following type of competences should be part of the competence framework (Megahed, 2018):

- The core competences are the ones that support the organisations in their values and missions. They apply for all jobs in the organisation.
- Technical competences or job specific competences apply to a job-role or job-family within an organisation. The technical competences outline the technical expertise and the scope of that skill and knowledge.
- General competences refer to a certain general role for certain jobs that apply across organisations, e.g., for management roles.
- Meta competences are competences that may be required for future roles, e.g., for the recruitment of so-called high potentials.
- Leadership competences are skills and knowledge that contribute to the performance on leadership roles.

One-dimensional frameworks focussing on only cognitive or behavioural components are inadequate (Delamare Le Deist & Winterton, 2005). Knowlegde, skills and attitudes should be included in the competence framework. Besides, both conceptual competences as well as operational competences should be included. Conceptual competences deal with cognitive abilities, knowledge and understanding. Operational competences deal with social competences as behaviours and attitudes.

In summary, the following points are important for selecting or compiling a competence framework:

- The competence framework should be built up from different types of competences. At least job specific competences should be included to cover the technical skills needed on the job and the general competences for covering basic social skills should be included in the framework. For some positions also leadership competences and meta competences will apply.
- Knowledge, skills and attitudes should be included in the framework.
- The competences in the framework should be defined in an activity-based manner, i.e, the behaviour the practitioner has to show has to be described.
- For all competences in the framework, a definition should be included.
- When performance levels apply, examples of behaviour for each level should be described.

3.6 Existing competence frameworks

There are many competence frameworks, but most are unofficial in the sense that they are developed by companies in order to train and select employees. In this research, only official frameworks, i.e. published or from official bodies and for similar technical occupations are taken into account.
The six frameworks that are compared in this research, are described in the following sections.

3.6.1 NEN-EN 16234-1: A common European Framework for ICT professionals in all sectors (e-CF)

One formal competence framework is standard “NEN-EN 16234-1: A common European Framework for ICT professionals in all sectors” or in short, the e-Competence Framework (e-CF) (Olde Hartman et al., 2015). The e-CF 40 contains competences that are required for jobs in information and communication technology (ICT) in all sectors. The aim is to improve the interchangeability of the competences in the ICT sector so the EU countries can obtain a better position in the world economy.
The NEN-EN 16234-1 has 4 dimensions. The first dimension consists of the 5 competence clusters. These five clusters are “plan”, “build”, “run”, “enable” and “manage”.
The second dimension consists of 40 competences that are divided over the 5 competence clusters. Each competence has a definition.
The third dimension consists of the five levels at which can be performed on each competence. The levels of the competence framework for ICT are comparable to the levels of the EQF. The relation to the levels is given in table 6.
The fourth dimension consists of examples of the knowledge and skill per competence. Attitude is not used in the competence definition in the NEN-EN 16234-1. The competence framework is expressed in multiple tables. One table shows the clusters with the competences and a level needed for each competence. For each competence there is a separate table with the definition of the competence and examples of performance for each of the levels.

Figure 3 shows the interpretation of the e-CF. For each of the 40 competences, also a table is made with a description of the competence, descriptions of behaviours that have to be shown for the levels, examples of knowledge that need to be mastered and skills that need to be performed for mastering the competence.

Table 6 Relation between the levels in the NEN-EN 16234-1 and the EQF

E-CF	EQF
Level 1	Level 3
Level 2	Level 4&5
Level 3	Level 6
Level 4	Level 7
Level 5	Level 8

Dimension 1 5 e-CF areas (A – E)	**Dimension 2** 40 e-Competences identified	**Dimension 3** e-Competence proficiency levels e-1 to e-5, related to EQF levels 3-8				
		e-1	e-2	e-3	e-4	e-5
A. PLAN	A.1. IS and Business Strategy Alignment				x	x
	A.2. Service Level Management			x	x	
	A.3. Business Plan Development			x	x	x
	A.4. Product/Service Planning		x	x	x	
	A.5. Architecture Design			x	x	x
	A.6. Application Design	x	x	x		
	A.7. Technology Trend Monitoring				x	x
	A.8. Sustainable Development			x	x	
	A.9. Innovating				x	x
B. BUILD	B.1. Application Development	x	x	x		
	B.2. Component Integration		x	x	x	
	B.3. Testing	x	x	x	x	
	B.4. Solution Deployment	x	x	x		
	B.5. Documentation Production	x	x	x		
	B.6. Systems Engineering			x	x	
C. RUN	C.1. User Support	x	x	x		
	C.2. Change Support		x	x		
	C.3. Service Delivery	x	x	x		
	C.4. Problem Management		x	x	x	
D. ENABLE	D.1. Information Security Strategy Development				x	x
	D.2. ICT Quality Strategy Development				x	x
	D.3. Education and Training Provision		x	x		
	D.4. Purchasing		x	x	x	
	D.5. Sales Proposal Development		x	x		
	D.6. Channel Management			x	x	
	D.7. Sales Management			x	x	x
	D.8. Contract Management		x	x	x	
	D.9. Personnel Development		x	x	x	
	D.10. Information and Knowledge Management			x	x	x
	D.11. Needs Identification			x	x	x
	D.12. Digital Marketing		x	x	x	
E. MANAGE	E.1. Forecast Development			x	x	
	E.2. Project and Portfolio Management		x	x	x	x
	E.3. Risk Management		x	x	x	
	E.4. Relationship Management			x	x	
	E.5. Process Improvement			x	x	
	E.6. ICT Quality Management		x	x	x	
	E.7. Business Change Management			x	x	x
	E.8. Information Security Management		x	x	x	
	E.9. IS Governance				x	x

Figure 3 The e-CF framework extracted from (Olde Hartman et al., 2015, p. 12)

3.6.2 Strategic framework for European skills, competences, qualifications and occupations (ESCO)

The strategic framework for European skills, competences, qualifications and occupations (ESCO) is a classification system that gives categories in skills, competences, qualifications and occupations that are relevant in the European Union (European Commission, n.d.-b). The classification system is available in 25 European languages. The ESCO classification consists of three pillars:

- The first pillar of the ESCO classification is that of the occupations. The occupations used in the ESCO classification are structured according to the International Standard Classification of Occupations (ISCO-08). The first four levels are derived from the ISCO-08. The fifth and, when relevant, further levels are provided by the ESCO classification. For each occupation the scope and content of the occupation are defined.
- The second ESCO pillar is the knowledge, skills and competences pillar and includes the knowledge, skills and competences. Knowledge is defined as "*the body of facts, principles, theories and practices that is related to a field of work or study. Knowledge is described as theoretical and/or factual, and is the outcome of the assimilation of information through learning"* (European Commission, n.d.-c). Skills are defined as "*the ability to apply knowledge and use know-how to complete tasks and solve problems. Skills are described as cognitive (involving the use of logical, intuitive and creative thinking) or practical (involving manual dexterity and the use of methods, materials, tools and instruments)"* (European Commission, n.d.-d). Competences are defined as "*the proven ability to use knowledge, skills and personal, social and/or methodological abilities in work or study situations, and in professional and personal development"* (European Commission, n.d.-a).
- The third pillar of ESCO is the qualification pillar. This pillar ensures that employers and other bodies have insight into and understanding of the individual qualifications that are needed. The information on the qualifications is now based on the National Qualification Frameworks of the EU member states.

In ESCO, 13,492 skills are described, each with a definition and a scope. Also, the type of skill is described. ESCO makes a distinction between skill/competence concepts and knowledge concepts. ESCO describes the reusability level of a skill. The four levels of skills reusability are given in table 7.

Table 7 Levels of reusability of skills according to the ESCO classifications. Adapted from (European Commission, n.d.-b)

Level of skill	Description
Transversal skills, knowledge and competences	Wide range of occupations and sectors
Cross-sector skills, knowledge and competences	Occupations across several economic sectors
Sector-specific skills, knowledge and competences	Specific for multiple occupations in one sector
Occupation-specific skills, knowledge and competences	For one occupation and its specialism

For each occupation, ESCO gives a description, a list of required and optional skills and a list of required and optional knowledge. The relationship between the occupations and skills, knowledge and competences is defined as essential when those skills, knowledge and competences are required for a successful employment in an occupation, independent of the work context or employer. When the skills, knowledge and competences are dependent on the working context or employer, they are defined as optional.
The ESCO classification does not indicate a level of competence, nor does it indicate a minimum level of education according to the EQF.

3.6.3 PROF/TRAC European Qualification Scheme

Research have been conducted on the skills needed for the design and construction of nearly zero energy buildings (NZEB). This has resulted in the PROF/TRAC European Qualification Scheme (IILPE & PP4, 2020). The PROF/TRAC European Qualification Scheme shows the competences that the employees need for the realisation of NZEBs. Competences are divided in categories, some examples are Energy Management and Energy production. The competences are represented in the rows, while the various positions are represented in the columns. For each position, the rows indicate which level of the relevant competence is required for each position.
The levels are different from those of the EQF, but they do correspond to each other. The skill levels range from 1 to 5, with level one being the lowest level and complying with the ability to communicate about a specific technology in general terms and level five being the highest level and complying with the ability of being able to be leading in the field of expertise. Level 1 corresponds to EQF level 4, the levels further increase up to level 5 which corresponds to EQF level 8. With starting at EQF level 4, the PROF/TRAC European Qualification Scheme is for higher educated functions in the construction sector.
Figure 4 shows the interpretation of the PROF/TRAC European Qualification Scheme.

	Work field	Architecture	Civil Engineering	Electrical Engineering	Mechanical Engineering	Building Management	Construction Management	Financing and Procurement
	Reference professions	Architect	Civil Engineer	Electrical Engineer	Mechanical Engineer	Facility Manager	Project Manager	Procurer
			Construction engineer	ICT engineer	Building automation eng.	technical energy engineer	Cost engineer	project developer
			structural engineer		Energy engineer	operator	Quality assurance	
	TECHNOLOGY, INTERDISCIPLINARY SKILLS AND PROFESSIONS							
EM	ENERGY MANAGEMENT							
EM1	Smart grid systems	2	1	5	3	3	2	1
EM2	Domotic systems	2	1	4	4	3	2	1
EM3	Building management systems	2	1	4	5	3	2	1
EP	ENERGY PRODUCTION (on-site and nearby renewable energy production and off-site renewable energy)							
EP1	Geothermal energy	2	2	3	4	2	2	1
EP2	Biomass	2	2	3	4	2	2	1
EP3	Biogass	2	2	3	4	2	2	1
EP4	District heating and cooling	2	2	3	4	2	2	1
EP5	Heatpumps	2	2	3	5	2	2	1
EP6	Solar power systems for electricity generation	3	3	5	4	2	2	1
EP7	Solar thermal systems for cooling generation	2	2	3	4	2	2	1
EP8	Solar thermal systems for domestic hot water and/or heating generation)	2	2	3	5	2	2	1
EP9	Mini wind power	3	3	4	3	2	2	1
EP10	Combined Heat and Power (CHP)	2	2	4	4	2	2	1
ER	ENERGY REDUCTION of construction							
ER1	Insulation	5	4	1	2	1	3	2
ER2	Air tightness building	5	4	1	2	1	3	2
ER3	Micro climates	4	3	1	2	1	3	2
ER4	Envelope systems	5	4	1	2	1	3	2
ER6	Window and/or glazing systems	4	4	1	2	1	3	2
ER	ENERGY REDUCTION of installations							
ER5	Hot water systems	3	2	3	4	2	3	2
ER7	Heating and cooling emission systems	3	2	3	5	2	3	2
ER8	Electric heating systems	3	2	4	4	2	3	2
ER9	Artificial lighting systems	3	2	5	3	2	3	2
ER10	Ventilation systems	3	2	3	5	2	3	2
IS	SUSTAINABLE INTEGRATED DESIGN							
IS5	Sustainable architectural design	5	4	3	3	2	2	2
IS6	Integrated design	5	4	4	4	3	3	3
IS7	Sustainable building materials	5	4	3	3	3	3	2
IS8	Sustainable installation materials	3	3	4	4	3	3	2
IS9	Environmental (indoor) quality	4	3	4	4	3	3	2
IS	INTERDISCIPLINARY SKILLS							
IS1	Communication	4	3	3	3	3	5	4
IS2	Information management	5	3	3	3	3	5	4
IS3	Collaboration	4	4	4	4	4	4	4
IS4	Quality assurance	4	3	3	3	3	4	3
IS10	Economics	4	3	3	3	3	5	4
IS11	Procurement	4	3	3	3	3	4	5

Figure 4 The PROF/TRAC European Qualification Scheme extracted from (IILPE & PP4, 2020, p. 14).

3.6.4 Professional competence framework for food science graduates

For graduates in food science, Weston et al. (2020) developed a competence framework. The main aim of the framework is raising the awareness of food science students of desirable skills and behaviours for their future roles.
In the competence framework, eight themes of desirable competences are identified. Also, 14 role types for graduated food scientists were identified. In the matrix of the framework, for each role desirable elements of competences are shown. Then, the elements are categorised in the eight competence themes named D1 until D8 and are placed in an order of relative importance for each role. The framework indicates how important a competence theme for a certain role is in relation to other roles in the framework. The darker blue colour of a competence theme means that for the role this the competence theme is more important than for other roles in the framework. For the white and light blue colour it means that the competence theme for that role is less important than for other roles in the framework.
In the competence framework for food science graduates, no competence levels are indicated.
The result is shown in figure 5.

Auditor (not based in a single factory)	Company Graduate Scheme	Customer Support Technologist	Factory Based Technologist	Laboratory Technician/Technologist	Law and Regulatory New Graduate Role	NPD, Development or Process Role	Nutritional Graduate Role	PhD or other Postgraduate Research Role	Research or Materials Technician/Technologist	Retail Technologist	Sensory Technologist Graduate Role	Specifications or Quality Systems Technologist	Sustain, Env, Ethical or Threat Management Roles
D4	D2	D8	D4	D7	D7	D6	D5	D3	D3	D2	D5	D3	D2
D5	D1	D5	D7	D1	D1	D8	D3	D6	D6	D4	D8	D7	D3
D1	D6	D3	D5	D2	D3	D5	D7	D4	D5	D8	D3	D2	D5
D7	D5	D1	D8	D5	D2	D7	D2	D1	D8	D1	D4	D1	D1
D3	D8	D4	D1	D8	D5	D2	D6	D2	D7	D6	D2	D5	D6
D8	D4	D7	D2	D3	D4	D1	D8	D7	D4	D7	D7	D8	D4
D2	D7	D2	D3	D6	D6	D3	D1	D8	D1	D5	D1	D4	D8
D6	D3	D6	D6	D4	D8	D4	D4	D5	D2	D3	D6	D6	D7

Figure 5 Competence framework for food science graduates extracted from (Weston et al., 2020, p. 21)

3.6.5 Competence framework for fire engineers

The competence framework for fire engineers consists of 12 categories as engineering, problem analysis, design development of solutions and the use of modern tools (Lange et al., 2022). The framework is presented in a table with a column the categories, a column for a short description of competences within the category, a column for the definition of the competences and a column with indicators for attainment of the competences.
The competences are activity-based and subdivided based on skills and knowledge. There is no use of levels for the different competences.

3.6.6 Competence framework for PV installers

The research carried out by Tsoutos et al. (2013) was mainly aimed at investigating the importance of appropriate training for PV installers. In the research a curriculum for training PV-installers was developed based on accreditation criteria established in the same study. During fieldwork in the research, the key tasks, attitudes and competences of the PV-installers were recorded. Customer satisfaction was measured using a survey. The ratings of the installer's skills are compared to the satisfaction of the customers. The result is a framework with six competences which are important for customer satisfaction.
Only technical competences are used in the framework.

3.6.7 Selection of a framework

Table 8 shows the extent to which the various frameworks meet the criteria set in section 3.5.

Table 8 Overview of how of the described frameworks meet the criteria. X means the framework complies with the criterium, 0 means the framework does not comply with the criterium

Criteria	Different types of competences	KSAs includes	Activity-based	Competences defined	Levels are applied
Framework					
NEN-EN 16234-1	X	X	X	X	X
ESCO	X	0	X	X	0
PROF/TRAC	X	0	X	0	X
Food science graduates	X	X	X	0	0
PV-installers	0	0	X	0	0
Fire engineers	X	X	X	X	0

The framework of the NEN-EN 16234-1 meets all criteria and will be used as a basis for the competence framework for the professional competences for the 5GDHC.

3.7 Competence framework for positions on 5GDHC project sites

3.7.1 Structure of the framework for 5GDHC competences.

The structure of the framework for the positions at the 5GDHC project sites is based on the structure of the NEN-EN 16234-1, the e-CF for ICT-professionals. To define the required knowledge, skills, and attitudes (KSAs), the ESCO database is used.
To provide structure to the framework, it is organized into four dimensions, each with its own code consisting of a letter and three digits separated by dots. The structure of the coding used in the framework is shown in figure 6.
The first dimension is the main area of competence, which is indicated by the first letter of the code. The framework for the 5GDHC project sites has 12 main areas of competence, with ten based on vocational competences, one on academic competences, and one on attitudes.
The second dimension provides further structure to the main area of competence of “Specific engineering expertise”, by subdividing it according to subject areas, e.g., drilling engineering, mechanical engineering etc.. This dimension is indicated by a number separated by a dot from the letter of the main area of competence. For the other main areas of competence, the first digit in the code is a zero as they have no subdivision into subject areas. This level is maintained to keep the same structure in coding for all main areas of competence.
The third dimension consists of 63 competences that are divided between the main areas of competence and the subject areas. The competences are listed in tables by position, with each item indicating how often it was mentioned in surveys. Some subject areas and main areas of competence have a "general" competence, which is a collection of general KSAs required within that area.
The competences are further divided into KSAs, with each KSA indicated by the last digit in the code. Appendices provide job descriptions, performance levels, and required KSAs and competences for each position. The order of the list is maintained in the appendices.
The framework and the appendices per position, are included in appendices 5 and 6.

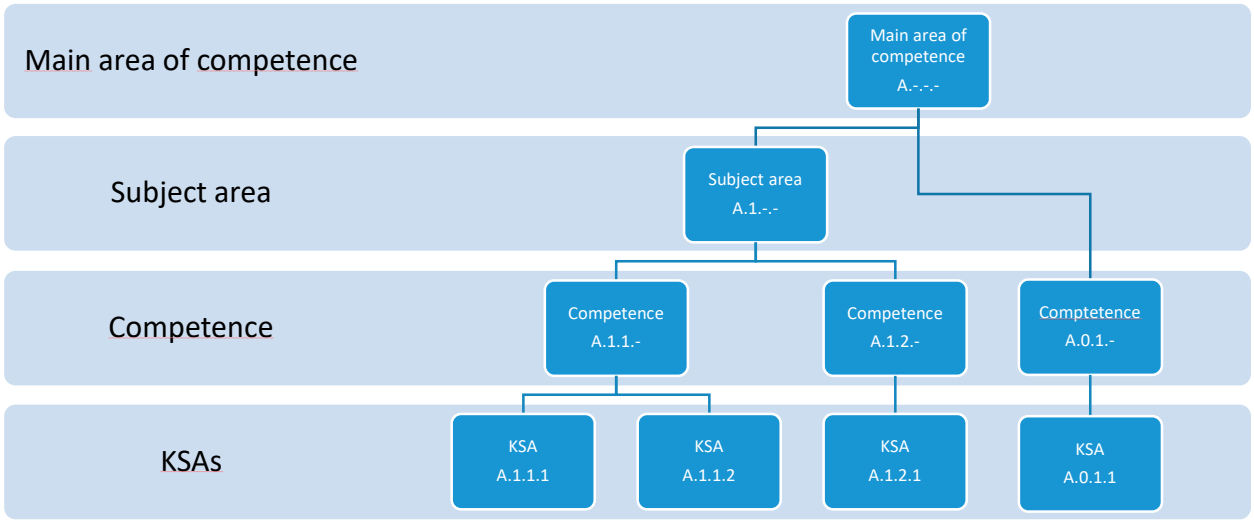

Figure 6 Structure of the competence framework for 5GHDC competences with examples for the codes

3.7.2 Competences per position

Multiple fully completed responses were received for the positions of project manager, project coordinator, heating engineer and PV design engineer. In table 9 is shown what competences are important for these positions. Competences and KSAs mentioned by multiple respondents of the same position are indicated here as important. For a complete overview of all competences and KSAs required by position, is referred to the framework included in appendices 5 and 6.

3.7.2.1 Project managers

A total of six project managers from four 5GDHC projects completed the survey in full. The survey responses resulted in a large list of desired competences.
Important competences identified for the project manager position include experience in the construction industry, knowledge of other disciplines present on the project, project management, and mastery of communication skills. Within the project management competence, different skills were highlighted by different respondents, including overseeing construction projects, leading a team, and monitoring parameters' compliance in construction projects.
Communication was mentioned as an important competence by all six respondents, with knowledge of communication techniques and dealing with stakeholders being highlighted. Knowledge of laws and regulations, particularly health and safety regulations, was also mentioned as important.
For work attitude, having a flexible attitude and thinking proactively were mentioned.

3.7.2.2 Project coordinators

The position for project coordinator is related to that of the project manager, with the difference that the project manager is responsible for more disciplines than just his own.
Only two completed surveys were returned for project coordinators, both from the same 5GHDC project. The focus of the listed KSAs is in the main areas of competence "Interpersonal/ communication competences" and "Leadership and management competences." The project coordinators describe fewer KSAs related to dealing with different parties involved in the project,m but emphasize the importance of communication. The project coordinators indicate less specific knowledge in their responses than the project managers, but they do request more practice-oriented knowledge for working on the projects. The project coordinators also emphasize the competence of managing health and safety.

Table 9 Important and less important competences for the positions with multiple responses in the survey

Position	Important competences/ KSAs	Less important competences/ KSAs
Project manager	• Having experience in the construction industry • Having knowledge of the other disciplines present on the project • Project management • Communication • Dealing with customers and stakeholders	• Specific 5GDHC knowledge- different topics • Health and safety regulations • Environmental legislation
Project coordinator	• Having knowledge of the other disciplines present on the project • Communication • Project management • Manage health and safety • Specific technical knowledge about ones discipline	• Building codes • PM software
Heating engineer	• Design of heating and cooling systems • Specific engineering knowledge of 5GDHC systems • Professional attitude	• Project management related KSAs • Advising • Work independently
PV design engineer	• Engineering processes • Reading engineering drawings • Renewable energy technology • Electrical engineering • Technical communication skills	• Costs • Advising • Professional attitude

3.7.2.3 Heating engineers

Four fully completed surveys for the position of heating engineer, from three different 5GDHC projects, were received. The heating engineers mentioned many KSAs falling into the main areas of competence of "Designing and Engineering Competences" and "Specific Engineering Expertise." While KSAs for all main areas of competences were mentioned by the respondents, many competences and KSAs are mentioned by no more than two respondents, with the exception of the main area of competence "Specific Engineering Expertise." Within this main area of competence, KSAs related to the design of heating and cooling systems and specific engineering knowledge of 5GDHC systems were frequently mentioned. The variety of KSAs requested is wide, and they can be divided into a large number of competences. KSAs for the competences of "professional attitude" and "work ethic" were mentioned by three respondents, with the exception of being able to work independently, which is mentioned by two respondents.

3.7.2.4 PV design engineers

The survey was completed in full by two PV design engineers working for the same 5GDHC project. The main areas of competence emphasized for this position are "Designing and Engineering Competences" and "Specific Engineering Expertise." The KSAs for "Designing and Engineering Competences" were indicated by both respondents and largely match those indicated by heating engineers.
The KSAs for "Specific Engineering Expertise" for PV design engineers focus mainly on "electrical engineering" and "Renewable energy technology". Both PV design engineers indicate that KSAs for providing information on energy saving measures and giving information about solar energy or wind energy, as well as mastering technical

communication skills, are important for "Interpersonal/ communication competences." For the other main areas of competence, only one of the two respondents named KSAs.

3.7.2.5 Other positions

Of all the remaining positions, only one fully completed response per position was received. Because the results and reporting should not be traceable to an individual, the results are not described in full detail. Also, because only one response per position was received, it cannot be determined which KSAs are important and which to a lesser extent.
The specific skills and competencies required vary widely depending on the position, but many positions require knowledge of financial and commercial aspects, as well as engineering principles and project management. Communication skills and the ability to work independently are common competences required across many positions.

3.7.3 Results per main area of competence

The importance of a main area of competence to work on a 5GDHC project site, depends on the type of position. For each area of competence, the specific knowledge, skills, and abilities (KSAs) required for various positions are identified. Table 10 shows an overview, indicating for each main area of competence for which positions it is most applicable, and for which positions it is less applicable. In addition, examples are given of which competences and KSAs are most applicable. For a complete overview of all competences and KSAs required by position, is referred to the framework included in appendices 5 and 6.
What the results of the survey in particular highlight, is that every position studied needs competences or KSAs for the main areas of competence ”Specific engineering expertise”, “Interpersonal/ communication competences” and “Attitudes”.
For main area of competence “Specific engineering expertise” this concerns mainly competences in the various subject areas that belong to the area of expertise of the position. For example, heating engineers mainly require competences in the subject area mechanical engineering, geothermal engineers mainly require competences in the subject area of geothermal engineering.
For main area of competence “Interpersonal/ communication competences” this concerns mainly the skills to work in a (multi-disciplinary) team, competences to deal with customers and having knowledge of communication techniques and being able to apply them.
For main area of competence “Attitudes” the ability to adapt to change stands out, as well as being able to work independently. Attitudes as demonstrating willingness to learn and demonstrating curiosity are also important.

Table 10 Overview, indicating for each main area of competence for which positions it is most applicable and for which positions it is less applicable and examples of which competences and KSAs are most applicable

Main area of competence and subject area (if applicable)	Most important for positions of:	Most important competences/ KSA(s):	Minor importance for positions of:	Most important competences/ KSA(s):
Designing and Engineering competences	Heating engineer PV design engineer	Whole engineering and design process and creating a design	Project manager Financial analyst Electrical engineer	Engineering processes Engineering principles Adjusting and approving designs
Reading and interpreting technical documentation and drawings	Electrical engineer Technician DHC Heat pump technician	Reading wiring diagrams Reading 2d and 3d plans Use technical resources	Heating engineer Regulatory, financial and commercial affairs manager	Reading engineering drawings Interpret technical requirements
Expertise from construction or having a technical background	Financial analyst Project manager Heating engineer	N.A.	N.A.	N.A.
knowledge of other project disciples than ones own	Project manager Project coordinator Electrical engineer	N.A.	N.A.	N.A.
Specific Engineering Expertise-Drilling engineering	Drilling engineer	General drilling engineering knowledge and skills	Geothermal engineer	Drilling technology
Specific Engineering Expertise-Electrical engineering	Electrical engineer PV design engineer	Designing electrical systems Knowledge of electricity and its design principles	Regulatory, financial and commercial affairs manager Project coordinator Sales engineer	General knowledge electrical engineering
Specific Engineering Expertise-Geothermal engineering	Geothermal engineer	General geothermal engineering knowledge and skills	Drilling engineer	Geology
Specific Engineering Expertise-Special 5GDHC	Heating engineer	Extensive knowledge about 5GDHC systems and design of 5GDHC systems	Project manager Sales engineer	General understanding of 5GDHC systems

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Main area of competence and subject area (if applicable)	Most important for positions of:	Most important competences/ KSA(s):	Minor importance for positions of:	Most important competences/ KSA(s):
Specific Engineering Expertise- Renewable energy technology	PV technician	Extensive knowledge of the design of solar and wind energy	Business manager Heating engineer Geothermal engineer	General knowledge of renewable energy technologies
Installation and project works	Technician DHC Heat pump technician	Installation, supervision and coordination work Taking care of supplies	Project coordinator Heating engineer PV technician	
Interpersonal/ communication competences	All positions Communication principles and techniques	Working in a team	N.A.	N.A.
Leadership and management competences	Project manager Project coordinator Business manager	Project management Leadership Make decisions Risk management	Heating engineer Drilling engineer Geothermal engineer Electrical engineer	Manage a team Monitor progress
Financial and commercial competences	Financial analyst Project manager Business manager	Extensive knowledge of financial principles Cost management Tendering procurement	Regulatory, financial and commercial affairs manager Sales engineer Heating engineer	Budgetary principles Control of expenses and budgets
Legal competences	Regulatory, financial and commercial affairs manager Project manager Business manager	Extensive knowledge of legislation applicable to 5GDHC systems Comply with regulations	Project coordinator Heating engineer	Knowledge of buildingcodes and product regulation codes
Health, quality and safety competences	Project coordinator Project manager	Ensure compliance with health and safety regulations	Electrical engineer PV design engieneer DHC technician	Electrical safety regulations Follow health and safety procedures

Main area of competence and subject area (if applicable)	Most important for positions of:	Most important competences/ KSA(s):	Minor importance for positions of:	Most important competences/ KSA(s):
Organisational capacity of the own work	Project manager	Helicopter view Work in organised manner	Heating engineer PV design engineer	Have computer literacy Use MS office and other software
Attitudes	All positions	Adapt to change Demonstrate willingness to learn Work independently	N.A.	N.A.

3.7.4 Special 5GDHC competences

In the survey, respondents were asked about specific knowledge and skills needed to work on 5GDHC systems. Respondents mentioned different 5GHDC skills. General knowledge about 5GDHC systems and gaining a holistic understanding of how the system should operate were mentioned for the project managers, heating engineers and sales engineers. More specific knowledge and skills varied among the different positions. For the positions of project manager, project coordinator, heating engineer and sales engineer, technical 5GDHC KSAs are mentioned in the subject area “Special 5GDHC” in the main area of competence “specific engineering expertise.”
In the overview in table 10, the need for competences in the subject area “Special 5GDHC” is given.
Heating engineers in particular mention many specific KSAs for the competence "special 5GDHC". Since they design the 5GDHC systems, that doesn't seem special. KSAs as knowledge of and the design of ambient water loops, knowledge of design temperatures, the design of the stations, maintenance of 5GDHC systems and legacy systems to which the 5GDHC systems have to be connected to, are mentioned. A few respondents from different positions mention technical 5GHDC skills as well. One of the project coordinators mention the sizing of plants and knowledge of spatial requirements.
Some of the project managers mentioned specific technical knowledge for working on 5GDHC systems, such as special knowledge of pipe construction, controls and design. The sales engineer indicates a need for knowledge of the legislation concerning 5GDHC.

Also, many KSAs mentioned were not specific for 5GDHC systems. Knowledge of renewable resources, understanding carbon-savings, understanding energy models, knowledge of geology, ground conditions and drilling and having a technical background or having experience in construction were mentioned multiple times. Many of the KSAs mentioned as special 5GDHC skill or knowledge, concerned non-technical KSAs, such as working in multidisciplinary teams, dealing with different parties, social interaction. Attitudes mentioned to be special for 5GDHC are willingness to learn, being open for new technologies and being able to adapt to change.

Few respondents did not answer the question about the specific knowledge and skills needed to work on 5GDHC systems, this concerns one of the PV design engineers, financial analyst and the DHC technicians. One of the project managers responded that no specials 5GHDC skills were needed as project management is a general skill. One of the project coordinators answered to this question that essential knowledge needed, is not unique.

4 Discussion

The aim of the research is to gain insight into the competences for 5GDHC practitioners in order to put together a curriculum for a training course for these workers. A variety of positions exists at the 5GDHC sites studied, each position requiring a different set of competences depending on the technical and social aspects of the position.
It was found that technical competences were important for the engineering positions, while project management competences were crucial for the supportive positions. Social competences, such as communication and teamwork were important for all positions, regardless of the technical nature of the position. These findings suggest that developing social competences that enable effective collaboration and communication within (multidisciplinary) teams should be in the curricula of training and education programs for 5GDHC practitioners.
The results of the research revealed that there are special competences for 5GDHC practitioners. Some technical competences were named mostly by the heating engineers, but also by project managers, project coordinators and the sales engineer. These competences concerned general knowledge and understanding, and many more specific competences, such as the design of ambient water loops and the stations.
Many competences that were named by the respondents as specific for 5GDHC, were competences that are already mentioned in the ESCO database and for those competences is referred to other occupations for which the competences are essential as well. These competences are essential for 5GDHC practitioners, but they are not unique 5GDHC competences. These competences cover a wide range, from working in teams and deal with third parties and stakeholders to being able to learn, show interest in renewable resources and being able to adapt to change.
The research also showed that competences required for different positions vary significantly across the studied 5GDHC sites. The different stages of development of the projects and the technical differences in the design of the systems can cause these variations. These variations should be taken into account in the training and education programs for 5GDHC practitioners.

4.1 Validity of the research

In this study, surveys among 5GHDC practitioners were used to determine which positions are present at the 5GDHC pilot sites of the D2Grids project, and which competences practitioners at these 5GDHC sites have to be able to perform their construction tasks. A purposive sampling method was used in which the participants were selected (instead of randomly assigned) to ensure that the participants have relevant experience and knowledge on the topic. The sample size is limited, which can limit the generalizability of the finding of this study.
A total of 24 fully completed responses were received. For nine of the 13 positions surveyed, one fully completed response per position was received. For two of the positions, two fully completed responses were received. As a result, outcomes can be influenced by the personal perception of the respondents. The qualitative research design affects the validity of this research because of the subjectivity of the responses of the participants, especially when only one or two respondents per position completed the survey. The credibility and dependability of the findings are ensured by a rigorous approach in the collection and the analysis of the data.
The EQF levels were assigned based on the descriptions of the respondents' tasks. It was assumed that the respondents' task descriptions were complete. In the case of multiple respondents per position, it is expected that a more complete picture emerged than for the positions for which one response was received.

4.2 Limitations of the research

4.2.1 Positions

There are a number of explanations why the first survey did not find all positions present at all 5GDHC project sites. The six positions found at all five sites involve positions that may be applicable to each project. In every project, the heat grid will have to be constructed for which the technicians DHC loops or pipeworkers will be required. Also, every project will have to be managed and is cost and schedule driven, which is why project managers and project coordinators are present at every 5GDHC project site. Differences in the topology of the grids and how seasonal storage is arranged in the grids may explain why, for example, the geothermal engineer and the drilling engineer are not present on every project. In addition, local conditions may vary from one 5GDHC project site to another. The use of groundwater could explain the presence of a hydrologist at only two 5GDHC

project sites. The presence of the intelligent management system at Paris-Saclay could explain the presence of a data analyst.
Another explanation could be that each project is at a different stage of development. A project in the concept phase may require a different type of positions than when a project is in the implementation phase. In the conceptual phase, financial viability may be important which explains, for example, that Plymouth, where the project is in the concept phase at the time of the study, employs a financial analyst. Other projects are already in the construction phase or partially completed. This could explain why in Glasgow, a site where part of the construction is ready, there is an operations and maintenance engineer.
It is also notable that in the second survey, responses were received for positions that were not found in the first survey. It can be caused by the human factor, respondents might forget some positions, or the job title of the respondent was different than was indicated in the first survey. The first survey was filled in by the contact persons of the sites and not by the job incumbents that responded on the second survey. In the first survey, for example, “building construction” was given as answer. This might be the architect that responded to the second survey. Also, in the first survey “financial manager” was given as answer, while that might be the business manager that responded on the second survey.
In follow-up research, a more complete picture of the positions needs to be made. This could be done by having several respondents per 5GDHC project site complete the inventory for positions, sending the inventory also to contact persons of all subcontractors or by organising a group discussion in which several persons holding key positions at the 5GDHC project sites brainstorm about positions.

4.2.2 Number of responses

For the second survey, 24 fully completed responses were received across the five 5GDHC project sites. From some sites, like Paris-Saclay and Brunssum, only a few responses were received, from others like Bochum slightly more. There are a number of explanations for the low number of fully completed responses. The first lies in the way respondents were approached. Due to privacy regulations, it was not possible to approach potential respondents directly. Instead, the link to the survey was sent to the D2Grids contact person at the 5GDHC project sites, this contact person was then asked to distribute this link to practitioners at the relevant 5GDHC project site. The link was also to be sent to subcontractors who should further disseminate the link themselves to their practitioners performing work at the 5GDHC project sites. The researcher has no insight into to what extent the link reached all practitioners at the 5GDHC project sites, the subcontractors and their practitioners.
The second explanation for the low number of respondents may have to do with the time when the surveys were sent out. The surveys were sent out in July and August 2022. This is the summer holiday period. Many potential respondents will have been on holiday. In most cases, practitioners had four weeks to complete the survey so they also had an opportunity to do so before or after holidays. It is possible that due to prioritising other work, practitioners chose not to complete the survey, despite the fact that the importance of completing the survey was emphasised in the introduction letter.
Of the 51 respondents who opened the survey, only 24 completed it completely. A (partial) explanation for this could be that the online survey tool used (Limesurvey) already lists the total number of questions in the survey on the first page of the survey. In this case, it was 28 questions. But because the questions are selected based on the position checked, respondents only had to answer a maximum of 10 questions; the remaining questions were not relevant to their position. It is possible that the large number of questions suggested at the beginning of the survey discouraged some respondents from completing the survey. The indication of the total number of questions in Limesurvey could not be adjusted.
One group of respondents did consent to the processing of responses, did fill in the 5GDHC project location and their position and then stopped filling in. After filling in the 5GDHC project location and position, the open-ended questions are displayed with ten answer options per question. This may have discouraged the respondents from completing the survey.
A final explanation for the dropout of the group of respondents is that they didn’t agree to let their answers be used even though the survey didn’t ask for personal information. The reason for this cannot be traced. The participation is anonymous, and therefore, the respondents cannot be contacted based on their answers.
Finally, there was a notable response from the 5GDHC project site Paris-Saclay. Here it was stated that they could not forward the link to the subcontractors because completing the survey was not part of the sub-contractor’s contractual obligations. Two responses were received from Paris-Saclay, of which one was fully completed.

To get more respondents to complete the competence survey in follow-up research, it will be necessary to identify which practitioners and which subcontractor practitioners are in which positions at the 5GDHC project sites.
It would then be necessary to monitor whether the link for the survey about the competences reaches the right people. When it is known how many practitioners per position are present at the 5GDHC project sites, it is also possible to monitor how many surveys per position are completed and the relevant group of practitioners could also be more specifically requested to complete the survey.
To get more fully completed responses, the survey will have to be sent out outside the holiday period, so that more practitioners are present. Also, managers will have to plan dedicated time for the practitioners to fill in the survey.
To discourage fewer respondents, the introduction letter can be adapted. Besides stressing the importance of completing the survey, the maximum number of questions respondents will be asked can also be mentioned and it can be emphasised that the survey does not collect personal data that will be stored.
In order not to discourage respondents after they have started, it is recommended to make fewer open questions visible at once or to stop using open questions.

4.2.3 Competence levels

Determining the levels per competence was not possible on the basis of the questionnaire. To measure levels, definitions of the level per competence must be established, and respondents must be able to determine the desired level. The question is whether determining the level per competence can be done by the respondent himself. Therefore, determining the level should be done in a different research design not using a survey filled in by job incumbents.
A possibility for follow-up research is to ask experts on the competences concerned to advise about the levels of competence. The experts can say what levels KSAs per competence are typical per level and can say at what level the practitioners need to perform in their position.

4.2.4 Competence frameworks

For this research, six competence frameworks for positions with competences that were assumed to be similar to those for practitioners at the 5GDHC project sites were compared, but the list will not be complete and another framework that is not part of this research, might be a better fit for the purpose.

4.2.5 5GDHC competence framework

The aim of the second survey was to gain insight in the competences practitioners need on the 5GHDC project sites. The survey consisted of two parts, the first were the open-ended questions concerning the job advert model and the second part consisted of a list of skills and knowledge that may be required for the relevant position. Because in the survey the correct type of question was not used, the data of the responses on the list was not stored. The intention was to use the list of competences to indicate the importance of KSAs by the respondents. Due to the absence of this data, it cannot be used to determine the importance of the competences for fulfilling the job.
The definitions of competences and KSAs were taken from the ESCO database. The competences involving specific knowledge and skills for 5GDHC were not included in the database. The competences were defined by the researcher, using existing ESCO competences where possible. Some competences and KSAs have been defined by the respondents themselves. In both cases, agreement will have to be reached on the correct definitions of the competences and KSAs, as the definition of the competences or KSAs can affect the content of the curriculum of the training. Also, reaching agreement is important to increase willingness to work with the framework.
The same goes for the classification of the KSAs into competences and the division of the competences into main areas of competence and subject areas. In part, the classification from the ESCO database was followed, but following it too closely would have led to many more areas of competence. Then, as a consequence, most areas of competence would contain only one or two competences.
The requested KSAs for the positions for which there were multiple respondents present a very diverse picture. This may be due to different requirements for each 5GDHC project site due to differences in the design of the 5GDHC system.
For follow-up research, an inventory will have to be made of which competences are indispensable for holding the various positions and which are of less importance. To begin with, this would require several respondents per position to fill in the survey, but with the competences and KSAs that this yields, expert opinion should be sought.

In this case, experts could be people who have been involved in the realisation of 5GDHC systems from the beginning. These experts could be asked to participate in a focus group discussion or to participate in research that uses the Delphi technique to reach consensus on the importance of the various competences and KSAs.
Second, the framework itself will have to be refined by reviewing the classification of the competences into the main areas of competence and by improving the definitions of the competences not included in the ESCO database. Again, experts can be asked to participate in a focus group discussion or the Delphi technique can be used.

4.3 Follow-up research in a different research design

Follow-up research will have to focus in particular on making the framework robust. Suggestions for improvements in follow-up research using the same kind of research designs, were mentioned in the section concerning the limitations of the research.
A different method of the inventory of the competences needed by practitioners is given by Goldstein and Ford, (2002). Their method is specifically designed to create training programs for working professionals. During the needs assessment phase is determined what KSAs need to be taught in the training.
The needs assessment phase starts with a task analysis. The aim is to get a full set of tasks the practitioners have to perform. To this end, the job of the practitioners are broken down into a list of tasks. Several methods can be used. The practitioners can be observed and the researcher describes all their activities during a certain period. The period depends on the extent to how often activities occur in the work. Or, practitioners can be asked to participate in surveys or interviews, but the focus is on making clear what tasks the practitioners have to perform.
The second step in the needs assessment is to cluster the tasks in major groups or task clusters. Proposed by Goldstein and Ford (2002) is to make a list of task clusters first. Each task cluster has to be defined. Then a group of subject matter experts (SMEs) are asked to group all individual tasks into the clusters.
Third, for each task cluster KSAs that are relevant for fulfilling the tasks are determined. To this end, SMEs are asked to describe concrete examples of good and poor performance on the task cluster. The SMEs are also asked to describe what KSAs are needed for a good performance on each task cluster and what they expect that people learn in the new training.
Fourth, for each task cluster is determined how important the cluster itself and the KSAs are for effective performance on the job. Usually a survey is used in which SMEs can indicate on a scale how important each task cluster is.
The result of the needs assessment phase is a list of KSAs that are needed for a good performance on the job. The list is used as input for the development of the training.

5 Conclusion

This study aimed to determine the knowledge and skills required for different positions and vocational levels to work on 5GDHC systems in order to give input for a curriculum for a training. The first central research question was “What knowledge and skills are needed by position and vocational level to work on the 5GDHC systems as a practitioner.” The study found that a variety of positions exist at these project sites, with varying knowledge and skills requirements. The study identified the types of competences that are particularly important for practitioners in different positions, such as technical competences for engineering positions and project management competences for supportive positions. Several special 5GHDC competences were found. KSAs that concern knowledge and understanding of the 5GDHC system in general were found for four of the 13 studied positions. The study also determined the EQF level for each position.

The second central research question was “How can a competence framework be compiled that describes knowledge and skills needed to work on 5GDHC systems”, focussing on criteria for the compilation of a competence framework that describes skills and knowledge needed to work on 5GDHC systems and the compiling the competence framework for 5GDHC competences. From the research on criteria for compiling a competence framework and a comparison of similar frameworks, a framework based on the NEN-EN 16234-1, e-CF for ICT professionals, was developed.

The study resulted in a comprehensive list of competences, knowledge, skills, and attitudes required for 13 different positions at 5GDHC project sites, which can be used to develop training and education programs for 5GDHC practitioners. No direct measures of levels of knowledge or skills were found. However, methods describing levels in the acquisition of skills and knowledge have been found. The EQF level per position was determined based on the description of tasks and varies per position. EQF levels range from 3 for technicians to 7 for geothermal engineer and business manager. The study also found, that technical and social competences are both important for fulfilling these positions, and that the importance of specific knowledge and skills varies depending on the type of position.

With the research results, it cannot be determined whether different competences are needed to fill positions at 5GDHC project sites located in the five different countries. There are too few respondents in the study to draw valid conclusions about the competences required to successfully hold positions in the different countries. Further research is needed to determine specific competences required for each county.

In the research, it was possible to compile a competence framework for positions at 5GDHC project sites in which the competencies required to work with 5GDHC systems are included. On the basis of this competence framework, it appears that, special 5GHDC competences do exist and that in addition to technical competences, social competences such as communication skills and working in a team that are not unique for 5GDHC, are also important. The extent to which social competences are important, depends on the position, but apply to almost all positions to at least some extent. For a number of positions, dealing with stakeholders is especially important. Curricula should include social competences related to dealing with stakeholders and collaboration.

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