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Identifying the skills requirements related to industrial symbiosis and energy efficiency for the European process industry

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Abstract

The need for sustainable production, efficient use of resources, energy efficiency and reduction in CO_2 emission are currently the main drivers that are transforming the European process industry besides Industry 4.0. Since the potential of industrial symbiosis (IS) and energy efficiency (EE) about environmental, economic and social issues has been discovered, the interest in them is gradually increasing. The funding and investments for IS and EE are highly encouraged by the European Commission, while more and more policies as well as research and innovation (R&I) activities are initiated to promote European industry's advancement towards a circular economy and CO_2 neutrality. The aim is to maintain the competitiveness and economic progress of the industry. The key to build a competitive and sustainable European manufacturing industry is to create a competent, highly qualified workforce that is capable of handling the new business models coming with IS and EE requirements and digital technologies. We can generate this by identifying the skills needs and upskilling and reskilling the current workforce accordingly by delivering the suitable training programmes. Therefore, this work identifies the most critical skills needs related to IS and EE for six different energy-intensive sectors (steel, ceramic, water, cement, chemical and minerals) in Europe. The effect of the digital transformation on the skills needs is as well discussed. The identified skills are aimed to be included in vocational education and training (VET), tertiary education and other kinds of training curricula. We also identify the cross-sectoral most representative job profiles linked with EE and IS in these sectors and demonstrate the methodology for the selection process. Furthermore, we present a key tool for identifying the most significant current and future skills requirements. Also, we define the critical skill gaps of the European process industry using this tool. Once the skill gaps are defined, they can be reduced by delivering well-developed continuous trainings. We also link our work to the respectable ESCO, the European Classification of skills, competences, qualifications and occupations, to attain a common ground with other studies and frameworks, minimise the complexity and contribute to their work. Our work is developed to be an academic and industrial guideline to prepare well-developed training programmes to deliver the needed skills.

Keywords Skills, Workforce, Sustainability, Circular economy, Industrial symbiosis, Energy efficiency, Process industry, Energy-intensive sectors

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Introduction

The industry world is currently in the search of ideas for enabling an efficient use of the resources and reducing the levels of the CO2 emission, while preserving their economic growth and competitiveness. Therefore, not only companies but also policy-makers are progressively incorporating sustainability concerns in their strategies and agendas. These strategies principally focus on developing circular economy and industrial symbiosis, handling the efficient use of energy and other resources, improving sustainability and enhancing employees' safety.

Subsequently, in recent years, the general interest in industrial symbiosis (IS) and energy efficiency (EE) has considerably increased by acknowledging their potential with regard to not only its environmental and economic but also social prospects [1]. To achieve a considerable shift towards a circular economy and CO_2 neutrality in the European industry, more and more innovative research activities are carried out, while the funding and investments for IS and EE are growingly strengthened by the European Commission [2].

The synergy between the industrial companies and the environment is critical for the performance of the industry [3–5]. Since the manufacturing activities have a significant influence on every element of a sustainable (environmental, social, institutional and economic) development, the pressure on industrial enterprises has been gradually growing due to environmental consequences [6].

Moreover, the extraordinary increase in industrial activities and forthcoming consumer societies has resulted in growing waste generation, environmental emissions and landfills [7–10]. It is not possible to fulfil the demand for ascending economic and statistical growth under these circumstances [6, 7, 11].

Under these circumstances, environmental contamination has become a serious threat besides the worldwide resource scarcity [4, 12]. The European Commission (EUCOM) acknowledged its objective of accomplishing a greenhouse neutral Europe by the year 2050, acting as a cutting edge organisation in the battle against climate change and taking a crucial step forward dealing with the environmental problems [5, 7, 13]. EU countries have already made an exemplary sacrifice through promoting the climate-neural economy proactively instead of performing an adaptive reduction, to compliance with the commitments declared in the Paris Agreement [9]. In addition, the industrial sectors, especially energy-intensive industries, are expected to follow the climate neutrality roadmaps that are defined by the EU Industrial Strategy [14]. These roadmaps are linked with zero-carbon technologies, with the Industrial Ecosystems—a concept introduced by the Strategy, that encompass all players operating in a value chain-, besides the expected introduction of norms, quotas and standards for zero-carbon materials (especially chemicals, steel and cement). Moreover, the EU Industrial Strategy states that one of the main drivers for the industrial decarbonisation will be leading a shift from linear production to a circular economy [14].

The manufacturing sectors are also seeking innovative solutions related to renewable energy sources and modification of the company activities to guarantee that the operations are carried out considering energy efficiency [15, 16]. The growing adoption of energy-efficient technologies and renewable energy sources is a commonly observed trend in the industrial sectors, especially in energy-intensive industries [17]. It supports both the climate transition and sustainable development [17].

Consequently, apart from the daily activities, the industry is handling the pressures of the price volatility of resources, risks related to resource supplies and environmental legislation [7]. The development and implementation of digital technologies in industry is a crucial element for overcoming the challenges as well as for accelerating the shift to sustainable and energy-efficient manufacturing industry in Europe [16, 18].

Therefore, if the purpose of Industry 4.0 is comprehended accurately and the latest technological advances are implemented correctly, these technological innovations can be used as an efficient tool for the completion of circularity and material and energy efficiency. In other words, the digital transformation of the industries not only enables increased productivity, but also presents enormous opportunities for the fulfilment of a resource-saving, sustainable manufacturing and energy efficiency.

As a result, the new era of digitalisation (Industry 4.0) and the adaption of sustainability and energy efficiency in European industry caused the use of the term "twin transition". The European Union is counting the so-called "twin transition", since it will be the key for implementing a circular development strategy and decarbonising the economy, turning Europe to boost its innovation capacity, competitiveness and the industrial chain value [18–20].

As a proof of the aims of the EU about this subject, *The European Green Deal* is provided as a roadmap by the EU for making the EU's economy sustainable by boosting the efficient consumption of resources by shifting to a circular, clean economy, avoid climate change and reduce pollution. It not only highlights the needed investments, available financing instruments, but also clarifies how to assure an inclusive transformation. It aims to dissociate economic development from resource use by the year 2050, keep the materials and products in use for longer time and support the regeneration of ecosystems [21]. It underlines how the technological developments introduced by Industry 4.0 are going to accelerate the transition towards the circular economy (CE) and achieve the European Green Deal done in many areas—from social innovation to waste recovery [18]. In addition, initiatives—such as the Sustainable Products Initiative—aim to make all products placed in the EU market more enduring, energy efficient and available for reusing, repairing and recycling. These initiatives are expected to target industrial sectors in general.

As a result, technological developments urging with digitalisation as well as growing energy costs and newly developed strict policies about circular economy and sustainability will transform job profiles of the energy-intensive industries. Thus, they will result in the demand for new skills in the workforce and are presumably to speed up the shifts in skill needs in comparison to the real trend.

Accordingly, in addition to Industry 4.0 and sustainability, (raw) material scarcity and energy costs are emerging as the most dominant factors shaping the evolution of skills demanded by the energy-intensive industries [10, 22].

A highly qualified labour force that is capable of managing the implementation of new business models compatible with IS and EE and technological developments is the major key condition to create a competitive and sustainable (circular) manufacturing industry in Europe. This competent workforce can only be obtained on time through foreseeing and addressing the future skill demands and updating the existing qualifications or creating new ones. By this way, it will be possible to provide the identified skills to the current labour force by upskilling and reskilling activities.

There are countless benefits of digitalisation for the realisation of sustainable production. Therefore, to respond to new skills demands and achieve a workforce proficient in IS and EE, a holistic approach should be adopted for the workforce reskilling and upskilling. This approach should consider not only the IS and EE requirements but also the technological developments and transformations in the industry and their effect on the skills demands of the future workforce [23]. In this work, the same all-embracing approach was developed to define the skills that will be in demand in the future and identify the skill gap between nowadays and future.

Our work consists of the studies carried out in the SPIRE-SAIS-Skills Alliance for Industrial Symbiosis (SAIS)—A Cross-sectoral Blueprint for a Sustainable Process Industry (SPIRE)—project. The project gathers stakeholders from different backgrounds including industrial companies and associations, training and education providers, research institutions, regional companies and organisations to empower and speed up the adoption of industrial symbiosis (IS) and energy efficiency (EE) by establishing an inclusive cross-sectorial blueprint regarding skills [23].

This work is developed to be an academic and industrial guideline for the training providers to develop appropriate training programmes with high level of quality to provide the required skills.

Therefore, considering the future technological developments for implementation of IS and EE solutions and skills development concepts stated in other recent and respectable sources and portfolio review of the projects related to industrial symbiosis by European Commission, examining studies published by several book chapters and scientific articles, this document identifies and specifies the new skills and training needs within the process industry, taking a framework of increasing environmental constraints and energy costs into account. The effect of the digital transformation on the skills requirements is as well analysed. In other words, the work focuses mainly on the alterations in the skill needs of the selected energy-intensive sectors that are expected in the future. The identified skills are aimed to be included in the vocational education and training (VET) and tertiary education curricula, after clarifying the recent and future skill requirements and redefining the cross-sectoral job profiles [23].

We also present a methodology—job profile description—to define the gap between the current and future skills needs and identify and overview the most significant skills gaps clearly. To this end, we identified and redefined the job profiles related to IS and EE in these sectors. We not only defined the most relevant skills requirements related to IS and EE, but also the skills gaps between today and future. These identified skills gaps can be reduced by delivering well-developed continuous trainings. In terms of capacity building, both IS and EE, including their benefits and potential, are required to be incorporated in the education programmes of business and engineering students to guarantee the presence of an adequate skill base [2, 23].

The work also provides ideas and hints from diverse points of view to handle the recent skill needs and to meet the skill demands that are expected in the future, resulting from the implementation of IS and EE and digitalisation. Our work also offers support about the organisational change processes related to the adoption of EE and IS in daily work and digitalisation. It also demonstrates how the relevant departments of a company (such as Human Resources, etc.), training providers, training developers, etc. can benefit from the developed job profiles during the career development processes such as assessment and curricula design. Additionally, this work provides a concise guidance on linking the generated job profiles with the respectable frameworks such as ESCO.

Industry skills requirements related to IS and EE

Industrial symbiosis together with energy efficiency are two main goals for energy-intensive industries (EII) towards higher environmental sustainability.

In this chapter, we explain “industrial symbiosis” and “energy efficiency” concepts as well as analyse the recent skills needs related to these two concepts. Then, we examine and determine how digitalisation affects the skills needs. The skills selection process in the methodology section is performed by analysing the factors identified in this chapter.

The definition of "Industrial symbiosis (IS)" pertains to the utilisation of underutilised resources, such as energy, waste, materials, residues, water, logistics, equipment and by-products, from one company or sector to another, resulting in extended usage of resources for productive purposes. This approach enables the companies to derive mutual benefits from these resources for a longer period [24]. The main goal of IS is to increase in production while saving resources and energy, thanks to the collaboration of companies which utilise by-products or waste from other enterprises [25, 26].

In an industrial context, “energy efficiency” refers to using less energy to carry out the same tasks needed to provide products and services [27–29]. It means more efficient and moderate use of energy—which eliminates energy waste resulting in in a wide range of benefits: cutting down greenhouse gas emissions, minimising the consumption of natural resources including oil, coal, biomass, etc., reducing the need for energy imports and decreasing costs on an economy-wide level [23, 27, 28].

The skills related to IS and EE are a wide-ranging skills classification and, at the same time, it involves the skills in different categories: technology, regulatory, business and interpersonal. The significance of skills falling under this category can be attributed to the commitments made by industrial stakeholders in Europe to achieve the environmental, energy and climate targets set for 2050 by the EU. As companies in various sectors increasingly prioritise efficient resource utilisation and industrial symbiosis and energy efficiency, there is a growing expectation that the skills directly connected with IS and EE will become even more important in the coming decade.

Public actors will play a crucial role in providing guidance and organising skill development and training activities. To effectively incorporate the skills development in this category, they should be integrated into the broader training and skills development policies rather than being considered as an additional or separate category.

Skills needed for industrial symbiosis

In presented industrial symbiosis cases and in industrial symbiosis projects, the need for establishing new jobs is evident or apparently anticipated. For presented cases, the main drivers for the IS implementation as well as for the creation of new jobs are improvement of sustainability of operations, growth of the involved businesses involved and new business development [2].

During the development of new technologies for future implementation in IS, the research and innovation operations themselves create additional activities and employment [2].

Implementation of IS certainly creates new jobs for a neutral and independent party. A potential new job necessary for IS will be linked to the specific requirements and skills (technical, regulatory, business related, etc.). Moreover, taking the significance of the local and regional background into account for building the necessary collaboration, many entities would cultivate in different European countries and regions [2]. Boosting the competitiveness of the companies and entities is another significant advantage of IS, which allows the newly created jobs to be retained in Europe which is of crucial importance [2].

Most of the stakeholders involved in IS implementation rely on a multidisciplinary and complementary team [30–33]. Therefore, first, skills regarding *knowledge* are of importance, meaning awareness, familiarity, or understanding of objects, situations, science, techniques, as well as theoretical frameworks and methodologies gained through field experience or study. Here, being knowledgeable about systems thinking were among the most needed skills. [30] Systems thinking is a valuable skill that allows individuals to analyse complex systems and identify the interrelationships between different components. It involves considering the larger context and understanding how various parts of a system work together to achieve a desired outcome. Owning a basic understanding of IS and EE, but also understanding environmental regulations, resource properties and waste processing technologies are highlighted as critically needed as well [30, 31]. Facilitators should be familiar with EU, national and regional regulations, legislation and policy on waste management and circular economy to develop regulatory compliance, and, consequently, to lead the project in the right direction [32]. They must be able to understand the ramifications of legislative changes, ideas and processes at national and international levels [30]. Having knowledge about multidisciplinary areas such as economics, commercial, circular economy and business culture will gain importance [2, 30–32]. In addition, the facilitator must be able Eco-design and Life Cycle Thinking skills [31].

An IS facilitator is expected to have social and interpersonal skills. These skills are crucial for individuals who need to interact and communicate effectively with others in a variety of settings, both verbal and nonverbal. Having the right attitude and the ability to deal correctly with industry matters is important as it can help individuals establish trust and build relationships with colleagues, clients and stakeholders. Being able to speak different lingos or industry-specific jargon can help individuals communicate more effectively with others in their field and can also demonstrate expertise and credibility [30–32].

Encouraging collective decisions are not only based on the IS facilitator's technical knowledge, but also based on every stakeholder's input [31]. Collaboration, networking and negotiation, skills are very crucial since being as a team player and acting a bridge between different stakeholders are the new roles of an IS facilitator. Moreover, developing strong stakeholder management skills through the mentioned skills can help IS facilitators establish and maintain strong relationships among companies, local institutions and public bodies [32]. It can also help ensure that projects and initiatives are successful and sustainable, as stakeholders are more likely to support and contribute to activities that they feel are aligned with their interests and priorities**.**

Other crucial are interpersonal skills are having a systematic, multidisciplinary and complementary thinking and developing an entrepreneurship mindset, problem-solving, dealing with detail, change and time effectively [30–32]. Having a motivation and interest is another important skills. Remaining interested and enthusiastic throughout the industrial symbiosis implementation process is crucial for the IS facilitator and the facilitation team. This can also help inspire stakeholders to become more involved and committed to the initiative. In addition, the facilitation team needs to be flexible and adaptable in the face of challenges or unexpected developments. This requires the ability to think creatively and find innovative solutions to problems, as well as the ability to communicate effectively with stakeholders and manage conflicts when they arise. Therefore, creativity and innovation, goal setting, adaptability and flexibility (resilience), time management, willingness to take risks and to learn, leadership and teamwork are other important soft skills [31, 32]. Moreover, remaining neutral and objective in the process, but having values, taking a clear position, being honest, neutral and vigilant towards ethical problems is crucial [30].

Additionally, the benefits and the potential of IS should be incorporated in the education of engineering and business students as along with the work-place training programmes to promote the concept faster [23].

Skills needed for energy efficiency

A broad scope of skills are demanded for implementing EE practices and strategies effectively. In most cases, such a wide range of skills cannot be present in one person, this a team-bases approach is vital for the energy implementation in large enterprises [33, 34]. The most compelling solutions gather people from diversified backgrounds with different skill sets.

Functional skills related to the energy efficiency assessment are the practical skills required in several discipline areas that enable individuals and teams to effectively fulfil EE assessments [35]. They can be mainly categorised as follows [23]:

(1) Project planning and management: the ability to manage and lead a group in fulfilling tasks and reaching targets of EE assessment. (2) Communication planning and implementation: the ability to express, exchange and engage ideas knowledge related to EE. (3) Understanding energy use: the ability to organise and recover data, ideas and knowledge, research and investigation of particular financial and technical knowledge. (4) Identification of potential opportunities: the abilities to think in a logical and creative way. (5) Decision-making: the ability to develop and evaluate business cases for implementation of EE opportunities. (6) Monitoring and investigating: the abilities to install convenient monitoring equipment and establish analysis systems [36]. Other identified knowledge, skills and experience consist of financial planning, understanding the legislative and compliance requirements of EE programmes, accounting skills, understanding of new trading mechanisms and their strategic business indications [34, 35].

Some of the revealed skills gaps and shortages that can prevent companies from reaching their full potential of EE assessments are as follows [34, 35]: (1) energy data collection and analysis, (2) selection and application of metering and monitoring equipment, (3) development of business cases for EE projects and (4) the ability to incorporate EE findings in cross-business operational activities and plans. These skills gaps were not only a lack of formal qualifications, but also a lack of specialised skills, experience and knowledge required to adjust to novel technologies and working methods [34].

The effect of the digital transformation on the skills needs

Digitalisation provides a wide range of opportunities for industry: smart technologies and methods improves the product quality, minimise lead time and maximises the general productivity and efficiency of an industrial plant [22, 36–38].

"Real-time decision-making" combining information, automation and optimisation technologies (such as AI, Machine Learning, IoT, etc. enable the users to take important and secure decisions in a short period of time, taking economic, technological and environmental elements into account all at once. Novel digital technologies such as Data Mining and Machine Learning can be utilised to forecast the required maintenance operations before anything malfunctions or fails. [22, 36–38].

The digital transformation also presents tremendous opportunities for the fulfilment of resource-saving and sustainable manufacturing. Industry 4.0 technologies can help companies optimise their use of resources, such as energy and raw materials, by providing real-time data on consumption and waste. This can help companies identify areas where they can reduce their environmental impact and improve their resource efficiency. The use of Big Data techniques and tools is crucial to effectively manage, analyse and process the diverse and complex data types that exist, which is necessary for providing timely and valuable insights for Machine Learning and Artificial Intelligence applications. To fully leverage the complexity of today's monitoring and automation systems, it is necessary to extensively utilise advanced modelling and simulation techniques to create effective Environmental Decision Support Systems [39, 40].

In addition, Industry 4.0 technologies can enable companies to create more flexible and responsive manufacturing processes, which can reduce the need for excess inventory and minimise waste. This can help companies operate more sustainably and reduce their environmental footprint.

Overall, through the implementation of the digital technologies, companies can improve their sustainability performance and contribute to a more sustainable future.

The principal consequence of the implementation of digital technologies in industry is the growing demand for the technological skills [10, 20, 41–43].

In this study, instead of directly naming the digital technologies and skills that can be used for IS and EE, we identified the technological skills that are directly connected with IS and EE, and that require the knowledge of the smart technologies. They are already presented in Sect. "Skills needed for Industrial Symbiosis" and "Skills needed for Energy Efficiency": system optimisation and process analysis and monitoring, data collection and analysis, management of processes, systems and equipment, etc.

One of the outstanding drawbacks of the digitalisation that the current workforce is experiencing is the difficulty to getting accustomed to novel, digitised and automated manufacturing processes [44]. To overcome the skills needs emerging with digitalisation, companies can collaborate with educators to modify college or school curricula. Industry associations can support building talent pipelines, while labour unions can help with cross-sector mobility [45].

The Future of Jobs (2020) report published by the World Economic Forum assesses that by the year 2025, 85 million jobs would be moved by a shift in the division of labour between humans and machines, while 97 million new jobs which do not exist today would appear. 84% of employers would engage in digitalised working processes, along with a significant expansion of remote work [46, 47]. Thus, as a result of digitalisation, competition for high-skilled workers will build up, while dislocation will be generally concentrated on low-skilled workers. It leads to keeping a trend that has aggravated income inequality and minimised middle-wage jobs. For high-skilled workers, it is quite possible to be hired and retrained, and to observe rising wages. Companies in the frontline of adopting automated technologies anticipate to attract the talent they need, but slower adopters worry that their options will be limited [22, 48, 49]. While changes caused by technological developments and globalisation in the world of work affect everyone, low-skilled adults are most at risk of experiencing a considerable dislocation in their labour market prospects [50]. The demand for their skills is declining, as many jobs they conventionally do are already automated or off-shored in advanced economies. OECD research indicates that occupations that require no specific skills and training have the highest risk of being automated. Therefore, dealing with the specific training barriers of low-skilled adults is obligatory for them to proceed in the labour market and reach to better jobs [50]. As well, reskilling of lower-skilled workers is a very critical issue for the industrial sectors.

Materials and methods

As stated in Sect. "Introduction", the methodology of this work is developed during the SPIRE-SAIS project. This section details the methodology which we has been followed to obtain the results in this study.

The aim of the methodology can be divided into 4 sections: (a) Step 1: Identifying the cross-sectoral job profiles related to IS and EE for 6 main considered energy-intensive industries (chemicals, steel, minerals, water, cement and ceramics).; (b) Step 2: Identifying the industrial skills requirements related to IS and EE; (c) Step 3: Standardisation of the selected job profiles by developing "job profile description" and (d) Step 4: Identifying the gap between current and future skills needs using "job profile description". The four-step methodology is presented in Fig. 1 below.

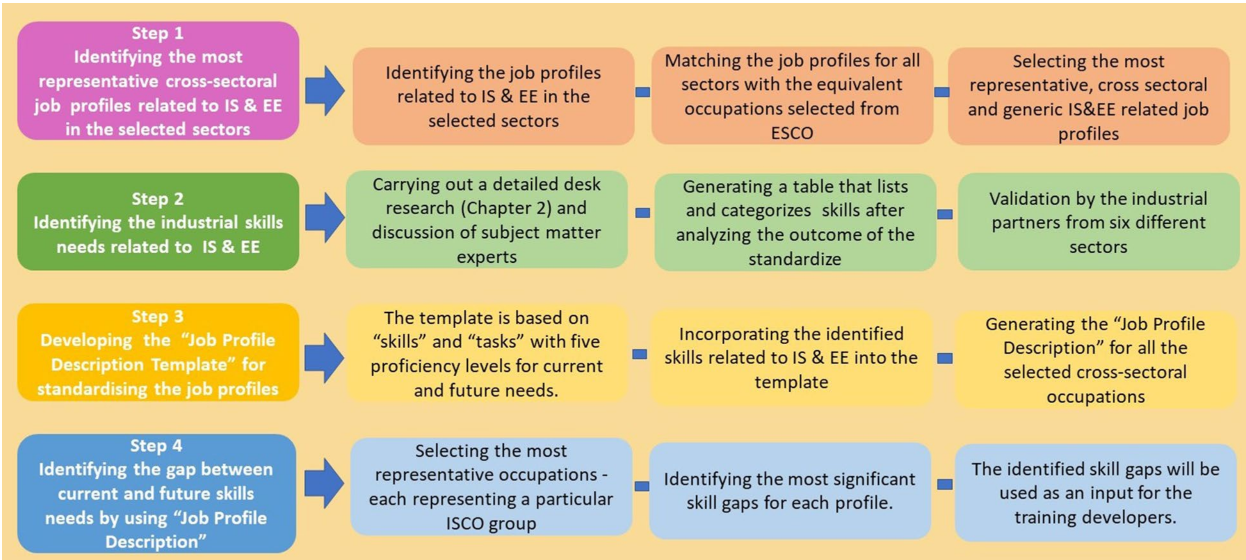


Fig. 1 The methodology of the research

Identifying the most representative cross-sectoral job profiles related to IS and EE

The initial goal of the methodology is to generate the list of the current generic job profiles related to industrial symbiosis (IS) and energy efficiency (EE) for the 6 selected sectors. In this section, we demonstrate how to obtain that list step by step.

1) *Defining all the job profiles related to IS and EE in each of the six selected energy-intensive sectors*: The process is carried out with the collaboration of the companies in each sector to have an accurate industrial point of view. As a first step, each sector analyses the profiles for the production and maintenance roles, starting from the manager profiles reaching down to blue collar profiles. Then, among that list, they identify the job profiles related with IS and EE in their sector with the support of the industrial partners.
2) *Merging and standardising the job profiles through finding their ESCO equivalences:* Throughout the six energy-intensive sectors, there is an immense variety of job titles. These job titles have many different purposes, such as attracting recruits with new job titles or by enhancing existing job titles, recognising loyalty to an organisation. Although each job has distinctive characteristics, similar titles are often used to describe very different jobs. Likewise, jobs that are very similar and encompass the same tasks are often described with very different titles. These two cases can lead to confusion amongst different sectors in the understanding of the different responsibilities comprised by each job profile.

Therefore, once the job profiles related to IS and EE are identified for each sector, ESCO framework is used as a reference while merging the job profiles with common backgrounds.

To clarify the ESCO approach, a detailed information of ESCO needs to be provided; ESCO, European Skills/Competences, Qualifications and Occupations, is an EU initiative that is supported by the EUCOM, which introduces a common European classification of Skills, Competences, Qualifications and Occupations [51]. It is used as a dictionary, describing, identifying and classifying professional occupations, skills and qualifications relevant for the labour market and education and training. ESCO grants a common classification; because the information in ESCO is founded on the work titled ISCO-08, "International Standard Classification of Occupations" created by the International Labour Organisation (ILO). We also benefit from ESCO database, during the development of the "job profile description template" which is detailed in sect. "Development of the "job profile description template"". Therefore, it also important to find the ESCO equivalences of the selected job profiles to generate their profile descriptions.

3) *The selection of the most representative IS and EE-related cross-sectoral job profiles:* During the development of the work, so as to reduce the number of profiles and make the resulting work more manage-

able and useful, we just selected the most important occupations at management and operations levels, (technician, engineer, supervisor, manager profiles). To select the most representative cross-sectoral profiles, the following criteria inspired from the ESSA project [38] are considered for the selection process:

a) Relative importance of the job profile in context of IS and EE in the energy-intensive industries.
b) Potential added value of the analysis of the job profile for the project.
c) Relative coverage of the job profiles that are differently affected by IS and EE in the future (operational and management level is a good example)
d) Covering more generic occupational groups such as 'production managers' who can have all sorts of occupational backgrounds and have many job profiles in that occupation group in ESCO database.
e) Representative coverage of ISCO major groups: occupations selected from varying occupational groups of ESCO will increase representativeness.
f) Being among most in-demand jobs.

The selection of the most relevant IS and EE-related skills

Even though workers use multiple skills to perform a given task, for the purposes of simplifying the work and finding a common base for the selected energy-intensive sectors, we identify the predominant and most relevant IS and EE-related skills. They are identified as a result of the thorough desk research presented in Chapter 2. During the selection process, we posed the question, "What skills are required to effectively implement EE and IS practices and strategies?" Once these skills were identified, they were classified and summarised through discussions among the subject matter experts from industry and academia. The subject matter experts involved in this study include the project leader, industrial partners and academic researchers of the SPIRE-SAIS project, who are also the authors of this study. The analysis results are shared with the other partners of the SPIRE-SAIS project and validated by them.

Development of the "job profile description template"

This chapter presents a methodology for identifying the most significant current and near-future skills requirements of the European process industry: the "job profile description" template. After comparing existing and future skills demands by the template, we could identify workforce skill gaps, which will be set as a basis for the training developers.

The potential equivalence of ESCO occupations and the industrial job profiles opens the door for the automatisation of the "job profile descriptions"; Therefore, the description of occupations in the ESCO database is taken as the main reference for the complete profile description of the IS and EE-related job profiles in the energy-intensive industries.

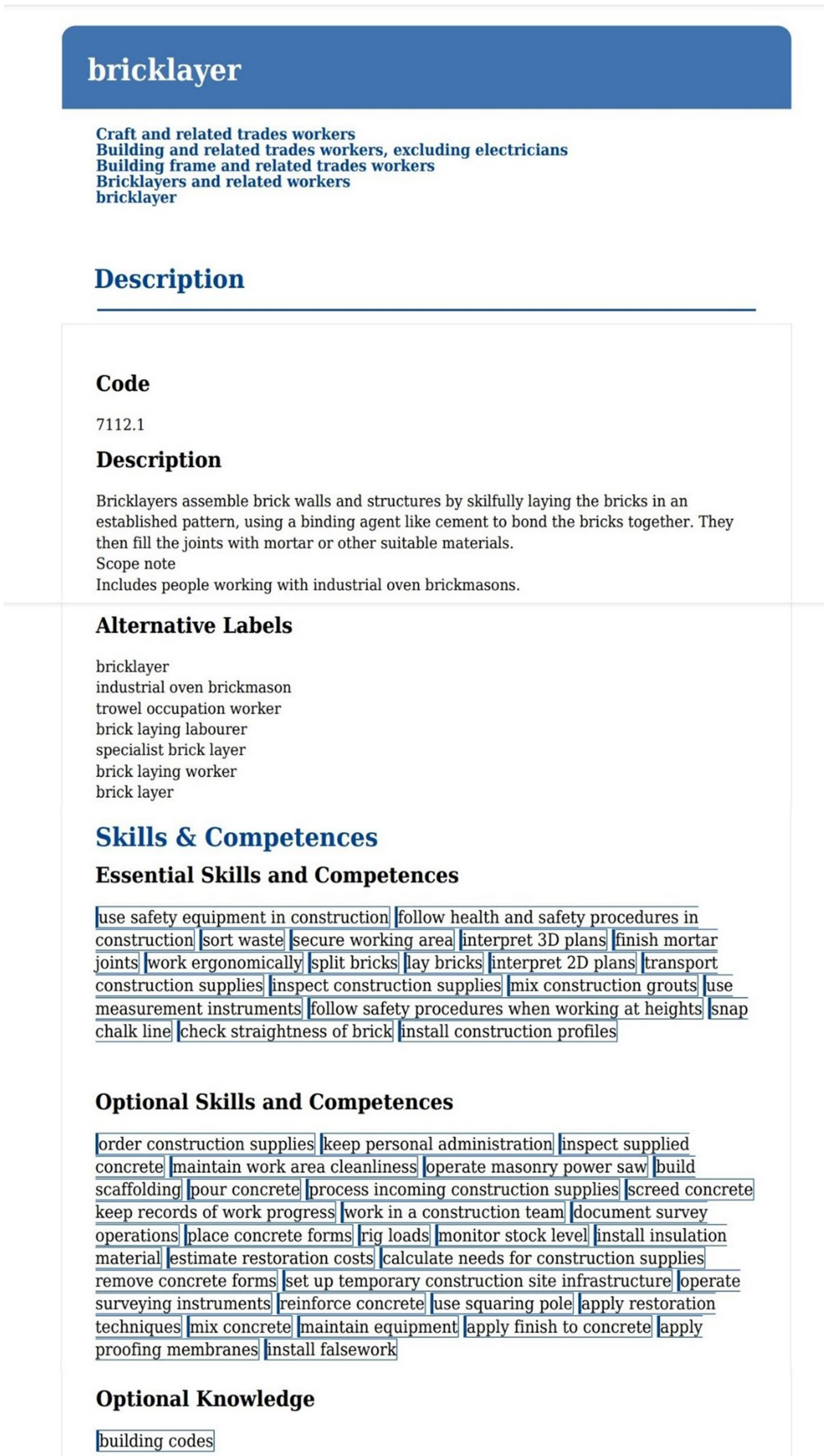
As an example, the ESCO descriptions of "bricklayer" or "recycling specialist" could be used to describe a group of titles or job profiles related with these ESCO occupations. In summary, ESCO provides a description of these occupations that could fix with the mission and tasks of the job profiles dealing with "refractories" and "waste recycling" in the process industry, with only small modifications. The ESCO description of "bricklayer" is shown in Fig. 2. As can be seen, in the database of ESCO, every occupation has a profile where hierarchic occupation group that the occupation (in this case "bricklayer") belongs to, as well as its description, alternative labels are present. As well, in this profile, the skills, competences and knowledge which are needed by the occupation are classified. ESCO's skills pillar contains knowledge, skills and competences. In ESCO database, the differentiation between "skill", "competence" and "knowledge" terms is not obvious. They are mostly mentioned as same elements. Thus, we altered the use of these terms and generated "job profile descriptions" established on "tasks" and "skills" concepts to minimise the complications and to reach a common understanding.

The "job profile description" is built precisely to offer a standard template. Because, the easiest way (1) to compare various job profiles, (2) to have a basis to develop or design new job profiles and (3) to adjust the descriptions of existing job profiles would be having a common template [41].

The "job profile description" is generated to be simple and universal to be used and get referenced by the organisations in all categories, independent of their structure or size. It is created to be understandable for both companies and training centres including VET systems institutions. The concept is inspired from the European Steel Professional role profiles created in the ESSA project [38] as well as European ICT professionals role profiles framework created with the support of CEN (European Committee for Standardisation) and CEPIS (Council of European Professional Informatics Societies) [52].

The fundamental rule to apply during the construction of the "job profile descriptions" is to emphasise the most important features which precisely represent the job profile and make a clear distinction between the profiles.

A template for the "job profile description" is offered (shown in Fig. 3) to be generic and be implemented to any sector. In addition, maintaining the structure and layout of the template but utilising other content to build



bricklayer

Craft and related trades workers
Building and related trades workers, excluding electricians
Building frame and related trades workers
Bricklayers and related workers
bricklayer

Description

Code

7112.1

Description

Bricklayers assemble brick walls and structures by skilfully laying the bricks in an established pattern, using a binding agent like cement to bond the bricks together. They then fill the joints with mortar or other suitable materials.
Scope note
Includes people working with industrial oven brickmasons.

Alternative Labels

bricklayer
industrial oven brickmason
trowel occupation worker
brick laying labourer
specialist brick layer
brick laying worker
brick layer

Skills & Competences

Essential Skills and Competences

use safety equipment in construction | follow health and safety procedures in construction | sort waste | secure working area | interpret 3D plans | finish mortar joints | work ergonomically | split bricks | lay bricks | interpret 2D plans | transport construction supplies | inspect construction supplies | mix construction grouts | use measurement instruments | follow safety procedures when working at heights | snap chalk line | check straightness of brick | install construction profiles

Optional Skills and Competences

order construction supplies | keep personal administration | inspect supplied concrete | maintain work area cleanliness | operate masonry power saw | build scaffolding | pour concrete | process incoming construction supplies | screed concrete | keep records of work progress | work in a construction team | document survey operations | place concrete forms | rig loads | monitor stock level | install insulation material | estimate restoration costs | calculate needs for construction supplies | remove concrete forms | set up temporary construction site infrastructure | operate surveying instruments | reinforce concrete | use squaring pole | apply restoration techniques | mix concrete | maintain equipment | apply finish to concrete | apply proofing membranes | install falsework

Optional Knowledge

building codes

Fig. 2 Example of ESCO description for "bricklayers and related workers" and "bricklayer" [51]

PROFILE TITLE	PROFILE NAME		
Summary Statement			
Mission	Direct information from ESCO		
TASKS	Current	Future	
Main task/s	ESCO description	(here it should be listed, which tasks are changing/modified in which way, and if new tasks appear)	
Equivalent profiles	This information will be collected during our study		
SKILLS		Current Level	Future Level
Skills Category	Skill 1		
	Skill 2		
	Skill 3		
	Skill 4		

0	Novice
1	Awareness/Basic Actor
2	Practitioner
3	Expert
4	Master

Fig. 3 Job profile description template

considerably different jobs is also feasible. Distribution of the same template across different sectors and organisations would increase transparency among them.

This template will incorporate the skills related with IS and EE which have already been identified and categorised through a detailed research and discussion with subject matter experts and presented in Sect. "Development of the "job profile description template"".

The job profile descriptions will be initially generated for the most representative and generic industrial symbiosis (IS) and energy efficiency (EE)-related profiles of the process industries. Their selection process is already detailed in Sect. "Identifying the most representative cross-sectoral job profiles related to IS and EE".

The "job profile description" for identifying the skill gaps between present and future

The "job profile description" serves as a key tool for identifying the most significant current and near-future skills requirements of the European process industry through evaluating the needed levels of each skill. After filling in current and future skill levels demanded by each job profile and comparing these levels, it is possible to identify the most critical skill gaps, which will be set as a basis for developing the training programmes.

As can be seen from Fig. 3, the template incorporates the current and future levels for each skill for different skill categories. Therefore, the 5 proficiency levels used to identify current and future skills levels are described as follows [42]: Level 0, or "Novice," refers to those who have no knowledge or skills in the field; Level 1, or "Basic Actor," describes those with a basic level of proficiency who cannot execute operations autonomously; Level 2, or "Practitioner," denotes individuals with substantial skills who can perform operations independently but may require guidance in unforeseen circumstances; Level 3, or "Expert," signifies those with a high level of skills who can carry out operations without any assistance, deal with complicated circumstances, mentor and give advice and establish new methods and finally Level 4, or "Master," designates those with extremely advanced knowledge and skills, who can take initiative, show adaptability in dealing with complex problems, lead and train others, and proactively build capability.

The needed current and future skills levels of the selected job profiles are analysed and filled in the generated job profile descriptions. The analysis is carried out by the same subject matter experts that have identified the skills (the project leader, industrial and academic partners of the SPIRE-SAIS project).

Results and discussion

Identifying the most representative cross-sectoral job profiles related to IS and EE

A) *Defining all the job profiles related to IS and EE in each of the six selected energy-intensive sectors*: The job profiles related with IS and EE in the six energy-intensive sectors are identified with the support of the industrial partners. Table 1 shows the job profiles related to IS and EE for six different areas, production, maintenance, purchase section, waste management, logistics and energy and environment section. The table is repeated for other five sectors (ceramic, chemical, mineral, water and cement).

B) *Merging and standardising the job profiles through finding their ESCO equivalences:* Once job profiles related with IS and EE has been identified for each sector, the job profiles that perform similar tasks (such as profiles related to operations with furnaces, profiles related with refractories, with waste water, environment, energy, etc.) are grouped together. After these groups are formed, their equivalences are examined with in the ESCO database of those occupations whose tasks are adapted to those of the groups defined below (Table 2). It should be pointed out that the relation between two groups (ESCO occupations and selected industrial job profiles) does not portray a precise equivalence, however, it can be a starting point to build that kind of equivalence in the future.

As each occupation in ESCO database, it is within a hierarchical level defined in turn by a code or ISCO group, it will be possible to find the equivalences between

Table 1 The job profiles of steel sector related to IS and EE

Area	Steel		
	Melting shop	**Rolling Mill**	**Finishing**
Production	EAF production manager	Rolling mill production Manager	Bright finishing production Manager
	Ladle Furnace production Manager	Heat treatment production Manager	As rolled finishing production Manager
	Continuous casting production Manager		
	ScrapYard supervisor		
	EAF Operator/LF Operator/ CC Operator	Reheating furnace operator	
	Energy Manager		
	Energy Technician		
	refractory bricklayer		
	Melting shop process Manager	Rolling mill process manager	
Maintenance	General maintenance manager		
	Electrical maintenance supervisor		
	Electronic and combustion supervisor		
	Civil works supervisor		
	liquid and solid waste treatment plant operator		
	Water, gas, steam and air foreman		
Purchase section	Purchase manager		
Waste management	Wastes valorisation responsible		
Logistics	Logistics manager		
Energy and Environment section	Environment manager		
	Environment technician		

Table 2 Cross-sectoral job profiles and their equivalent ESCO occupations

Area	Level	Job Profile	Equivalent ESCO occupation
Production	Management	Production manager	Industrial production manager
Production	Operational	Production/Processing line Operator/Foreman	Production engineering technician
Functional	Management	Materials/Products manager	Product manager/Materials engineer
Functional	Operational	Materials operator/Foreman	Production supervisor
Functional	Management	Energy manager	Energy manager
Functional	Operational	Energy technician	Energy analyst
Functional	Management	Environmental manager	Environmental engineer
Functional	Operational	Environmental technician	Environmental technician
Functional	Management	Waste manager/Responsible	Waste manager supervisor
Functional	Operational	Waste management technician	Waste manager supervisor
Functional	Management	Maintenance manager/Supervisor	Maintenance and repair engineer
Functional	Operational	Maintenance/Repair Operator/Foreman	
		(a) Water, gas, stream, air foreman	Maintenance and repair engineer
		(b) Mechanical/Electrical technicians	Electrical Supervisor Electromechanical engineering Technician
Functional	Management	Purchase manager	Purchasing manager
Functional	Operational	Purchase technician	Purchaser
Functional	Management	Logistic manager	Logistics and distribution manager
Functional	Operational	Logistic technician	Logistics engineer
Functional	Management	Legal/Regulatory manager	Regulatory affairs manager
Functional	Operational	Legal/Regulatory technician	Environmental engineer
Functional	Management	HR manager	Human resources managers
Functional	Operational	OHS responsible	Environmental technician
Functional	Management	Quality manager (quality of recycling materials)	Industrial quality manager
Functional	Operational	Quality technician	Quality engineer

Table 3 SPIRE-SAIS selected cross-sectoral generic job profiles and their ESCO equivalences with ISCO codes

Identified job profile	Equivalent ESCO occupation with ISCO number
Production manager	132.2.1 Industrial production manager
Production/Processing line operator/Foreman	81 Stationary plant and machine operators
Energy manager	1349.12 Energy manager
Energy technician	3112.5 Energy analyst
Maintenance manager/Supervisor	2141.8 Maintenance and repair engineer
Maintenance/Repair operator/Foreman	7112.1 Refractory bricklayer
Waste manager/Supervisor	2143.1 Environmental engineer
Environmental manager	2143.1 Environmental engineer
Environmental technician	3111.2 Environmental technician
Waste management technician	3132.2 Liquid waste treatment operator

the occupations and the ISCO group numbers (see Table 3).

The ISCO code will be used in two ways:

- As ESCO is developed to enhance the interaction between the training and education sector, the ISCO code can be used to identify training programmes for European VET systems matrix elaboration.
- ISCO code can be used to automatically fill the job profiles description templates (Sect. "Development of the "job profile description template"") for each group of sectoral profiles.

The SPIRE sectors occupations which are present in ESCO database will be defined through generating the "job profile descriptions" (Please see Sect. "Development of the "job profile description template""). Therefore, matching the IS and EE-related job profiles of six selected sectors with the equivalent ESCO occupations is very critical step. For this aim, the map in the table format indicating the equivalences, Table 2, will be used. It simplifies and speeds up the general process.

One of the emerging concerns is about the industrial job titles that are not encompassed by ESCO database. In that case, new job profiles need to be developed. This will represent an advantage for ESCO, since a gap of the database is detected. Accordingly, ESCO database will be enrichened with newly introduced job profiles and information related to profile descriptions. From our side, instead of elaborating a stand-alone database about IS and EE, integration of the developed information into an existent database is also advantageous.

C) *The selection of the most representative IS and EE-related cross-sectoral job profiles:* During the development of the work, so as to reduce the number of profiles and make the resulting work more manageable and useful, we just selected the most important occupations at management and operations levels, (technician, engineer, supervisor and manager profiles).

After defining the selection criteria in Sect. "Identifying the most representative cross-sectoral job profiles related to IS and EE" (3) the most representative, generic, cross-sectoral IS and EE-related profiles are identified. As a result, 10 job profiles are selected as shown in Fig. 4 Their equivalent ESCO occupations are demonstrated in Table 3.

The selection of the most relevant IS and EE-related skills

After a detailed desk research, we end up with a set of skills across four broad categories: technological, individual and personal, regulatory and business related. We categorise the technical skills required for the implementation of IS and EE as "technological skills." Additionally, we acknowledge the intrinsic qualities that facilitate effective task execution and positive interactions with others in the context of IS and EE activities as "personal individual skills." The skills associated with legislation pertaining to IS and EE are classified as "regulatory skills." Finally, we designate the skills necessary for managing the

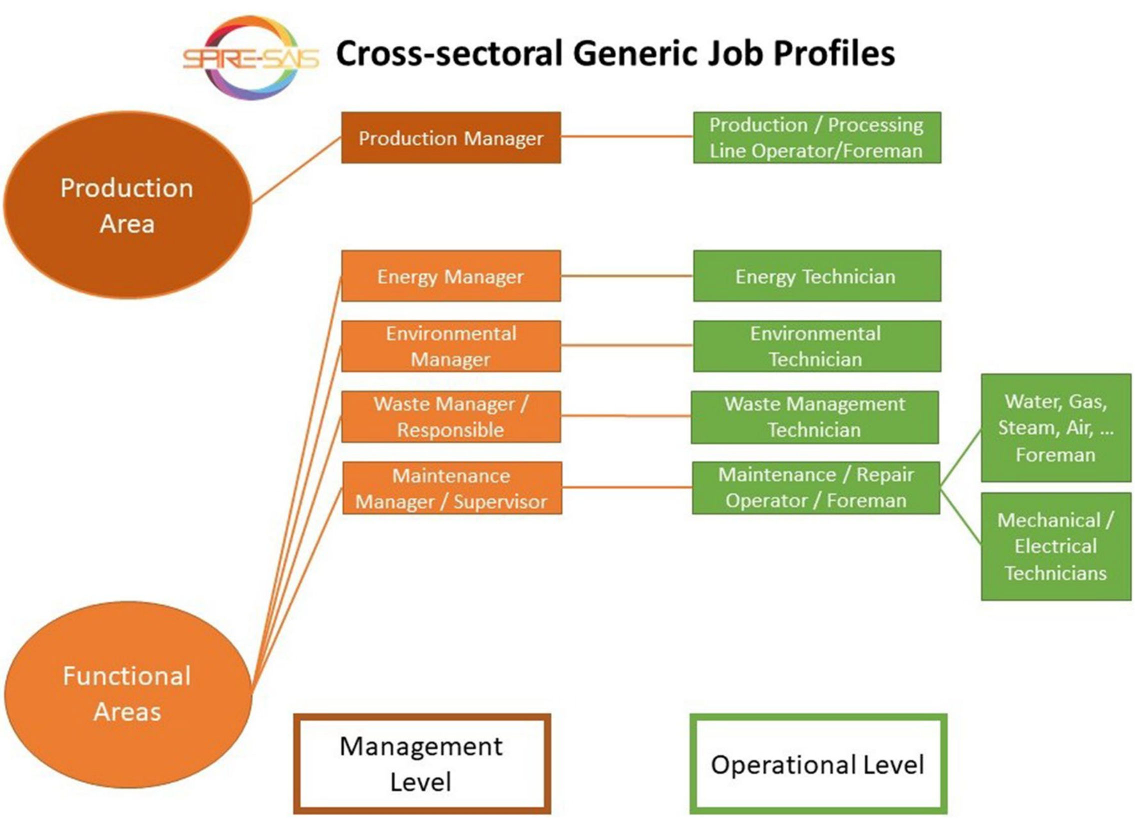


Fig. 4 SPIRE-SAIS selected cross-sectoral generic job profiles both in management and operational level

business aspects of IS and EE implementation as "business-related skills." Within each category there are more specific skills. After the discussions carried out with subject matter experts involved in the SPIRE-SAIS project, the skills list has reached to its final version (Fig. 5). It is also validated by all the partners of the project.

A detailed description of each defined skill in the table has been generated and can be found in ANNEX I. These descriptions are based on the work on ESSA project and SPIRE-SAIS project.

Development of the "job profile description template"

First, thanks to the potential equivalency between the occupations in ESCO database and industrial job titles, we formulated a software that allows to automate the description of several IS and EE-related profiles. Therefore, with the job profile description and tasks, the profile description is automatically generated from ESCO database with this developed software. This allowed us to minimise the confusion and to reach a common understanding about of creating the descriptions of all IS and EE-related jobs for each SPIRE sector.

In addition, the most relevant IS and EE-related skills for the selected sectors, which have been already identified in Sect. "The selection of the most relevant IS and EE-related skills" are incorporated into the "job profile description" template. Then, the "job profile descriptions" are generated for the most representative 10 cross-sectoral IS and EE-related occupations in the six industries. (The selection process has already been detailed in Sect. "Identifying the most representative cross-sectoral job profiles related to IS and EE") In other words, standardisation of these 10 IS and EE-related job profiles are completed using the "job profile description template". Figure 6 shows the job profile description for the "Maintenance and Repair Operator" profile, of which the ESCO occupation "7112.1 Refractory Bricklayer" is equivalent.

The "job profile description" for identifying the skill gaps between present and future

After generating the job profile description template, it is used to evaluate the current and future skills and identify the most critical skill gaps related to EE and IS in the six energy-intensive sectors. The results will be an important input for the development of efficient training programmes.

Therefore, the job profile descriptions of the selected 10 cross-sectoral IS and EE-related occupations are completed. In addition, the current and future skill levels for each skill category is analysed and defined by the subject matter experts. Figure 7 demonstrates the completed job profile description of "Waste Management Technician" profile, of which the ESCO occupation "3132.2 Liquid Waste Treatment Operator" is equivalent. In the case of this specific job profile, as can be seen, the skills

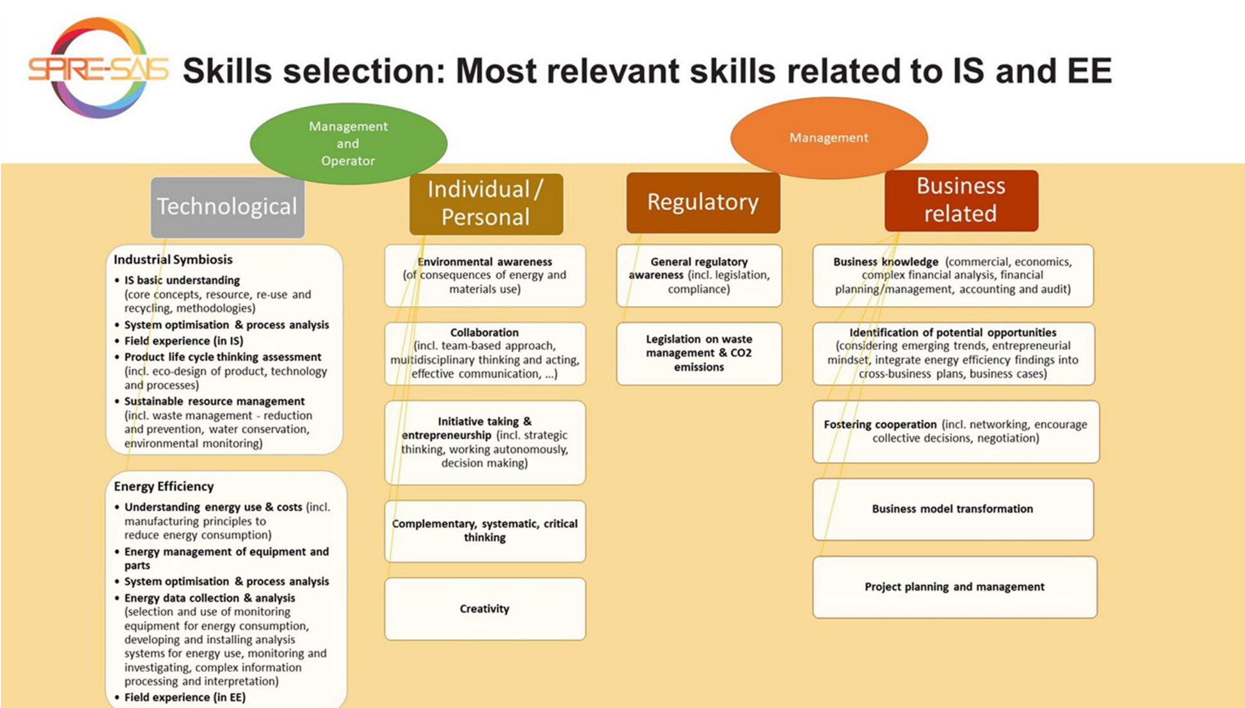


Fig. 5 Final version of the list of the most relevant skills for industrial symbiosis and energy efficiency

PROFILE TITLE	Maintenance & Repair Operator (Refractory Bricklayer)		
ISCO Code	7112.1		
Mission	Bricklayers assemble brick walls and structures by skilfully laying the bricks in an established pattern, using a binding agent like cement to bond the bricks together. They then fill the joints with mortar or other suitable materials.		
TASKS	Current	Future	
Main task/s	Lay bricks, pre-cut stones and other types of building blocks in mortar to construct and repair walls, partitions, arches and other structures such as smokestacks, furnaces, converters, kilns and ovens, piers and abutments;	(here it should be listed, which tasks are changing/modified in which way, and if new tasks appear)	
Equivalent profiles	Refractory masonry officer Refractory Technician Refractory linings technician Refractory lining coordinator Refractory lining Supervisor Refractory lining foreman Refractory Preparation Operator Refractory Supervisor		
SKILLS		**Current Level**	**Future Level**
Technological skills			
Industrial Symbiosis skills	IS basic understanding		
	System optimisation & process analysis		
	Field experience (in IS)		
	Product life cycle thinking assessment		
	Sustainable resource management		
Energy efficiency	Understanding energy use & costs		
	Energy management of equipment and parts		
	System optimisation & process analysis		
	Energy data collection & analysis		
	Field experience (in EE)		
SKILLS		**Current Level**	**Future Level**
Transversal skills			
Individual, personal skills	Environmental awareness		
	Collaboration		
	Entrepreneurship and initiative taking		
	Complementary, systematic, critical thinking		
	Creativity		
Regulatory skills	General regulatory awareness		
	Legislation on waste & energy management & CO2 emissions		
Business related skills	Business knowledge		
	Identification of potential opportunities		
	Fostering cooperation		
	Business model transformation		
	Project planning and management		

Fig. 6 The job profile description template for "Maintenance and Repair Operator" profile, of which ESCO occupation is "7112.1 Refractory Bricklayer" is equivalent

PROFILE TITLE	Waste management technician (Liquid waste treatment operator)		
ISCO Code	3132.2		
Mission	Liquid waste treatment technicians remove hazardous chemicals and pollutants from liquid waste such as oil so that it can be safely used for new applications. They operate and maintain liquid waste treatment equipment, monitor operations, and test samples to ensure the safety standards are met.		
TASKS	Current	Future	
Main task/s	analyse experimental laboratory data document analysis results drain hazardous liquids ensure compliance with environmental legislation handle chemicals handle waste measure density of liquids perform laboratory tests perform water treatments test chemical samples	There are no additional or modified tasks	
Equivalent profiles	liquid waste treatment plant worker liquid waste plant monitoring operator liquid waste tester liquid waste treatment plant operative liquid waste treatment plant operator liquid & solid waste treatment plant operator		
SKILLS		Current Level	Future Level
Technological skills			
Industrial Symbiosis skills	IS basic understanding	3	4
	System optimisation & process analysis	3	4
	Field experience (in IS)	3	4
	Product life cycle thinking assessment	3	4
	Sustainable resource management	3	4
Energy efficiency	Understanding energy use & costs	1	2
	Energy management of equipment and parts	1	2
	System optimisation & process analysis	1	2
	Energy data collection & analysis	1	2
	Field experience (in EE)	1	2
SKILLS		Current Level	Future Level
Transversal skills			
Regulatory skills	General regulatory awareness	3	4
	Legislation on waste & energy management & CO2 emissions	4	4
Individual, personal skills	Environmental awareness	4	4
	Collaboration	3	4
	Entrepreneurship and initiative taking	2	3
	Complementary, systematic, critical thinking	2	3
	Creativity	1	2
Business related skills	Business knowledge	0	1
	Identification of potential opportunities	1	2
	Fostering cooperation	2	3
	Business model transformation	1	2
	Project planning and management	1	2

0	Novice
1	Awareness/Basic Actor
2	Practitioner
3	Expert
4	Master

Fig. 7 The completed job profile description (with current and future skills levels) for "Waste Management Technician" profile, of which ESCO occupation is "3132.2 Liquid Waste Treatment Operator" is equivalent

which are related to IS are needed at expert level (3) at the moment, whereas they are anticipated to be required at highest level in the future. The skills related to EE will be more significant for this job profile (practitioner level), but not as much as the skills related to IS. Waste treatment operator will be expected to have highest level of regulatory skills. They do not and will not demand highest level of personal, individual and business-related skills (except the skills related to collaboration and cooperation), since it is a job profile on the operational level. On the other hand, the skills in these categories will increase in relevance for them.

The complete job profile descriptions with the identified skill levels for the rest of the selected profiles (Production manager, Production / Processing Line Operator/Foreman, Energy Manager, Energy Technician, Maintenance and Repair Operator, Maintenance Manager/Supervisor, Waste Manager/Supervisor, Environmental Manager, Environmental Technician, Waste Management Technician) can be found in Additional file 1: Annex S1.

In training, this performed skill gap analysis enables the design of precise training paths that can effectively enhance proficiency levels, ensuring alignment with the organisation's requirements.

In the progression of an organisation, the outcome of the analysis can be utilised to steer the organisation's structure, efficiently allocate resources and identify areas of competency deficiency to aid the recruitment procedure.

Within career development, recruitment and talent management, individual skill gap assessments can be leveraged to determine the most suitable career advancement trajectories for professionals in the process industry. This benefits both the employee and the organisation.

Additionally, through this information, we can identify the most critical skills needs related to IS and EE for the European process industry in another study.

Conclusion

The European process industry is currently being reshaped by not only digital transformation but also sustainability concerns. While maintaining the competitiveness and ensuring the economic development, the industry is investigating solutions for an efficient use of resources, sustainability and the reduction of CO_2 emission. In addition, day by day, the interest of industrial companies and policy-makers in IS and EE is significantly growing since their potential with regard to the environmental, economic and social aspects has been acknowledged. Accordingly, technological developments resulting from the industrial digitalisation as well as increasing energy costs and recently established strict policies about sustainability and circular economy are transforming job profiles of the energy-intensive industries. Thus, they bring about the demand of new skills for workforce. Digitalisation, sustainability needs, (raw) material scarcity and energy costs are the main drivers for the evolution of skills needed in the European process industries.

The main condition to create a competitive and sustainable (circular) European manufacturing industry is to create a high-skilled, competent workforce that is qualified enough to handle the implementation of contemporary business models compatible with IS and EE and technological developments. This workforce can only be built by addressing the future skills needs and updating the qualifications of the current labour force. Thus, our work, first, aims to identify the most relevant and predominant IS and EE-related skills for the six European energy-intensive sectors (steel, ceramic, water, cement, chemical, minerals) considering a framework of increasing environmental constraints, digitalisation and resource scarcity. The effect of the digital transformation on the skills needs is particularly discussed. The skills needs are identified and categorised after a detailed desk research (including recent and reliable book chapters, scientific articles, reports published by European Commission) and a discussion with the subject experts and as well as with the academic and industrial partners. Long-term plan is to incorporate the identified skills into syllabuses of tertiary education and VET.

Our work also identifies the cross-sectoral most representative IS and EE-related job profiles in these sectors and demonstrates the methodology for this process.

We also link our work to the respectable ESCO, the European Classification of skills, competences and occupations, to reach a common ground, diminish the complications and contribute to their work.

This work also presents a methodology, "job profile description" template, for identifying the most significant current and near-future skills requirements of the European process industry. It serves as a key tool to define the gap between the current and future skills and define the skills gaps. Once the skill gaps are defined, they can be reduced by delivering well-developed continuous trainings.

Therefore, as the next step, the "job profile description" template is used for identifying the most critical IS and EE-related skill gaps in the selected sector. These gaps are defined through identifying the current and future skills levels. As a result, this output, will be a significant input for the development of efficient training programmes.

In addition, due to the potential equivalence between ESCO occupations and industrial job profiles, we developed a software that allows to automate the description of the different IS and EE-related profiles. Therefore, the description of the profiles is automatically generated from ESCO database with this developed software.

It is important to underline that the presented work is based on the studies that is carried out by our research group in the SPIRE-SAIS-Skills Alliance for Industrial Symbiosis (SAIS)—A Cross-sectoral Blueprint for a Sustainable Process Industry (SPIRE)—project and it is developed to be an academic and industrial guideline for the training providers to prepare convenient and well-developed training programmes to deliver the needed skills.

In addition, this work provides assistance about the organisational changes caused by the daily activities related to IS, EE and digitalisation as well as how to deal with the skills needs. It also shows how the companies, training designers, training providers, etc. can use the created job profiles with their descriptions during career development, syllabus design or job assessments. Furthermore, our work explains in detail how to link the developed job profiles to the honourable and well-known frameworks, such as ESCO.

ANNEX I

The description of the skills related to IS and EE

Category 1: Technological Skills

Skills related to IS

IS basic understanding: to have acquaintance/familiarity with IS approach, and its core concepts and methodologies, as well as resource reuse and recycling*.

**Resource reuse/recycling* is the ability to reprocess of discarded waste materials for reuse, which involves collection, sorting, processing, and conversion into raw materials which can be used in the production of new products.

System optimisation and process analysis: (1) Optimisation is the discipline of finding the best alternative among a set regarding a specific criterion and given constraints**.** System optimisation, as a skill, is the ability to enhance system capabilities about IS and integrate of subsystem elements to the extent that all IS components operate at or above user expectations.

(2) Process analysis as a skill refers to the ability to carry out a systematic review of all IS steps and procedures followed to perform a given IS activity. A process analysis can be used to improve understanding of how the IS process operates, and to determine potential targets for IS process improvement and increase efficiency.

Field experience (in IS): It refers to the level of experience achieved through applying IS knowledge gained during the classroom with supervised practice in the production field.

Product life cycle thinking assessment: Every part of a product's life cycle—extraction of materials from the environment, the production of the product, the use phase and what happens to the product after it is no longer used—can have an impact on the environment in many ways.

Product life cycle (thinking) assessment, as a skill, is the ability to evaluate the environmental impacts of a product, process or service from the very first life cycle (development) stage to the very last (market entry and market removal) or to any life cycle stage in between.

This skill includes having a knowledge about *eco-design** of product, technology and processes. **Eco-design* is the integration of environmental aspects into the product development process, by balancing ecological and economic requirements. Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle.

Sustainable resource management: Sustainable resource management, as a skill, can be defined as the ability to perform sustainable practices by managing resources in a way that will benefit current and future generations.

This skill includes *waste reduction and prevention**, *waste management***, as well as *water conservation****and *environmental monitoring*****.

**Waste reduction and prevention* is the ability to use less material and energy to minimise waste generation and preserve natural resources. It is broader in scope than recycling and incorporates ways to prevent materials from ending up as waste before they reach the recycling stage.

***Waste management* herein refers to the skills required to collect, transport, dispose or recycle and monitor waste.

****Water conservation* refers to the ability to perform a more efficient, conservative use of water in the production plant which includes the ability to monitor sites, to negotiate with regulatory authorities, or professionals such as engineers, planners and surveyors, to advise about possible water conservation solutions and to keep up to date with changes in legislation/EU directives.

*****Environmental monitoring* is the ability to assess environmental conditions and trends, support policy development and its implementation, and develop information for reporting to national policy-makers, international forums and the public.

Skills related to EE

Understanding energy use and costs: It refers to have (1) an understanding of the principles needed to perform a more efficient, conservative use of energy in the production plant, (2) the ability to collect, arrange and analyse energy and financial data for the purpose of identifying energy use and savings and (3) the ability to arrange and retrieve data, knowledge and ideas, research and investigation of specific technical and financial knowledge.

It also includes to have an acquaintance with the manufacturing principles to reduce energy consumption.

Energy management of equipment and parts: to be able to target, implement and track progress to ensure energy savings of machinery, equipment, processes and technologies. This skill includes efficiently monitoring energy and metering energy data, finding opportunities to save energy, targeting energy opportunities and tracking the progress.

System optimisation and process analysis: (1) Optimisation is the discipline of finding the best alternative among a set regarding a specific criterion and given constraints**.** System optimisation, as a skill, is the ability to enhance system capabilities about EE and integrate of subsystem elements to the extent that all components operate at or above user expectations about EE**.**

(2) Process analysis as a skill refers to the ability to carry out a systematic review of all steps and procedures followed to fulfil EE objectives. A process analysis can be used to improve understanding of how the process operates, how to monitor energy use and to determine potential targets for EE [1].

Energy data collection and analysis: This skill consists of the ability to collect data to measure the energy performance, ability to undertake the detailed analysis required for energy audit savings calculations, ability to assess, select, install and use appropriate monitoring equipment and develop analysis systems.

It includes *complex information processing and interpretation**

**Complex information processing and interpretation* can be referred as the ability to get complex raw data transformed into a meaningful form (information) in the CPU (central processing unit) and evaluate the output.

Field experience in (EE): It refers to the level of experience achieved through applying EE knowledge gained during the classroom with supervised practice in the production field.

Category 2: Individual/Personal Skills

Environmental awareness: Being environmentally aware means understanding how our behaviour of energy and materials use impacts the environment and committing to making changes to our related activities to protect the environment. This skill includes the capacity to include environmental concerns about the consequences of energy and material use alongside others (such performance and safety) in taking decisions, including in the choice of processes and technologies.

Collaboration: Collaboration skills can be defined as the interpersonal and intrapersonal qualities and competencies we leverage to collectively solve a problem or make progress toward a common goal.

Skills in this category include *team-based approach*, effective communication*** and *multidisciplinary thinking and acting****.*

To understand the **team-based approach*, first, we need to define "teamwork". Teamwork is the cooperation between people characterised by a unified commitment to achieving a given goal, participating equally, maintaining open communication, facilitating effective usage of ideas The team-based approach is a style of project management in which everyone on the project team is held equally responsible for the quality and success of the project.

**Effective communication: refers to the ability to exchange ideas, thoughts, opinions, knowledge and data so that the message is received and understood with clarity and purpose. When we communicate effectively, both the sender and receiver feel satisfied.

***Multidisciplinary thinking and acting: refers to have perspective defined by the ability to draw insights from multiple disciplines and to apply them to your own area of focus in a way that challenges traditional notions and enriches the process.

Initiative taking and entrepreneurship: Sense of initiative and entrepreneurship refers to an individual's ability to turn ideas into action. It includes creativity, innovation and risk-taking, as well as the ability to plan and manage projects to achieve objectives. This supports individuals in the work-place in being aware of the context of their work and being able to seize opportunities, and is a foundation for more specific skills and knowledge needed by those establishing or contributing to social or commercial activity. This should include awareness of ethical values and promote good governance.

This skill includes *working autonomously*, strategic thinking** and decision-making***.*

*Work autonomously: The more expertise you have, the greater responsibility you have in making these decisions independently. With greater autonomy comes less support or supervision but increased accountability. Working autonomously requires ability to achieve results with no supervision or with limited supervision, ability to work both independently and as a member of a team, to make independent decisions and solve problems on your own. It also demands self-motivation, confidence and time management. It can be defined as the ability to develop one's own ways of doing things, motivating oneself with little or no supervision and depending on oneself to get things done.

**Strategic thinking: It is the ability to acquire business insights and possible opportunities, in order to achieve competitive business advantage on a long-term basis. It involves seeing the big picture, planning ahead and putting thought into action, typically to gain a competitive advantage in business. It is an organisational and pragmatic type of critical thinking.

***Decision-making is defined as making a choice from several alternative possibilities. It is a valuable leadership ability which demonstrates the capacity to think objectively and weigh different options. In this case, it refers to the ability to develop and assess business cases for implementation of EE and IS opportunities.

Complementary, systematic and critical thinking

Critical thinking refers to the ability to analyse information objectively and make and defend judgements based on internal evidence and external criteria and to critically evaluate the credibility and reliability of information before using or passing it on to others.

It involves the evaluation of sources, such as data, facts, observable phenomena and research findings before making a reasoned judgement/logical decision.

Good critical thinkers can draw reasonable conclusions from a set of information, and discriminate between useful and less useful details to solve problems or make decisions. An employee with critical thinking skills can be trusted to make decisions independently and will not need constant handholding.

Complementary thinking refers to be able to adopt multidisciplinary approaches which complement each other.

Systematic thinking is an holistic approach to problem-solving considering every part of the issue. It is an approach of analysing and understanding problems in detail before making conclusions and understanding the underlying structures that cause the issue and thinking of a wide range of different solutions before deciding which one is the most appropriate.

Creativity: Creativity is the ability to think about a task or a problem in a new or different way, or the ability to use the imagination to generate new ideas. Creativity enables you to solve complex problems or find interesting ways to approach tasks. If you are creative, you look at things from a unique perspective.

Category 3: regulatory

General regulatory awareness: to be able to understand and keep up with the latest general legislation on IS and EE and to commit to act in compliance with them.

Legislation on waste management and CO_2 emissions: to be able to understand and keep up with the latest legislation on waste management and CO_2 emissions and to commit to act in compliance with them.

Category 4: business related

Business knowledge: It refers to the basic knowledge that is needed to start, run and/or grow a business. It covers the knowledge in Business life cycle, Business model, Marketing, Production, Human resource, Financial (analysis, planning and management), Accounting and audit, Business management areas. It is a sum of skills, experiences, capabilities and insight which you collectively create and rely on in your business.

Identification of potential opportunities: The ability to identify potential opportunities about IS and EE requires the capability to think logically and creatively, to have knowledge about business cases, to have an entrepreneurial mindset, to keep up with emerging trends, to integrate EE and IS findings into cross-business plans.

Fostering cooperation: It refers to the ability to achieve and sustain the networking and cooperation between stakeholders and also between facilitators, as well as the skills related to the use of collective intelligence facilitation tools, encouraging collective decisions and negotiation. It is not only based on the IS facilitator's technical knowledge, but also based on every stakeholder's input.

Business model transformation: It refers to the skills needed to transform the current businesses into a sustainable and energy efficient ones. These skills include broad and deep industry knowledge on sector-specific best practices and processes, globally relevant emerging trends about IS and EE and business challenges.

Project planning and management: ability to direct and guide a group in completing tasks and attaining goals of EE assessment and IS.

Abbreviations

IS	Industrial symbiosis
EE	Energy efficiency
EII	Energy-intensive industries
EU	European Union
VET	Vocational education and training
EUCOM	The European Commission
ESCO	European Skills, Competences, Qualifications, and Occupations
ISCO	Standard classification of occupations
ILO	International Labor Organisation
ICT	Information and communications technology

CEPIS	Council of European Professional Informatics Societies
CEN	European Committee for Standardisation
ESSA	Blueprint "New Skills Agenda Steel": Industry-driven sustainable European steel skills agenda and strategy
SPIRE-SAIS	Skills alliance for industrial symbiosis—a cross-sectoral blueprint for a sustainable process industry

Supplementary Information

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Additional file 1: Job profile descriptions of the selected IS and EE-related occupations

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Author contributions

TA, writing, conceptualisation and investigation; AG conceptualisation, writing and funding acquisition; FB, AS and MK conceptualisation and investigation. All authors have read and agreed to the published version of the manuscript.

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Competing interests

The authors declare no competing interests.

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