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D2.3 ALCHIMIA Training Programme

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Abstract

This Deliverable, "ALCHIMIA Training Programme", outlines a potential training programme for the ALCHIMIA project, which aims to integrate a Federated-Learning based AI system into production processes in the European metallurgy industry. The report focuses on identifying training needs for workers and managers, emphasising the importance of general transversal competencies for digital transformation and specific transversal competencies related to the ALCHIMIA system. The report outlines a training programme rather than specific training products, considering factors such as the diverse needs of companies using the system and the varying levels of digitalisation in the metal sector. The document provides a three-part framework for training activities, including a comprehensive list of relevant transversal skills, and it addresses the implications of ALCHIMIA's integration into specific production contexts at two participating companies.

Statement of originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

Executive summary

This document, "ALCHIMIA Training Programme", outlines a potential training programme to facilitate the integration of a Federated-Learning-based AI system into production processes in the European metallurgy industry. The report, which focuses on identifying the training needs of workers and managers, is part of the ALCHIMIA project, which aims to optimize production in line with environmental, economic, and quality parameters. The report emphasizes the importance of training for both worker acceptance of the new technology and to ensure its optimal use.

Rather than offering specific training products, the report proposes a three-part framework for training activities. This approach recognizes that companies have different needs and a one-size-fits-all training product does not meet the needs of all potential users. Additionally, it acknowledges the varying levels of digitalization in the metal sector.

The three pillars of the framework address both general and technology-specific competency requirements:

- Pillar 1 focuses on identifying the general transversal competencies required for the wider digital transformation of companies.
- Pillar 2 focuses on specific transversal competence requirements arising from the integration of the ALCHIMIA system into specific production contexts.
- Pillar 3 focuses on identifying the competence requirements related to the operation of the ALCHIMIA system.

The document provides a comprehensive list of relevant transversal skills, addressing personal, social, methodological, digital, and environmental competencies, and offers examples of relevant training products for each.

The training needs for workers directly using the ALCHIMIA system are expected to be low because the system largely operates in the background, offering decision support without fundamentally changing tasks. However, workers in roles indirectly impacted by the system, such as those providing input data or those whose work is affected by the system's outputs, will require some training.

A final summary table (Table 16) provides a condensed overview of the recommended training plan, suggesting specific competencies, training approaches, and implementation timelines for each pillar.

List of abbreviations

ALCHIMIA - Data and decentralized Artificial intelligence for a competitive and green European metallurgy industry

CAR - Cardiff

CEDEFOP - European Centre for the Development of Vocational Training

CL – Continuous Learning

CRM – customer relationship management

D – Deliverable

EC – European Commission

ERP – enterprise resource planning

ESCO – European Skills, Competences, Qualifications and Occupations

ESSA - European Steel Skills Agenda

EU – European Union

IoT – Internet of Things

F2F – face-to-face

FL – Federated Learning

ML – Machine Learning

PU - Public

R - Report

R & D – Research and Development

T – Task

UN – United Nations

VET – Vocational Education and Training

WP – Work Package

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1 Introduction

1.1 Interpretation of Deliverable

The interpretation of the Deliverable description is based on three elements:

1. The description of D2.3 itself
2. The description of the associated task T2.5
3. Descriptions of Project Objectives specifically related to D2.3

The ALCHIMIA project proposal describes the Deliverable 2.3: *D2.3 Training Programme (CAR, R, PU, M27) – T2.5. This Deliverable develops training products based on existing good practices, findings and recommendations.* It sets out that the principal consortium partner responsible for D2.3 is Cardiff University. The deliverable will take the form of a publicly accessible report submitted November 2024. The description also sets out that D2.3 is based on work undertaken as part of Task 2.5, and it is informed in part by Task 2.3 and D.2.1 (Weinel et al 2023a).

To start clarifying the meaning of D2.3 a significant ambiguity in the descriptive text has to be resolved as it appears to use 'training programme' and 'training products' interchangeably even though there is a significant difference of meaning between the two terms. The reference to 'products' can be interpreted in line with the Oxford English Dictionary as referring to some sort of 'object produced by a particular action or process'. In the context of D2.3 this would mean some concrete training resources – such as complete training courses ready for practical use. 'Programme' as defined in the Oxford English Dictionary, in contrast, refers more generally to 'a plan or scheme of any intended proceedings (whether in writing or not); an outline or abstract of something to be done.' Going forward with the Deliverable, we understand D2.3 to be about the development of a comprehensive training *programme*, which means in practice that we will produce outlines or themes for training activities that should cover all identified potential competence gaps.

Such an interpretation is, in fact, necessary once it is taken into account that the ALCHIMIA system is to be deployed in potentially very different contexts, involving different companies, located in different countries, operating in different markets and producing different products (see also Section 4.1). Indeed, given that different companies in different countries are likely to use and run different qualification and training approaches for their workforce and can be in very different phases of the digitalisation of their operations, developing one universally applicable 'training product' is not aligned with the requirements of industrial partners. For example, pathways to digitalisation and workforce capabilities might differ significantly between two companies using the ALCHIMIA system, which might mean that one company has to invest a lot into training while another might only require minimal additional training effort to ensure optimal use of the system.

Thus, instead of producing a rigid training *product*, the potential training programme outlined in this report provides the necessary flexibility by identifying what kind of competences[1] of different employee groups are likely to be affected both by the implementation of ALCHIMIA and by the wider digital transformation currently affecting

[1] Throughout this report we use the terms 'competences' and 'skills' interchangeably but have the more encompassing meaning of the term competence in mind. The European Centre for the Development of Vocational Training (Cedefop) defines competence as '[d]emonstrated ability to use knowledge, know-how, experience and – job-related, personal, social or methodological – skills, in work or learning situations and in professional and personal development.' In contrast, the same organisation defines skills as '[a]bility to apply knowledge and use know-how to complete tasks and solve problems.'

all industries across Europe, including the metal and steel sector. The former can be conceptualised as *direct competence requirements* arising out of the practical use of the ALCHIMIA system. The latter, in contrast, can be conceptualised as *indirect competence requirements* linked to the wider process of digitalisation in the European metal sector (e.g. Stroud *et al.* 2024a). Companies can use this report to inform their own bespoke training plan by focusing and implementing the elements that aligns with their needs.

The description of Task 2.5 which underpins D2.3 clarifies what these ideas for training activities should focus on: '*This task identifies training opportunities and develops a potential training programme to meet emerging skill needs arising from the usage of federated learning (as well as machine learning and AI in general) in the workplace.*' T2.5 helps outlines two substantive lines of work: first, to identify emerging training opportunities and second, to develop a potential training programme (supporting our interpretation of D2.3) to meet emerging skill requirements. With regard to the first aspect, this aligns with what has been outlined in the previous paragraphs with regard to desk-based research into existing resources, practices, ideas, findings and recommendations related to training. Additionally, empirical research conducted as part of the ALCHIMIA (D2.1, Weinel et al. 2023b) as well as work undertaken by the ALCHIMIA consortium to define use cases (D5.1, Gálvez 2023) has also informed this aspect.

The second aspect specifies on what sort of issues the potential training programmes should focus: on preparing workers for the consequences that come from working with a system that utilises Federated Learning in particular and AI and ML (machine learning) in general. In this report, we translate these instructions into a training programme consisting of three pillars. Pillar 1 focuses on identifying the general transversal competencies required for the wider digital transformation of companies. Pillar 2 focuses on specific transversal competence requirements arising from the integration of the ALCHIMIA system into specific production contexts. Pillar 3 focuses on identifying the competence requirements related to the operation of the ALCHIMIA system.

D2.3 should also specifically contribute to one WP2-related and to one project-related objective that partly overlap. The WP-level objective suggests that one of the aims of WP2 is '*to develop a training programme to facilitate worker acceptance and optimal use of federated-learning based AI and big-data based technologies within the case scenario context*'. The project-level Objective #4 aims to 'guarantee the highest levels of trust, safety and seamless collaboration between workers and AI-powered industrial solutions (related WPs: WP2, WP5)' (p.5). More specifically, within Objective #4, the goal is formulated that the envisaged training programme is '*to facilitate workers' acceptance and optimal usage of ALCHIMIA*' (p.5). A further clarification regarding the audience and the focus of training effort is provided by the description of ALCHIMIA Objective #4: "All proposals should incorporate training programs for non-expert users of AI, data and robotics systems, who are domain experts and need to know basic AI, data, robotics concepts, including the basics concepts of Trustworthy and ethical AI". These instructions suggest 4 additional aims that the potential training programme should contribute to:

- Facilitate worker acceptance
- Optimal use of FL-based AI and big data-based technologies
- Guarantee highest level of trust, safety and seamless collaboration between workers and AI tech
- Incorporate solutions for non-expert users which allow them to understand basic AI, data, robotics concepts, including the basics concepts of Trustworthy and ethical AI

Taking all the instructions relevant to D2.3 found in the descriptions of tasks, deliverable and objectives together, we understand D2.3 in the following way:

> *This Deliverable develops a potential training programme based on existing good practices, findings and recommendations. The training programme incorporates solutions for non-expert users which allow them to understand basic AI, data, robotics concepts, including the basics concepts of Trustworthy and ethical AI.*
>
> *Beyond meeting emerging skill needs, the training programme should also (A) facilitate worker acceptance, (B) ensure the optimal use of Federated-Learning-based AI systems, and (C) guarantee the highest level of trust, safety and seamless collaboration between workers and technology.*

1.2 Structure of the Report

Based on this wider interpretation of D2.3, this report will comprise three distinct parts.

The first part (Section 2) of the report will provide background on the concept of digitalisation, relate this to the European ferrous metal sector and highlight general effects and consequences of digitalisation for competence requirements and workforce development.

The second part (Section 3) deals with three specific issues concerning training that have been raised in the context of the wider objectives of the ALCHIMIA project. It summarises the state of social scientific research on the relationship between training and worker acceptance and suggests some key characteristics of training programmes to facilitate worker acceptance. It also sets out how the ALCHIMIA projects aims to ensure optimal use of the ALCHIMIA platform and summarises the activities undertaken to ensure the highest levels of trust, safety and collaboration.

The third part (Section 4) contains the outline of the suggested training programme that consists of three pillars. The comprehensive recommendations are based on a combination of empirical and desk research and taking the anticipated functionality of the ALCHIMIA system into account. Pillar 1 (4.3) focuses on identifying the general transversal competencies required for the wider digital transformation of companies. Pillar 2 (4.4) focuses on specific transversal competence requirements arising from the integration of the ALCHIMIA system into specific production contexts. Finally, Pillar 3 (4.5) focuses on identifying the transversal competence requirements related to the operation of the ALCHIMIA system.

The concluding fourth part (Section 5) summarises our findings in one large overview table (Table 16).

2 Digital Transformation of the European Ferrous Metal Sector

The ferrous metal industry as integral part of the European metal sector played a pivotal role in the establishment and development of the European Union (EU) (e.g. Weinel et al. 2024).[2] The emerging European project started as the European Coal and Steel Community (ECSC) in 1952, aimed at creating a unified and jointly regulated market for coal and steel.

Today, the European metal sector, comprising ferrous and non-ferrous metal producers as well as metal recyclers, faces technological, environmental and social challenges that it must successfully navigate for continued survival. In particular, Murri et al. (2023) identify seven drivers of change affecting European industries:

1. Advanced manufacturing (e.g. Industry 4.0 and 5.0),
2. Advanced materials development,
3. Complex and global supply chains,
4. Market competition and over-capacity,
5. Life cycle design, pollution prevention and product recyclability,
6. Decarbonisation and Energy Efficiency, and
7. Evolution of customer requirements.

Digitalisation, not mentioned explicitly in this list, takes up a somewhat hybrid status (Branca et al. 2024): one the hand, it drives these changes as an integral part of some of these drivers (for example, digitalisation and digital technologies are an integral part of change under Industry 4.0 and 5.0. On the other hand, it also offers companies a means to respond to pressures emanating from these drivers. For example, the digital ALCHIMIA system is designed to enable companies to respond to pressures to decarbonise and use energy more efficiently, which should in turn improve the competitiveness of companies.

2.1 What is Digitalisation?

Digital transformation has become a critical topic for organizations across various sectors. At its core, it involves leveraging technology to fundamentally transform business operations and how value is delivered to customers. This goes beyond simply applying digital tools to existing processes. Instead, it necessitates a fundamental shift in how businesses operate and engage with their customers (e.g. Branca et al. 2020, Pfatschbacher and Widter 2021).

The driving force behind this transformation is the digitalization of information, but digital transformation encompasses much more than just digitizing records or transitioning from manual to digital systems. It includes automating business processes, implementing intelligent data analysis capabilities, enhancing customer experiences, and enabling more informed decision-making. This transformation is facilitated by various technologies, such as enterprise resource planning (ERP) systems, customer relationship management (CRM)

[2] Within the context of the European Union, what is referred to as 'metals industry' consists of both ferrous and non-ferrous metal sectors. While the European ferrous metal sector comprises more than just steel production, ferrous metal foundries, for example, do not necessarily work with steel, this sector is often simply referred to as 'steel sector' due to the relative importance of steel production compared to the production of other ferrous metals. In this section, we use the labels 'steel industry' and 'ferrous metal sector' interchangeably.

software, financial and accounting applications, robotics, the Internet of Things (IoT), blockchain, and artificial intelligence (AI) (e.g. Branca et al. 2024).

The impact of digital transformation permeates into organizational structures, corporate culture, customer relationships, and even business models (e.g. Chamorro-Premuzic 2021). Digital transformation requires organizations to rethink and adapt their strategies to align with the digital reality. This affects how they perceive their business, interact with customers, manage data, organize production processes, deliver products or services, and plan for the future. Importantly, digital transformation is not solely about adopting new technologies but rather about the fundamental transformation and change required within the organization. Digital technologies are thus means to an end, which is to change processes and strategies to fully leverage the opportunities presented by the convergence of technological innovations. The ultimate goal is to drive improvements across the organization, including more informed decision-making, optimized processes, and enhanced communication.

2.2 Digitalisation in European Ferrous Metal Sector

Compared to other industries such as media and entertainment, retail, telecommunication and automotive, the digital transformation of the ferrous metal sector is not as well advanced and deeply embedded (e.g. Neef et al. 2018, Branca et al. 2020, Pfatschbacher and Widter 2021, Büchel and Engels 2022). According to a McKinsey survey (McKinsey 2021), the main areas affected by digitalisation within steel companies are:

- Procurement
- Raw materials handling
- (Production) Process control
- Maintenance and engineering
- Supply chain planning and logistics
- Support services and R&D
- Marketing & sales

The ALCHIMIA system itself has the potential to contribute to the digitalisation of (production) process control, raw materials handling as well as supply chain planning and logistics. According to the same McKinsey report, digital technologies are mainly deployed for:

1. Process digitization
2. Advanced analytics
3. Robotisation and Automation.

A review of already deployed technologies by Branca et al. (2020) suggests that the following technologies and processes are being implemented in European steel plants. We have represented these in Table 1:

Table 1: Main digital technologies used in the ferrous metal sector

❖ Internet of Things (IoT) system	❖ Vertical/Horizontal Integration
❖ Big Data Analytics and Cloud Computing	❖ Predictive Maintenance
❖ Robot-assisted production	❖ Cyber Security
❖ Production line simulation	❖ Augmented Work, Maintenance, and Service

❖ Self-Organizing Production	❖ Self-driving logistics vehicles
❖ Cyber-Physical System	❖ Digitalization of knowledge management
❖ Smart supply network	

Source: Authors

The ALCHIMIA system relates to several of these aspects such as Big Data Analytics and Cloud Computing, Production line simulation, Digitalization of knowledge management and Vertical/Horizontal Integration.

A survey amongst European steel companies by the Frauenhofer Institute about the expected benefits of digitalisation by 2030 (Neef et al. 2018: 13) suggests that most companies expect 'strong positive benefits' in the area of process efficiency, business model development and customer-supplier interactions and 'some benefits' when it comes to the development of new products and reducing energy demands and emissions.

Achieving successful digital transformation is, however, not a straightforward undertaking. A recent survey by McKinsey apparently found that less than 30% of digital transformation initiatives succeed across a wide range of sectors (McKinsey, 2018). It requires a clear vision, comprehensive planning, strong leadership, a culture of innovation, agility, customer-centricity, and the development of necessary digital capabilities and competences within the workforce. It is this last aspect, the development of an appropriately skilled workforce to support the wider digital transformations as part of Industry 4.0 as well as specific digital projects, such as ALCHIMIA, to succeed, that this report focuses on.

2.3 Implications for Competences and the Workforce

Digitalisation is widely recognised as a 'megatrend' and it is therefore expected to continue to shape technological and industrial developments in the near future. As an 'old industry' that creates physical products through the transformation of raw materials, it is likely that the hitherto relatively slow and incremental pace of digitalisation of the steel industry will continue.

For workforce development, this means that digitalization in the sector is likely to continue to change tasks and jobs even though this is unlikely to be fundamentally disruptive (e.g. Spöttl et al. 2016, Spöttl and Windelband 2021, Zinke 2019, Antonazzo et al. 2024). While some entirely new (in the context of the steel industry) task and jobs have emerged and are likely to continue emerging in future (e.g. data manager, data analyst, IT and cybersecurity professionals), the main production-related jobs are unlikely to be fundamentally transformed (see Spöttl et al. 2016 and Zinke 2019, see also Section 4.4 below). Out of eight possible development pathways for job and occupational profiles (based on Dostal 2005 and Zinke 2019; see Figure 1 below), the most likely developments will be 'profile modification', 'profile extension' and 'profile reduction' (see Figure 1). For training and development, this suggests incremental development of existing production-related qualifications and competences appears to be sufficient to meet requirements in the European metal sector (e.g. Spöttl et al. 2016 and Zinke 2019).

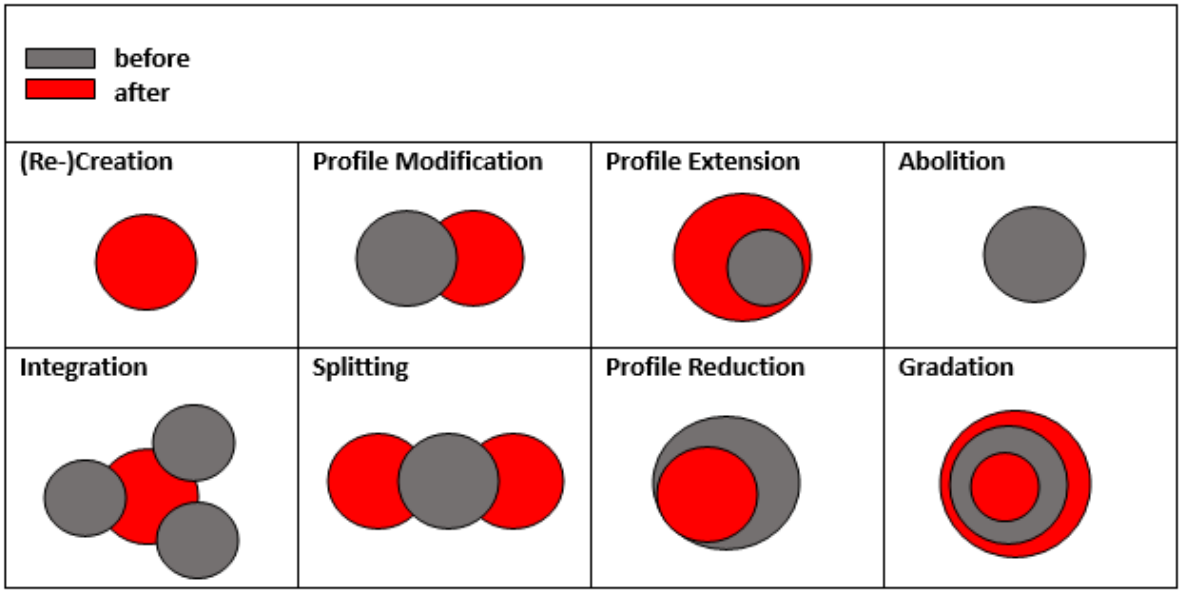

Figure 1 – Possible Pathways of Occupational Profile Development (Zinke 2019)

In the context of the digital transformation, not just of the steel industry, training and development activities need to pay attention to two different kinds of competence requirements. On the one hand, there are very specific competence requirements associated with specific new technologies and processes. For example, workers in the companies participating in the ALCHIMIA project, will need to receive very specific training that allows them to run and use the ALCHIMIA system efficiently and effectively (see Section 4.5). This might involve learning about its functionalities, how to operate the interfaces and how to use it in different situations. On the other hand, there are numerous other competences that are required to support the digital transformation of an industry (see Sections 4.3 and 4.4 in this report: also, Schröder and Stroud 2023, Stroud et al. 2024a Antonazzo et al. 2024 for overviews).

More specifically, as the large-scale Erasmus+ ESSA project (Schröder and Stroud 2023) has demonstrated, within national Vocational Education and Training (VET) systems, which in European states tends to operate at national and/or regional level, existing and established vocational qualification programmes used in the European steel industry to train new and develop existing workers are likely to remain relevant even though the qualification offers will need to be periodically updated and revised to accommodate changing and /or new requirements. At company level, incremental and continuous development of the already existing workforce is a viable option to meet the competence requirements associated with the digital transformation. Some entirely new or substantively modified competences will be necessary but mainly with regard to transversal skills rather than specific technical skills (e.g. Schröder and Stroud 2023, Stroud et al. 2024a).

3 Wider Objectives related to Training

3.1 Training and Worker Acceptance

The issue of 'worker acceptance' of (new) technology has garnered lots of interest and a huge body of literature exists that posits theories and suggests factors that affect this kind of acceptance. Despite the long-standing interest in the topic, no dominant or widely accepted theory or model has emerged that explains as to why technology might be accepted or rejected by workers (e.g. Venkatesh et al. 2003, Beaudry and Pinsonneault 2010). This is due to the multitude and complexity of factors that can shape acceptance or rejection. It is widely recognised, however, that well-designed training opportunities are one such factor that can positively contribute to workers' acceptance of (new) technologies (e.g. Cascio and Montealegre 2016, Feng et al. 2021, Molino et al. 2020), but there is limited evidence that training on its own can make workers accept technologies that they would otherwise reject.

The issue is nonetheless pertinent as the way workers interact and use technology can have important effects on companies' investment in and use of technology (e.g. Edwards and Ramirez 2016). Earlier research as part of the ALCHIMIA project (D2.1, Weinel et al. 2023b) has indicated that most workers in the partner companies view the potential introduction of the ALCHIMIA system positively. Workers' views and perceptions can, however, change over time, which suggests that companies should avoid complacency and be pro-active in trying to shape workers' views of new technologies. To some extent, this can be done through training activities where workers receive a variety of information about technologies and the wider context in which they will be embedded.

In what follows, the focus is not the content of any training measures but rather some characteristics that training efforts around the introduction of new technologies should display to increase the chances of workers' acceptance of these technologies. This is based on an argument advanced by Edwards and Ramirez (2016), who suggest that in the absence of widely accepted theories or models of workers' acceptance of technology, workers and their representatives might analyse any new technology along six dimensions to gain greater clarity as to whether technology effects are likely to be aligned with workers' interests or not. For this purpose, we discuss 6 dimensions of technology effects that are known to have effects on workers' perceptions of technology (see Edwards and Ramirez 2016 and Stroud and Weinel 2020, also Orlikowski 1992).[3]

1. **Intended and unintended effects:** These relate to the 'ends' or 'purposes' for which technologies are introduced. While some or most technologies are introduced with a clear and stated end or purpose – the intended effects –, technologies also tend to have unplanned effects, which means they can contribute to unrecognised (or unstated) purposes. Edwards and Ramirez (2016: 102) maintain that the more specific or narrow the intent of a technology is, the easier it is for workers and their representatives to anticipate and estimate the impact of a technology on their jobs and identities. The ALCHIMIA project proposal, for example, aims to build a platform based on Federated Learning (FL) and Continual Learning (CL) to help big European metallurgy industries unlock the full

[3] This approach is based on a number of assumptions that should be made transparent. Edwards and Ramirez (2016) effectively assume that 'progressiveness' – understood as effects that are seen as beneficial to workers such as higher pay, less work intensity, reduced risks of injury and accidents etc. – is always in the interest of workers and will therefore result in workers' acceptance of technology. They also assume that the analysis of progressiveness is sufficiently 'objective' which allows them in turn to assume that it makes no difference as to whether external 'analysts' (here, the two academics) or internal 'actors' (here, workers or their representatives) perform the analysis. If an analysis suggests sufficient progressiveness of a technology, they assume that workers' resistance will be relatively low (and vice versa).

potential of AI to support the needed transformations to create high-quality, competitive, efficient and green production processes. The clear intended effect of the ALCHIMIA platform is to improve production in several ways. To workers concerned about job security or remuneration levels, for example, these aims of the technology are likely to be viewed positively. A potential unintended effect could, however, be an intensification of work. Given the increased importance of sensor and other production-related data capturing infrastructure, it is reasonable to assume an increase in the volume of maintenance tasks in companies that adopt the system.[4]

2. **Direct and indirect effects:** While both (intended) improved production and (unintended) potential intensification of maintenance work are direct effects of the technology, an indirect effect of the ALCHIMIA system might be that it reaffirms the current model of globalisation that maintains a largely unfettered global market for metal products and lets companies with very different approaches to technology use, exploit differences in standards related to worker welfare and remuneration to compete against each other. While effects, both direct and indirect, of technologies become clearer with time of use, workers can and will anticipate the effects of technologies which, depending on what view is formed, can have both positive and negative consequences for technology acceptance.
3. **Reconstitution in use:** This is best understood as degree or potential of flexibility of a technology in terms of its usage. The greater this potential, the more unpredictable and unforeseeable the ways in which a technology might be employed in the future. Less predictability is likely to have an adverse effect on workers' acceptance of technology. Edwards and Ramirez (2016) contrast 'classic' telephones with 'smartphones': the classic phone could only really be used to make phone calls whereas a smart phone, beyond being still capable of calling someone, can also be used as a PC, a camera or a surveillance device. The ALCHIMIA system is more akin to the old telephone as it can only process data in accordance with pre-set models and formulas that are fairly specific and cannot be simply changed or expanded. But 'function creep' may lead to a reconstitution in use that is difficult to predict at the current time.
4. **Immanence of effect:** This refers to certain (organisational and social) affordances that are effectively inscribed in the technology. Edwards and Ramirez (2016: 103) illustrate the meaning of this in the following way: "Suppose that a machine gun is invented that calls for three men to operate it. It is natural to organise them in teams of three, a result which is strongly immanent in the technology. It may also… be natural to organise the three so that one has authority over the others, a result that we see as less strongly immanent but reasonably directly a result of the technology. … Certain technologies either require or strongly imply certain forms of social organisation." Immanence is relatively low when it comes to the ALCHIMIA system. This, according to Edwards and Ramirez (2016: 104), might positively impact workers' acceptance because "where effects are less immanent, there is more space to moderate any negative effects."
5. **Degree of success:** Success of a technology from a workers' perspective entails at least two aspects. One aspect concerns the question as to whether a technology works as intended – does it fulfil its stated aims. The other relates to the conditions under which a technology can be successfully applied or used. The two aspects should be regarded together: while some technologies might be regarded as 'working as intended', the amount of work to make them work or the organisational changes required to make them 'work' might negatively impact workers' acceptance. In the case of ALCHIMIA, the

[4] Of course, there is nothing inevitable about this and it demonstrates the complexity behind workers' acceptance of technologies. If maintenance workers can reasonably believe that the capacity of maintenance teams are increased in line with expected growth of workloads, this unintended effect might not play a role in developing workers' attitudes towards such a technology. If they cannot expect any capacity increase – for example, because management is also engaged in cost-cutting measures – such unintended effects might prove important for the rejection of technologies.

success of the technology will depend on both the accuracy of the models underpinning the AI system but also, in the case of EAF application, on improved accuracy of crane drivers tasked with loading scrap baskets or the accuracy of scrap yard workers in correctly classifying and storing scrap.

6. **Degree of discontinuity:** This relates to wider effects of a technology in terms of disruptiveness and change after its introduction compared to how things used to get done before its introduction. The greater the degree of discontinuity, the more difficult it will be for workers to assess the impact of a technology, and which might negatively impact workers' acceptance. In the case of the ALCHIMIA system, the degree of discontinuity is fairly low as the technology does not fundamentally change any productions processes. In the case of the EAF application, the platform simply offers decision support for already existing processes and tasks such as receipt selection and furnace control. In the case of the foundry application, the prediction of quality outcomes aims to produce faster assessments or product quality. While this might make certain existing tasks redundant (such as the performance of certain product tests), this is not a fundamentally disruptive process.

These considerations about the effects and consequences of inserting a technology into an organisation also support a few considerations about the characteristics of training efforts that might help to foster increased workers' acceptance of technology. Companies implementing ALCHIMIA should ensure that their training activities display the following characteristics:

- High-quality, engaging training can contribute to workers' acceptance by fostering understanding of technologies and their effects as well by dispelling concerns about potentially negative consequences
- Training content ought to be honest and transparent about intended direct and indirect effects
- Training should always acknowledge the potential for unintended (and unrecognised) effects
- Training should provide as much clarity and transparency as possible about potential for reconstitution in use and the degree of discontinuity
- Depending on the potential for reconstitution in use, training should assure workers about what the company considers to be the limits of reconstituted use of technology
- Depending on degree of discontinuity, training should provide as much transparency as possible with regard to wider consequences of technology use and the way in which the company intends to deal with these wider consequences

3.2 Training and Optimal Use of ALCHIMIA

The ALCHIMIA project takes a variety of steps to ensure the optimal use of the ALCHIMIA system. First, the training programme suggested in the present report should ensure that direct and indirect competence requirements needed to run the ALCHIMIA system in production contexts are taken into account. Second, the human-centred design approach that informs the development of the ALCHIMIA platform should lead to design solutions for users that are as ergonomic and intuitive as possible (see ALCHIMIA D2.1). Third, the development process also entails training workshops with users that provide additional opportunities within the companies to ensure staff can optimally use the ALCHIMIA platform.

With regards to training programmes to aide optimal use, we suggest three distinguishable but complementary pillars of a training programme that, when implemented together, should ensure the optimal use and functioning of the ALCHIMIA platform in real-life organisational settings (see Figure 2). The representation of the three

pillars (or elements) in the target diagram below signals that the three different pillars affect ever-increasing populations of employees in the companies.

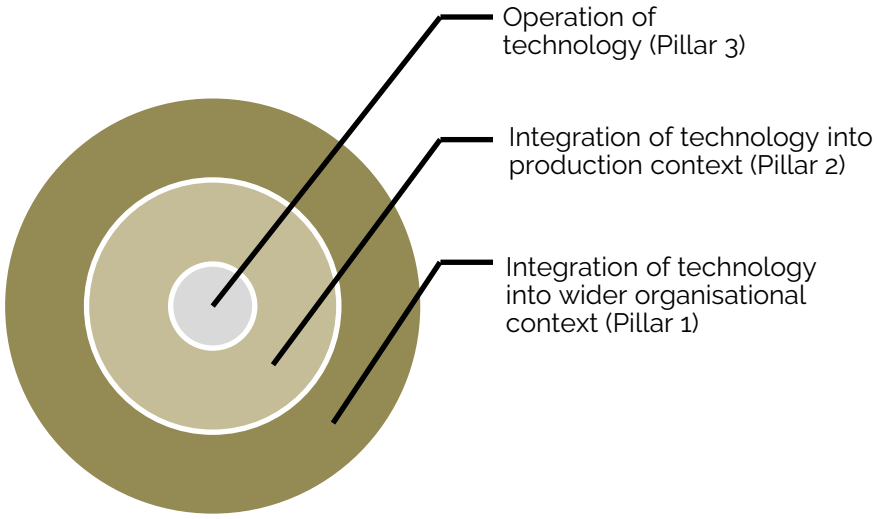

Figure 2 – Training Programme Pillars ensuring optimal use

The respective competence requirements related to the three pillars will be described and analysed in greater detail in Section 4 as three connected but distinguishable pillars of a comprehensive training programme. While the outline of the training programme in Section 4 will move from the most general (Pillar 1) to the most specific (Pillar 3) competence requirements, we briefly outline them here in reverse order.

The 'operation of technology' refers to the actual interaction between immediate users and platform via various interfaces. The interfaces allow immediate users, mainly operators or production managers, to directly control and configure the ALCHIMIA platform, such as selecting certain parameters that determine how the platform calculates the optimisation scenarios of the processes (for example, in the case of EAF steelmaking, the platform ought to allow operators to prioritise environmental performance over economic performance). These very narrow and specific competence requirements are dealt with in Pillar 3 (see Section 4.5). Only immediate users have to be familiar with the detailed functionality of the platform and need to be able to competently manipulate the interfaces in line with specific objectives and instructions.

The ALCHIMIA platform is, however, not an isolated technological artefact but will be integrated in larger production contexts, which will affect some existing tasks and jobs and might even create new tasks and perhaps even new jobs (see Weinel et al. 2023b). This means a new technology also needs to be integrated into specific contexts that consist of specific tasks and processes that vary from company to company, which is what Pillar 2 is designed to deal with (see Section 4.4). The effects of the technology go beyond the direct interactions with immediate users, i.e. operators who do not directly interact with the AI platform might still have to change routines and adapt tasks. This then requires what we refer to as (technology-)specific competence requirements. In the case of the ALCHIMIA platform, these requirements are relatively minor because the technology operates mainly in the background and most of its 'internal' workings are 'black-boxed', which means they are not accessible to users. This also means that only a few tasks of a few operators are specifically affected by the use of the ALCHIMIA platform.

Beyond these two ALCHIMIA platform-specific elements contributing to its optimal use are wider competence requirements that relate not to specific technologies but to greater transformations of companies. These are described under Pillar 1 of the proposed training programme. In this case, the digital transformation of companies (of which a production optimisation system such as the ALCHIMIA platform is just one instantiation) requires wider shifts in competence profiles. One crucial effect of digitalisation of businesses is the closer vertical and horizontal technological and organisational integration of businesses, which creates new interdependencies and closer collaboration/ interdependencies between technology and humans. This requires, among other things, understanding the potentials of new technologies, how humans and technologies (or different parts of a business) are connected and what this means in practice. For example, data driven technologies need elevated accuracy across whole systems; or interconnected production processes need better maintenance to ensure continuous running (as a fault anywhere can now affect the whole of production, which was not the case in more unconnected systems). In other words, the smooth working of each element in increasingly complex production system becomes more important due to ever-increasing interdependencies between different parts of a company. These wider and generalisable competence requirements are described in Section 4.3.

3.3 Guarantee highest level of trust, safety and seamless collaboration between workers and AI tech

Three separate processes and elements should ensure that the ALCHIMIA system is regarded as trustworthy and allows for seamless collaboration between the AI-based system and workers.

First, the human-centred design approach goes some way to ensure the trustworthiness and safety of the system as well as the seamless collaboration between workers and technology. By actively and directly involving stakeholders at all development stages of the project the ideas and concerns of end users have been considered and have been addressed as far as has been possible.

Second, aligning the ALCHIMIA system with EU guidelines on trustworthy AI ensures that the AI platform's design does not feature any elements that the High-Level Expert Group assembled by the European Union regard as ethically problematic. Repeated cycles of working through the Assessment List for Trustworthy Artificial Intelligence (ALTAI) has helped the ALCHIMIA development team to find the most ethical design solutions (see Weinel et al. 2023b (ALCHIMIA D2.1) for details).

Third, high-quality and engaging training can contribute to elevate workers' trust levels in the new technology. Fully understanding the capabilities, effects and wider consequences of the use of the ALCHIMIA system is just one aspect in this regard. By investing in excellent training, companies can also signal to their workers that the human element in the new collaboration between AI-based technology and workers is highly valued.

4 ALCHIMIA Training Programme

4.1 Rationale for focussing on a training programme

The interpretation of the Deliverable above has suggested a distinction between training products and training programmes. As the focus is firmly on the latter, in this part of the report we provide the outlines of a comprehensive training programme. This means end-users are not provided with ready-made and universally usable training products but must consider the wider catalogue of proposed training suggestions and then take the elements that suit them to produce or procure training products according to their own needs.

There are several factors operating at various levels that explain why the focus has been necessarily placed on a training programme rather than on training products. First, the ALCHIMIA system is designed to be deployable in many different European contexts (and beyond). This suggests that different companies, wanting to deploy the ALCHIMIA system, operate in potentially very different national and regional Vocational Education and Training (VET) systems.[5] Different companies have very different starting points when it comes to competence development. While some VET systems, for example the German system, aim to develop and train apprentices in a range of well-defined occupational qualifications, other systems seem to be content with providing the bare minimum so that novices can start to perform a 'job' and learn further while doing it. This means in practice that some of the elements of the ALCHIMIA training programme might already have been covered by vocational curricula in some countries but not in others.[6]

Second, apart from potentially significant differences in VET systems, companies tend to develop and follow their own training strategies and approaches to ensure that any competence gaps are closed quickly. We found evidence for this while conducting empirical research in the participating companies (Weinel et al. 2023b). A manager in FdT suggested:

> *'When the worker is subsequently hired [after an initial 12-month training period] by the company, there is a tailored training and career development plan within the company for each specific professional role. This plan unfolds annually as a training project, funded by the company, where we gather the training needs of each professional role to define the training plan for the upcoming year. This training activity involves all the company roles'. (…) So it's some training here on site, on the job, mainly. They can even attend like remote courses online. [Our] digital platform … holds up to 350 classes ranging from it to cybersecurity to foundry industry…' (FdT2).*

During earlier fieldwork, interviewees working for our industrial partners suggested that very different strategies and approaches are often used in parallel, depending on the particular needs of staff. According to interviewees training might be provided in-house or by external providers, might be class-room based or on-the-job, might be continuous or one-off, might be delivered 'online/remote' or 'in-person'.

[5] CEDEFOP's 'Future of VET' research project (https://www.cedefop.europa.eu/en/projects/future-vet) provides exemplary overviews over the distinctive features of all European VET systems. See also the special issue of the Hungarian Educational Research Journal (Markowitsch, Benke and Bjørnåvold 2022) which summarises the findings of the first project phase.

[6] For example, Germany has integrated a substantive module on digitalisation and digital competences as part of every apprenticeship in the metal sector.

Providing particular training products, say in the form of a remotely delivered online course, might not fit into the approaches of companies intending to use ALCHIMIA. Instead, the companies are themselves best placed to decide what type and form of training to use.

Third, companies intending to use the ALCHIMIA system might also be in very different phases of the digitalisation of their operations, which again means that developing one universally applicable 'training product' is not aligned with the requirements of industrial partners. For example, pathways to digitalisation and workforce capabilities might differ significantly between two companies using the ALCHIMIA system, which might mean that one company has to invest heavily in training while another might only require minimal additional training effort to ensure optimal use of the system.

A fourth aspect is that different companies might have very different ideas with regard to what depth training should have and, consequently, what level of proficiency workers should reach with regard to various aspects. Some companies seem to favour providing simple and shallow training, while other companies encourage and embrace training that enables workers to develop high levels of expertise in certain areas. The ALCHIMIA training programme suggested here remains neutral with regards to the depths of training efforts.

4.2 ALCHIMIA Competence Requirements

The ALCHIMIA project aims to develop an artificial intelligence-based system that uses company-internal production data to continuously optimise production processes with regard to, resource input, energy consumption and environmental performance to achieve the same or better product quality more efficiently and effectively.[7] A specific feature of the ALCHIMIA system is the use of an approach to machine learning (ML) that is known as 'federated learning'. Federated Learning (FL) is an approach that maximises data privacy by pooling data from different users in a way that departs from traditional ML approaches (Konečný 2016). The latter tend to work with so-called 'data lakes', where data from different users forms a singular 'data lake', which is the basis for the training and continuous improvement of a 'global model' that is used by all participants. In contrast, FL keeps user data separate. All separate participants in a 'federation' develop their own local models based on their own data and only share these local models with a central server. The 'global model' develops and improves on the basis of learning from pooled local models, i.e. already processed and abstracted information instead of raw data, thus protecting data privacy of individual participants. Therefore, Federated Learning enables users, who do not want to share data with others, to still benefit from ML technologies.

The following three sections (4.3, 4.4. and 4.5.) consider competence requirements related to the ALCHIMIA platform as an instantiation of AI-based production optimisation technologies. These sections are based on our detailed analysis of current production processes (ALCHIMIA D2.1.; Weinel et al. 2023b), a thorough use case definition process (D5.1., Gálvez 2023) that sets out the anticipated functionality of the ALCHIMIA system in the two application scenarios, and on extensive desk research. To structure this part of the report, we utilise two basic and widely used distinctions.

First, we distinguish between technical and transversal competences. In the context of this report, we use the term 'technical competences' to refer to job-specific competences,

[7] In practice, it might not always be possible to optimise all three major aspects simultaneously. For example, some types of scrap are cheaper than others, but cheaper scrap might require more energy input. This might make sense in periods of relatively low energy costs.

i.e. skills, knowledge and/or abilities that are prerequisites to perform specific jobs or occupations. They are sometimes also referred to as 'hard skills'. 'Transversal competences', in contrast, are those that are useful across sectors, occupations and jobs and relatively independent of specific technical developments. Transversal competences are also often referred to as 'technology-unspecific', 'soft' or 'transferable competences'.[8]

Second, we make a distinction between 'specific' competence requirements that arise out of the use of a particular technology, here the ALCHIMIA system, and 'general' competence requirements that arise out of the digitalisation of the steel sector and that are required to enable and support the digital transformation of the sector.

The two distinctions refer to different aspects of competences and can be combined to define four particular competence types:

1. (Technology-)Specific Technical Competences
2. General Technical Competences
3. (Technology-)Specific Transversal Competences
4. General Transversal Competences

Our analysis suggests, perhaps somewhat counter-intuitively given the prominence of 'technology', that no significant new 'technical' competences are required when it comes to the insertion of the ALCHIMIA system into the participating companies. This is mainly due to the fact that the ALCHIMIA system operates both largely autonomously and in the background. This means that while it certainly affects particular jobs in specific ways (see Section 4.4 below), it does not fundamentally change the basic processes that characterise any of the production-based jobs. Instead, the ALCHIMIA system gives operators an additional tool to perform their existing jobs differently, and hopefully, better.

What the insertion of the ALCHIMIA system does affect, however, is what might be called the 'qualitative' requirements of the relevant jobs. As will be shown in greater detail in Section 4.4 below, some of the involved jobs require greater need to communicate across production processes or require more accuracy and diligence. Thus, the additionally required competences due to the insertion of the ALCHIMIA system are typically transversal competences such as adaptability, communication, and process understanding/ knowledge and so on. For the remainder of this report this means that we are exclusively focussing on transversal competences.

Over the next three sections, we develop a training programme consisting of three main pillars or components which will be summarised in Section 6. The three pillars identify and set out the requirements related to transversal competences, both general and specific, to ensure the optimal working of the ALCHIMIA platform when inserted into real production contexts. The training plan will help end-users to identify their own, specific and context-dependent training requirements by comparing the competence requirements set out here with the available competences of their workforce.

[8] The distinction between transversal and technical competences is more complicated and beset with problems than made out here, but we use the terms pragmatically so that the classificatory difficulties that one might encounter when looking deeper into the concepts are irrelevant. One problem is that both concepts are 'relative' and not 'absolute' concepts, which means what counts as transversal and technical in any given context might vary. For example, a classic transversal or 'soft skill' is 'communication', yet it is obvious that for some jobs, the ability to 'communicate effectively and efficiently' is a pre-requisite to perform particular jobs such as shop assistant or marketing professional.

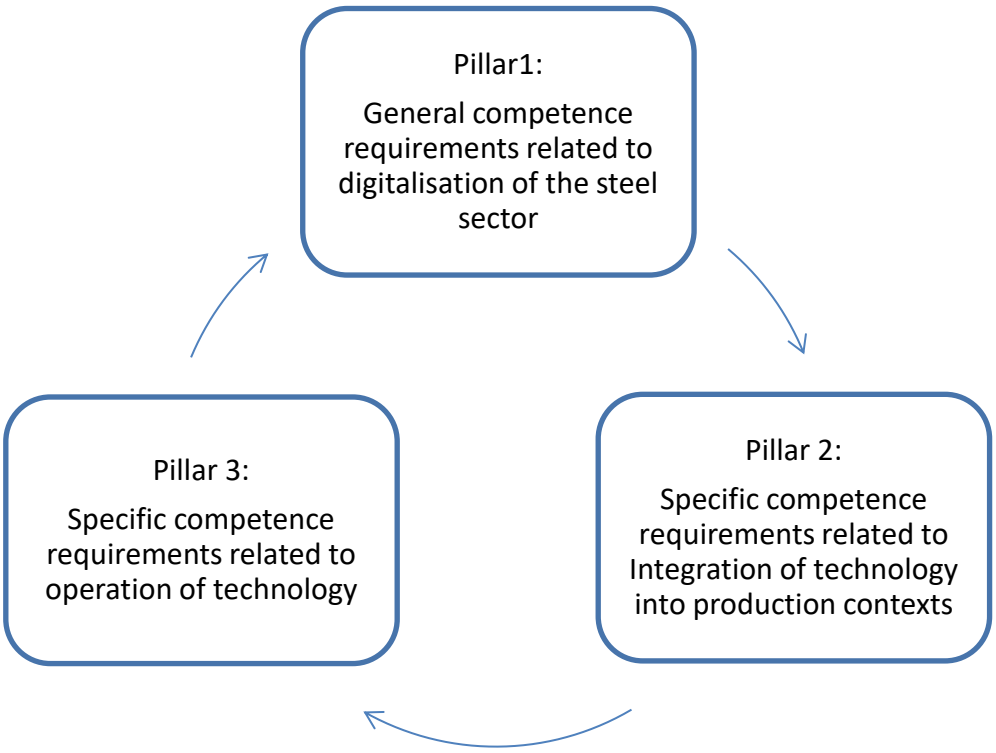

Figure 3: Overview of three pillars of Training Programme

The next section (4.3) considers Pillar 1 competence requirements, or more specifically, general competence requirements arising out of the digitalisation of the steel sector. We start with the general transversal competence requirements because this allows us to introduce some of the terminology that will also be relevant for the assessment of specific transversal competence needs. The focus is on how the competences of the wider workforce of metallurgical companies need to change to support the wider digital and environmental transformation of the metallurgical industry. It is anticipated that the continued move towards Industry 4.0 and/or 5.0, as well as the need to meet environmental targets set for the metals sector in Europe, will require a much wider and more intense use of digital technologies (Murri et al. 2023; Branca et al. 2024; Antonazzo et al. 2024). The focus of this report is mainly on production-based workers (supervisors, operators) and on senior staff in managerial positions. The findings presented in this section should be generalisable beyond the specificities of the ALCHIMIA project and should be applicable to any industrial company that undertakes a digital transformation.

After that, Section 4.4 considers Pillar 2 competence requirements, i.e. the specific competence requirements related to the use and operation of the ALCHIMIA system. For analytical and presentational purposes, we distinguish between what we call direct and indirect competence requirements, although it is important to stress that both kinds of competence requirements are essential to operate the ALCHIMIA system effectively. The section is based on an empirical analysis of actual production processes and anticipated effects of the ALCHIMIA system on existing tasks and jobs in the two participating companies (see Weinel et al. 2023b). The degree of generalisability of the findings in this section is limited due to the specifics of the technological platform and the social and technological organisation of the production processes in the two participating companies. Thus, the findings are not necessarily extendable to other AI-based optimisation platforms or to other companies that want to use the ALCHIMIA system.

Finally, Section 4.5 briefly considers Pillar 3 competence requirements which are related to the actual operation of the ALCHIMIA system when deployed in industrial contexts. As the ALCHIMIA system is still being developed and some of the crucial details are not yet known (e.g. the design of the interfaces is still under development) the considerations offered here are kept relatively general to ensure that the training programme covers all aspects needed to ensure the optimal use of the ALCHIMIA system.

4.3 Pillar 1: General Transversal competences

The increasing importance of Transversal Competences

As set out in the previous section, the proposed training programme will exclusively focus on transversal competences, both in the form of technology-specific and general transversal competences.

The overarching argument for the importance of general transversal competences is that the increased digitalisation of companies tends to result in closer vertical and horizontal technological and organisational integration of hitherto more separated parts of businesses and closer collaboration and/or interdependencies between technology and humans. While increased integration and connection presents some clear advantages, e.g. more efficient and flexible (production) processes, it also generates new risks as the smooth fault-free working of each element in increasingly complex production system becomes more important due to ever-increasing interdependencies between different parts of a company. This puts more demand on staff as the digital transformation of companies requires greater numbers of employees to understand the potentials of new technologies, how humans and technologies (or different parts of a business) are connected and what this means in practice. For example, data driven technologies need elevated accuracy across whole systems; or interconnected production processes need better maintenance to ensure continuous running (as a fault anywhere can now affect the whole of production, which was not the case in more unconnected systems). As a result, intra-company cooperation and communication will become more important given that actions in one part of a company are likely to create effects and consequences in many other parts. Likewise, a greater understanding of the overarching production system by all workers is required to avoid actions that can (inadvertently) affect other parts of companies negatively.

The increasing importance of transversal competences as part of a holistic approach to competence development is widely recognised within the European research community that focuses on digitalisation (and other contemporary transformations such as moving European industries onto a path to Net Zero emissions) as well as by companies. As a result, 'the mix of technical and soft skills and competencies is changing, with digital and soft skills increasing in their relative importance and catching up with technical and sector-specific ones' (Antonazzo et al 2024: 178). The BEYOND 4.0 project, which interviewed steel industry experts from Germany highlighted the importance of non-digital skills, such as personal skills and methodological skills (including many as pre-requisites) for digital skills due to the 'requirements for the continuous learning of new skills in dealing with digital systems and software…' (Götting et al 2024: 214).

During the ALCHIMIA-related fieldwork, a manager at the participating steel company elaborated on the increasing importance of transversal skills with regard to managers and engineers:

> *'The managers, the skills that we require for them on leadership etcetera, to engage these operators to do more things… And also, for the technical*

engineers, they require new skills related with everything, related with artificial intelligence, data management, all these issues. I mean now more and more we require people who are more familiar with how to analyse a big amount of data, or some engineers that are able to understand what a data scientist says. I mean, of course the process engineers won't be experts in data science, but they need to have which are the results and the conclusions, et cetera, and they require some skills about that' (CELS7).

The quote highlights the wide spectrum of new competence requirements as part of the digital transformation. These do not only apply to senior employees but to virtually all employees in all areas of a company.

The above quote also highlights, however, another very important insight: the respondent suggests that the mastery of additional competences does not necessarily need to reach 'expert levels' to be effective. For example, production engineers do not need to become full blown computer scientists to understand the opportunities and risks of AI applications for process optimisation. Likewise, a scrap yard operator does not necessarily need to completely understand how a combination of models, algorithms and data produces decision-support to optimise processes, but they need to develop an understanding of the relationship between their practice of classifying, labelling and storing scrap and the performance of a platform like ALCHIMIA. This insight, of course, has great importance for approaches to training. It suggests that training efforts do not have to turn novices into experts to make digital transformations work. Instead, inexpensive, simple and quick interventions that foster basic conceptual comprehension to allow for seamless communication between specialists and non-experts might often be sufficient.

The following sections outlining transversal competence requirements are mainly based on desk research that summarises and consolidates insights generated by recent European research projects (e.g. ESSA, BEYOND 4.0), by academic studies and other research efforts by EU institutions (e.g. EC, CEDEFOP, ESCO). In the next section (4.3.1.), the report considers a number of different transversal competences that have been identified as important for the European ferrous metal sector. We use European Steel Skills Alliance (ESSA) project's five transversal competence categories as a basis for the structure of the discussion of transversal competences. Further, we use definitions of transversal competences and skills from the ESSA project, Beyond 4.0 project and other EU institutions (e.g. EC, CEDEFOP, ESCO).

Classifying Transversal Competences

The Erasmus+ funded ESSA Project, which recently mapped competence requirements for the next decade or so in the European ferrous metal sector, grouped some of these transversal competences into five overarching competences categories (Weinel et al. 2023):[9]

1. personal competences;
2. social competences;
3. methodological competences;
4. digital competences
5. environmental competences[10]

The ESSA Project has systematically mapped and documented the competence needs for the sector over the next decade or so (until 2030) based on what industry stakeholders – sector organisations, employers, trade unions, educational institutions – reported when asked about the ongoing digital, environmental and technological transformation of the steel industry (e.g. Antonazzo et al 2023, Schröder and Stroud 2023).

Building on ESSA and informed by our fieldwork and analyses of likely impacts of inserting an AI-based platform such as the ALCHIMIA into the participating companies, we have identified the following 10 competences as being the most relevant in the context of ALCHIMIA:

- Adaptability;
- Communication;
- Teamwork;
- Learning to learn;
- Critical thinking;
- Process knowledge/understanding;
- Information and Digital literacy
- Digital safety;
- Digital problem solving;
- Sustainability

We do not consider the other two skills identified by ESSA in this report - metallurgical skills and advanced engineering – as they lack relevancy in the context of the ALCHIMIA project[11].

Under each of the five overarching categories, we consider category definitions, identify the most relevant competences and suggest how such training might be delivered. Additionally, we provide some illustrative, yet relevant examples of potential training products (see also Appendix A3 for additional examples related to the different competences). Where possible, we have identified best practice training products specifically for the metallurgy sector (e.g. steelHub) or by other respected providers (e.g.

[9] This approach is a pragmatic one to allow structured discussion. However, transversal competences can also be job specific, and these four categories are only one way to sub-classify transversal competences. For example, ESCO subdivides 'transversal skills and competences' into six 'narrower concepts': core skills and competences; thinking skills and competences; self-management skills and competences; social and communication skills and competences; physical and manual skills and competences; life skills and competences .

[10] The ESSA project tended to use the term 'green skills', but here we prefer to use the term 'environmental competences'. Elsewhere we suggest that the former term is unhelpful in supporting the much-needed greening of industries. For a critical discussion of the 'green skills' concept, see Stroud et al. 2024b.

[11] Metallurgical and advanced engineering skills will tend to be already in place at the sites. The training programme is concerned with additional or new competence needs due to the introduction of the ALCHIMIA system which are transversal in nature.

universities, EU, UN); otherwise, we have provided examples of easily accessible and widely used training sources (Coursera, LinkedIn, The Knowledge Academy)[12].

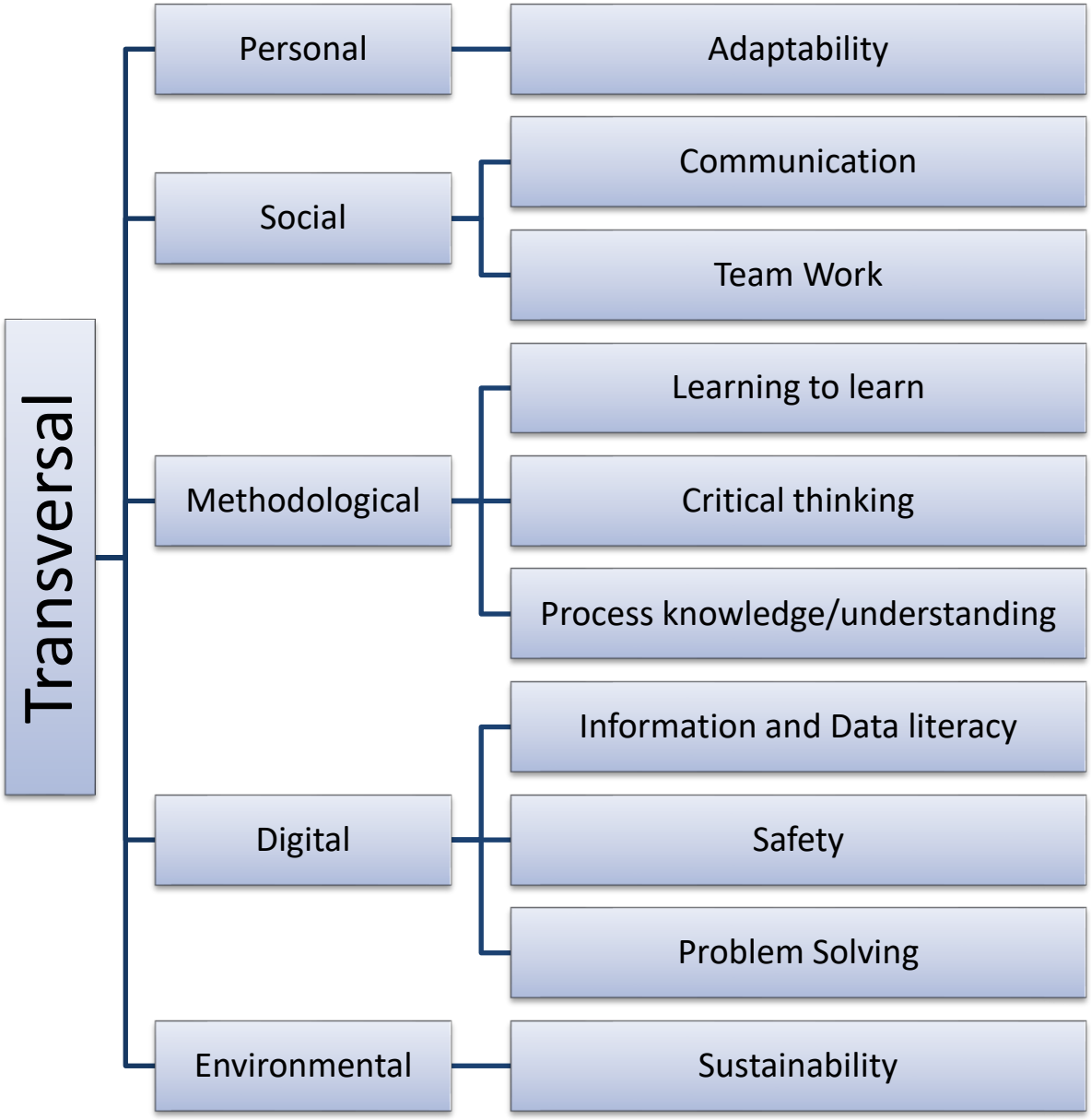

Figure 4: Overview of Types of Transversal Competences

Personal Competences

In the Beyond 4.0 Project, which 'aims to help deliver an inclusive European future by examining the impact of the new technologies on the future of jobs, business models and welfare' (https://beyond4-0.eu/the-project), personal competences are 'personal traits

[12] The courses are mostly at beginners' level to address Objective 4 and the needs of non-expert users. Individual sites will be able to identify when staff require more advanced courses and will be able to locate appropriate courses that are available in that particular country/language.

that people need in order to fulfil their working tasks and to succeed in the modern world of work' (Kohlgrüber et al. 2021: 35). Personal competences, such as openness, ethical skills and the willingness, ability and intrinsic motivation to work autonomously, learn, change and adapt, were found to be important in the digital transformation (Götting et al 2024; Antonazzo et al 2024; Abel 2018; Janis and Alias 2018; Kohlgrüber et al. 2021; Akyazi et al. 2022; Akyazi et al 2024; German National Academy of Science and Engineering 2016).

Adaptability was found to be one of the personal competences particularly important in the digital transformation, including in the steel industry (Götting et al 2024; Antonazzo et al 2024; Abel 2018; Janis and Alias 2018; Kohlgrüber et al. 2021; Akyazi et al. 2022, 2024; German National Academy of Science and Engineering 2016), as this manager confirmed: 'We cannot keep stop, no, have to keep going and changing with the timing and adapting the skills of the people with what the new times requires' (CELS7).

ESCO, the web-based multilingual classification of European Skills, Competences, and Occupations, describes the skill 'to adapt to change' as the '[ability to] alter one's attitude or behaviour to accommodate modifications in the workplace' (http://data.europa.eu/esco/skill/A1.1.0).

At FdT, it was anticipated by some interview participants that in order for the Alchimia system to have sufficient data, there would be an increase in the frequency of some tasks and therefore the potential to intensify work. Operators might be asked to take liquid metal samples and temperature measurements more frequently (i.e. collect data), which would involve putting on protective clothing and leaving their control booth. More frequent engagement with hot liquid metal is also a potential additional health and safety concern which may require additional training. Adaptability will be needed to incorporate these new routines into existing roles.

At CELSA, the main adaptability will be to consider/evaluate recipe proposals provided by the ALCHIMIA system via the digital interface. For example, a manager at Celsa Spain proposed that 'scrap inspectors can learn from the system' (CELS1). While a manager at Celsa France envisaged that a benefit of the ALCHIMIA system would be that it would allow workers to 'dedicate themselves to other things' (CELF6).

If adaptability as a competence has not been instilled during prior professional/vocational training, on-the-job training with adaptability as part of the company modus operandi might be sufficient to ensure sufficient competence in this area. If further external training is required, short online training courses are available. Table 2 lists two examples of available training products for personal competences (see also Appendix A3 for more examples of training products).

Table 2: Examples of training products for personal competences

Example training products	Description of training product
Adaptability and Resiliency | Coursera;	Beginner level, 8-hour course, covering: 'knowledge and tools to become more adaptable and resilient in your workplace and in your life'.
Building Adaptability in the Age of AI | LinkedIn Learning	Beginner level, 5-hour online videos, covering developing an adaptable and growth-centred mindset; building resilience; navigating change; enhancing

	flexible thinking; learning and upskilling effectively; and, cultivating mental agility.

Social Competences

Social competences are becoming more important due to digitalisation and changes in the organisation of work (Götting et al 2024; EC 2019; Akyazi et al. 2022; Deming 2015) and will continue to be important in the future because they resist automation (Cedefop 2019 and Eurofound 2018). Social competences are any which involve interpersonal interaction (Götting et al 2024), including basic communication skills (e.g. information exchange) and more complex social interaction competences (e.g. teamwork skills, connectivity, collaboration, interdisciplinary cooperation, intercultural skills, social network coordination, conflict resolution, teaching, mediation, negotiation, persuasion, personability, entrepreneurship, initiative taking, interpersonal skills, empathy, active listening, effective communication, leadership, managing others, conflict resolution, networking, teaching and training others) (Bacon and Blyton 2003; Kohlgrüber et al. 2021; Götting et al 2024; EC 2019; Schlegel et al. 2018; Gajdzik et al. 2020; ESSA 2019; European Centre for the Development of Vocational Training 2009; Akyazi et al 2024; Bughin et al. 2018; DRIVES 2020).

Of these, communication and teamwork in particular are becoming more important (Götting et al 2024; EC 2019; Akyazi et al. 2022; Deming 2015) and will continue to be in the future because they resist automation (Cedefop 2019; Eurofound 2018; Publications Office of the European Union 2018). ESCO describes **communication** as '[t]he exchange and conveying of information, ideas, concepts, thoughts, and feelings through the use of a shared system of words, signs, and semiotic rules via a medium' and **teamwork** as 'The cooperation between people characterised by a unified commitment to achieving a given goal, participating equally, maintaining open communication, facilitating effective usage of ideas etc.'.

At FdT, there will need to be increased interdepartmental communication and teamwork relating to the increased frequency of and more accurate timing of measurements and sampling and relating to the additional production-related data which will be available on the ALCHIMIA interface, as this casting department worker relayed:

> *'The ALCHIMIA system would require the monitoring of all parameters in all departments, and someone would need to make a report. Currently, there are various operators who perform hourly checks to see if there are any production-related issues. However, we only discover these issues once the piece has been made' (FdT4).*

At CELSA, there may need to be more communication and teamwork around recipe selection. For example, suggestions about scrap classification from the ALCHIMIA interface will need to be taken into account. This includes communicating the new scrap classification process to external scrap suppliers, who may be resistant to changes in their commercial relationship, as this manager proposed: 'Well it's going to be difficult to explain to the supplier that now what has been done by a person which is like 40 years of experience and you know how they work and you know the criteria' (CELS1).

At both companies, due to digitalization there will be increased communication and teamworking between IT and other departments, and externally with digital innovation companies and digital technology suppliers.

Communication and teamwork are already critical to the successful operation of this industry. Any improvements required would be best facilitated through customised on-

the-job training. There are also short online training courses available for these skills. Table 3 lists two examples of available training products for social competences (see also Appendix A3 for more examples of training products).

Table 3: Examples of training products for social competences

Example training products	Description of training product
Teamwork Skills: Communicating Effectively in Groups | Coursera	Beginner level, 11-hour course, covering: Learning how to communicate to resolve or diffuse group conflicts; Making better decisions about using technology for group work based on key practical and conceptual considerations.
Communication within Teams | LinkedIn Learning	Beginner level, 45-minute course, covering: essential elements of team communication; and, how to best communicate with your team in different settings.

Methodological Competences

At least two recent major competence-focussed research projects, ESSA and Beyond 4.0, emphasised the importance of both basic methodological competences (such as basic language, literacy, cognitive and numeracy skills) and advanced methodological competences (such as logic, decision-making, complex problem solving, creativity, and complex, critical, strategic, interdisciplinary and systematic thinking) as essential pre-requisites to knowledge acquisition, including learning digital skills and using digital technologies (Kohlgrüber et al. 2021; Götting et al 2024; Antonazzo et al 2024; Akyazi et al 2024; EC 2019). In addition, Akyazi et al (2024) identified other methodological competences as important: cross-functional process know-how; opportunity assessment; risk management; customer relationship management; quantitative and statistical skills; complex information processing and interpretation; advanced literacy. Furthermore, while digitalisation may lead to reduced work (and work process) complexity, non-routine work processes may become more complex and need advanced methodological competences, such as **process knowledge/understanding** (Kohlgrüber et al. 2021), because 'understanding of systems, expertise and experience are particularly in demand' (Götting et al 2024: 214; Kohlgrüber et al. 2021; Zinke 2019; Antonazzo et al 2024), as this manager relayed:

> 'Now we want operators that they think as part of the process. They are aware of the process; they suggest ways to improve the process... I mean technology is changing, the processes are changing and to be competitive you have to do more things in your work, I mean, here and everywhere I suppose' (CELS7).

Critical thinking is one of the pre-requisites to knowledge acquisition and lifelong learning, including learning digital skills and using digital technologies (Kohlgrüber et al. 2021; Götting et al 2024; Antonazzo et al 2024; Akyazi et al 2024; EC 2019; OECD 2019). ESCO describes **critical thinking** as the ability to 'Make and defend judgements based on internal evidence and external criteria. Critically evaluate the credibility and reliability of information before using or passing it on to others. Develop independent and critical thinking', For both these transversal competences a pre-requisite methodological

competence is the ability to **learn how to learn** (European Parliament 2006). The EU defines learning to learn as 'the ability to pursue and persist in learning, to organise one's own learning, including through effective management of time and information, both individually and in groups' (European Parliament 2006).

At FdT, improved process understanding and problem-solving skills may be required to consider and make sense of additional sources of information displayed on the ALCHIMIA interface. For example, control room operators may need to learn how to intervene depending on what the ALCHIMIA system predicts, as this Casting Department worker proposed: 'In my opinion, the combination is having qualified personnel who use important tools, so they can also have the sensitivity to evaluate whether the tool works or not' (FdT8).

At CELSA, improved critical thinking skills and process understanding may be required around considering recipe proposal provided by the ALCHIMIA system through the digital interface.

Given the specificity of industrial processes, any improvements in process understanding would be best facilitated through customised on-the-job training. There are short online training courses available for critical thinking and learning how to learn skills. Table 4 lists two examples of available training products for methodological competences (see also Appendix A3 for more examples of training products).

Table 4: Examples of training products for methodological competences

Example training products	Description of training product
Critical Thinking Skills for the Professional | Coursera	Beginner level, 7-hour course, covering: applying critical thinking skills to complex problems; applying a model for solving problems; and, posing questions to further understanding of specific problems.
Learning How to Learn: Powerful mental tools to help you master tough subjects Course (Deep Teaching Solutions) | Coursera	Beginner level, 15-hour course, covering: how the brain uses two different learning modes and encapsulates ("chunks") information; illusions of learning; memory techniques; dealing with procrastination; mastering tough subjects.

Digital Competences

The digital transformation of the steel industry is resulting in a growing demand for digital competences (Madl 2021; Deming 2015; Gonzalez Vazquez et al. 2019; Bughin et al. 2018; Kohlgrüber et al. 2021; Cedefop 2019), as this manager confirmed:

> 'From the point of view of process control, before I mean basically was Excel sheets, not very digital, not many digital tools to check the processes. Nowadays, everything is digital. We have every signal of the plant recorded for every second, this was not before. So, this gives you a lot of opportunities to check what has happened, to check how we can improve, where we have problems, and all those things. And the last two or three

> years we have added to this digital signals, I mean all the capability to develop advanced tools related with artificial intelligence in order to analyse data in a massive way, in order to detect ways to improve the processes' (CELS7).

Cedefop defines digital skills/competences as the:

> 'Ability to make confident, critical and responsible use of, and engage with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competences related to cybersecurity), intellectual property related questions, problem solving and critical thinking' (Glossary | CEDEFOP (europa.eu) accessed 02/09/2024).

The European Digital Competence Framework (DigComp) identified five strategic areas of digital proficiency, of which three are relevant to the ALCHIMIA project: Information and data literacy; Safety; Problem solving. The five strategic areas are divided into 21 (more specific skill) sub-dimensions (see Vuokari et al. 2022)

DigComp gives examples of: **information and data literacy** 'such as the ability to explain information needs; locate, retrieve, store and manage digital data, content and information, or to assess the relevance of the source and the validity of its content'; **safety** 'like the ability to ensure that personal and work devices are protected, including personal and work-related data and sensitive information in digital environments, or to understand how technology impacts mental and physical wellbeing and a general awareness of the environmental impact of digital'; and **problem solving** as 'the ability to identify needs and problems and resolve them in different digital environments, the ability to use digital tools to improve processes, services and products, and keep up to date with the evolution of technology' (Misheva 2021).

Furthermore, the European e-Competence Framework (e-CF) identifies 40 ICT competencies (CEN 2014a). Specifically for the steel sector, Akyazi et al (2024: 192) identified 32 future digital competences.

Workers at both FdT and Celsa will need at least a basic understanding of artificial intelligence, including the basics concepts of trustworthy and ethical AI, in order to have some knowledge of the purpose and workings of the ALCHIMIA platform. In addition, an understanding of the importance of data entry, data storage and cybersecurity (including federated learning) will be necessary.

At FdT, it was reported during an interview that the ALCHIMIA project is already impacting on the competences that they are requiring of new workers, from information and data literacy competences (such as Microsoft Office and SAP) to more advanced competences required of automation software. FdT also requires those with advanced competences in data science and data engineering.

At CELSA, safety competences are required due to the issue of different cybersecurity laws in the different countries that the company operates in will have to be covered in training. For example, in France there is strict regulation around cybersecurity where it involves worker privacy.

Digital competences can be acquired through short online courses or through certified programmes; many companies will already have suppliers of such courses. For more metal industry specific training, steelHub provides several short courses and the EU Digital

Skills and Jobs Platform 'collates training opportunities on digital skills and emerging technologies from all around Europe' (Training offers | Digital Skills and Jobs Platform (europa.eu)). Table 5 lists three examples of available training products for digital competences (see also Appendix A3 for more examples of training products).

Table 5: Examples of training products for digital competences

Example training products	Description of training product
MAN0202 – Digitalization towards the learning steel plant - steeluniversity	Beginner level, 1-hour lecture, covering: overview of digitalization for the steel industry; and, an example of a success story of the implementation of a technology and the optimization produced in the steel industry.
Introduction to Machine Learning (steeluniversity.org)	Beginner level, 4-hour course, covering: fundamental concepts of machine learning; learning to design and implement a variety of ML algorithms in a variety of real-world scenarios.
CYBERWISER Primer | Digital Skills & Jobs Platform (europa.eu)	Covers main themes and concepts, which underpin cybersecurity technology.

Environmental Competences

Environmental competences have been argued to be of key importance for the European steel industry 'to manage European regulations and policies about the sustainability, energy efficiency and environment, which is one of the current focuses of the European steel industry' (Akyazi et al 2024: 188; Kohlgrüber et al. 2021, ESSA 2019) and to sustain the competitiveness of the sector in the decarbonisation transition (EC 2019; OECD 2014; Spire-SAIS 2020). Akyazi et al (2024) provides a comprehensive list of environmental competences for the steel industry.

The target outcome for the ALCHIMIA project is resource optimisation and minimisation of waste, energy, or greenhouse gas emissions. Examples of environmental competences which are all relevant to the ALCHIMIA project are those related to sustainability, which include environmental awareness, a basic understanding of climate change, resource efficiency, recycling and material reutilization. In this report, we equate environmental competences to **sustainability competences**, which the European sustainability competence framework (GreenComp) defines as a competence that 'empowers learners to embody sustainability values, and embrace complex systems, in order to take or request action that restores and maintains eco-system health and enhances justice, generating visions for sustainable futures' (Bianchi 2022: 12).

For both FdT and CELSA, basic training courses on the importance of the circular economy and of reducing carbon emissions and energy/water usage to limit climate change are necessary so that the need for the ALCHIMIA system will be understood.

Several short courses for metal industry specific environmental competences are provided by steelHub (steeluniversity.org). Table 6 lists three examples of available training products for personal competences (see also Appendix A3 for more examples of training products).

Table 6: Examples of training products for environmental competences

Example training products	Description of training product
SUS0203 – Climate Change Fundamentals - steeluniversity	Beginner level, 35-minute course, covering: key fundamentals around climate change.
Steel: The permanent material in the circular economy - steeluniversity	Beginner level, 1-hour course covering: The reason and benefit for shifting from linear to circular economy; the role of steel in the CE; the advantages of CE.
Sustainability in EAF steelmaking (steeluniversity.org)	Beginner level, 1.5-hour course, covering: energy efficiency, resource efficiency and carbon footprint of EAF steelmaking; options to increase the sustainability of EAF steelmaking, like fossil carbon substitutes, energy efficiency improvements and circular economy approaches.

The main competence requirements identified through a combination of fieldwork within companies and extensive desk research are summed in Table 7 below. The Table also summarises what we consider to be viable approaches to training with regard to the respective competences.

Table 7: Summary of Transversal Competences for Operators

Overarching competence category	Identified as important competences	Training approach
Personal	Adaptability	On-the-job, online courses
Social	Communication, teamwork	On-the-job, online courses
Methodological	Critical thinking, process/system knowledge/understanding, learning to learn	Customised on-the-job, online courses
Digital	Information and data literacy, safety, problem solving	Online courses
Environmental	Sustainability	Online courses

General Transversal Competences for Senior Staff

In order to drive forward digital transformation, organizations will need managers or other senior employees to have general, i.e. technology-independent, competence requirements, as these managers confirmed:

> 'The managers, the skills that we require for them on leadership etcetera, to engage these operators to do more things... Now for more and more, we are requesting more management skills, leadership, how to motivate people, so more of this we call management competency skills or personal skills, not so technical skills. Because this is crucial to, I mean to have more autonomy, to give, to empower more the operators. You know, they capable to do more things that they do in the past so. So, in that sense, the skills of the operators are changing as well because they're making more decisions themselves... Now we are focusing ... on knowledge about artificial intelligence, data management, data engineers and data scientists. So, we think that in the near future we will need more of this. And then everything related with leadership. But this is not something that you, most of the times you don't get this from the university, is something that maybe you have to work afterwards, in some special, I mean, trainings or o this I would say that is what we are working about now, leadership' (CELS7).

> 'However, they don't have people specialised or that have enough time to work on artificial intelligence...They actually need extra people, but that also needs to come from the management level. Someone from above needs to realise the importance of having this kind of skills in the company'. (CELF3, interpreter summary).

While we use the same categories of transversal competences, the specific types of transversal competences differ for senior staff from the list presented in the previous section. This is due to the fact that senior staff will already possess many of the more standard transversal competences to a good level as a normal job requirement (e.g. process understanding, basic digital skills, communication, team work) and as their tasks differ, they have to have a broader outlook on digital transformation that normal operators do not need to have. These specific transversal competencies for senior staff are considered below.

Personal Competences include business insight, agile approach, adaptability, resilience, strategic thinking, risk oversight, user-centric focus, establishing foundations for the future. **Strategic thinking** and **leadership** competences will be important. ESCO defines the competence to apply strategic thinking as: 'Apply generation and effective application of business insights and possible opportunities, in order to achieve competitive business advantage on a long-term basis'. Table 8 shows an example of an available training product for personal competences for senior staff.

Table 8: Examples of training products for personal competences for senior staff

Example training products	Description of training product
Strategic Leadership: Impact, Change, and Decision-Making Specialization [4 courses] (Dartmouth College) | Coursera	Beginner level, 80-hour course, covering: decision-making; accelerating careers; leadership.

Social Competences include project leadership, change leadership, cross-functional collaboration, communication proficiency, vendor relationship management, team motivation, and managerial, including change management. **Project management** competences in particular will be important, which ESCO defines as: 'The discipline of project management, the activities which comprise this area and the variables implied in it, such as time, resources, requirements, deadlines, and responding to unexpected events'. Table 9 shows an example of an available training product for social competences for senior staff.

Table 9: Examples of training products for social competences for senior staff

Example training products	Description of training product
Leading transformations: Manage change | Coursera	Beginner level, 18-hour course, covering: designing successful change initiatives; creating change cycle; generating leadership strategies for transformation.

Methodological Competences include data analysis, financial acumen, and **regulatory compliance**. The latter of which is particularly important. ESCO defines the competence to meet the requirements of legal bodies as the ability to: 'Ensure the practice methods and procedures used are in compliance with the regulations and requirements of the legal governing authority in the field'. Table 10 shows an example of an available training product for methodological competences for senior staff.

Table 10: Examples of training products for methodological competences for senior staff

Example training products	Description of training product
Regulatory Compliance Specialization [4 courses] (Penn) | Coursera	Beginner level, 40-hour course, covering: creating a culture of compliance; building an effective compliance program to manage risk.

Digital Competences include cybersecurity awareness, technical familiarity, tech savviness, familiarity with programming languages, data analytics, artificial intelligence (AI), cloud computing, the Internet of Things (IoT), machine learning, and digital security.

Cyber/digital security is particularly important. ESCO describes **cyber security** as competence in: 'The methods and best practices that protect ICT systems, networks, computers, devices, services, processes and people against unauthorised access, modification and/or denial of service of assets'. Table 11 shows two examples of available training products for digital competences for senior staff.

Table 11: Examples of training products for digital competences for senior staff

Example training products	Description of training product
Cybersecurity Leadership and Management Specialization [3 courses] (Infosec) | Coursera	Beginner level, 10-hour course, covering: basic principles of cybersecurity leadership and management; aligning information security with business model.
Sustainable AI in Business - Agoria | Digital Skills & Jobs Platform (europa.eu)	Beginner level, > 2-hour course, covering: societal impact of AI; organisational, legal and ethical aspects when implementing AI within a business context; key aspects to sustainability, such as ethics, safety and meeting SDGs.

Environmental Competences include corporate sustainability, life cycle assessment (LCA – which the ALCHIMIA project will apply), and the environmental impact of digital technologies (e.g. 'Digitalization for Sustainability' and 'Sustainable Digitalization' Sustainable Digitalization | UNEP - UN Environment Programme Accessed 26 September 2024). In particular, **corporate sustainability** will be an important environmental competence for managers, which ESCO defines as: 'A business practice to conduct long-term sustainable growth by seeking environmental, economic, and social strategies as its three main pillars'. Table 12 shows two examples of available training products for environmental competences for senior staff.

Table 12: Examples of training products for environmental competences for senior staff

Example training products	Description of training product
Corporate Sustainability. Understanding and Seizing the Strategic Opportunity | Coursera	Beginner level, 15-hour course, covering: 'How each individual, organization and system can start to analyse its behaviours and change towards more sustainable practices and models'.
Digital4Sustainability Learning Path | UNSSC | United Nations System Staff College	Beginner level, 12-hour course, covering 'the transformational role digital solutions and innovations can play in advancing environmental and social sustainability'.

Table 13 provides a concise summary of the identified competence requirements for senior staff.

Table 13: Summary of Transversal Competences for Senior Staff

Overarching competence category	Identified as important competences	Training approach
Personal	Strategic thinking, Leadership	Online courses
Social	Project management	Online courses
Methodological	Regulatory compliance	Online courses

Digital	Cybersecurity	Online courses
Environmental	Corporate sustainability	Online courses

Both FdT and CELSA already have R&D teams which will possess many of the transversal competences outlined above. For example, at CELSA previous other current AI projects (e.g. 'iScrap') found that there is already a lot of awareness among managers about AI. However, given the context of accelerated technological change, those tasked with leading digital transformation will need to undertake continuous learning and professional development about leadership, project management, and digital transformation management so that they can lead on the deployment of 'mentoring and coaching programs to facilitate knowledge transfer within the organization' (https://neuroject.com/digital-transformation-manager/).

There are also specific **digital transformation management** courses, workshops, webinars (e.g. steelTalks), and conferences available, in which all or most of these competences mentioned above can be acquired, There are a range of courses at different lengths and levels available, from short courses to EQF Level 7 programmes, including from steelHub. Some examples are listed in Table 14.

Table 14: Examples of training products for digital transformation competences for senior staff

Example training products	Description of training product
Digital Transformation (steeluniversity.org)	Beginner level, 4-hour course, videos, covering: the uncertain world in which organizations and people are inserted; the mentality that we need for the cultural digital transformation; the fundamental axes of all cultural transformation, and the key elements for it to be a successful process.; exponential technologies that facilitate change; the success factors in change management in the digital age.
Digital Transformation II (steeluniversity.org)	Beginner level, 4-hour course, covering: agility and agile methodologies, SCRUM and KANBAN; new leadership styles in the digital era; key skills for a digital transformation.
Digital Transformation Course - United Kingdom (theknowledgeacademy.com)	Online 2-day intensive training covering how to adapt to and leverage digital technologies for improved efficiency, innovation, and competitiveness.
Digital Transformation Management - CUAS University (fh-kaernten.at)	EQF Level 7 course covering the changes that are necessary due to digital transformation in: the management of

Top Digital Transformation Courses - Learn Digital Transformation Online (coursera.org)	companies; strategy and business models; the expectations of employees. Over 300 digital transformation courses listed.

4.4 Pillar 2: Specific Transversal Competence Requirements

Use cases have been described in detail in ALCHIMIA Deliverables D2.1 (Weinel et al. 2023) and D5.1 (Gálvez 2023) and will not be re-described here. The focus is rather on the implications of inserting the ALCHIMIA system into production contexts for transversal competence requirements. The focus of this section is firmly on ALCHIMIA impacts on employees in production areas.

In general, our analysis, based on our understanding of both current production processes in the partner companies (ALCHIMIA D2.1) and the anticipated functionality of the ALCHIMIA platform (ALCHIMIA D5.1), suggests that the insertion of ALCHIMIA and its subsequent use will only specifically affect few tasks and therefore only a limited number of staff in very particular and limited ways. One of the two main reasons is that the ALCHIMIA system tends to work mainly in the background where it continuously computes, in the main, automatically generated production-related data to suggest ways to optimise production processes. The other reason for the limited impact of ALCHIMIA on specific competence requirements is that the few production-based workers that will directly interact with the ALCHIMIA platform will mainly deal with user-friendly interfaces while the complex technical underpinnings of the ALCHIMIA platform, e.g. the models and algorithms are 'black-boxed', i.e. they are not visible to operators. This also means, importantly, that because ALCHIMIA utilises FL - instead of other less privacy-protecting ML approaches - it makes little discernible difference to operators, and therefore for training because users of the system deal with outputs of the system, not with its 'inner' workings. While it will be critical for operators to conceptually understand that underlying models turn production data into predictions and suggestions, there is little need for operators to deeply understand the intricacies of the ALCHIMIA platform to evaluate its practical performance.[13] There is, however, a need to ensure that workers who directly interact and use the system are trained. This is already well understood within the participating companies, as this manager confirmed: *"Those who currently manage production will obviously need to be introduced to the system, be able to read it and understand the forecasts that are given to them, and if all the data is transmitted to them correctly. Training will be necessary' (FdT1).*

Specialist staff in the participating companies indicated that they have the required technical and transversal competences to contribute to the design, implementation, operation and maintenance of the ALCHIMIA system.[14]

In what follows, the report describes briefly the functions that the ALCHIMIA system will fulfil in the two participating companies and how it will be integrated in the respective production processes. The main part of the company-specific analysis is presented in two

[13] It is arguable that the current (pre-AI system) expertise of operators is far more important for using the ALCHIMIA system as it is their current understanding of relevant production parameters that will allow them to evaluate the performance of the ALCHIMIA system, not a deeper understanding of the underlying ML technologies.

[14] Having competent specialists within companies or working for it is an essential pre-condition of implementing the ALCHIMIA system in local contexts. Because the focus of this Report is on training requirements arising out of the use of the ALCHIMIA system, these competence requirements needed to actually insert the system into production processes is not dealt with.

tables per company, one dealing with technology-specific direct effects (FDT: Table 17; Celsa: Table 19) and one dealing with technology-unspecific effects of the ALCHIMIA system that have consequences for competence requirements effects (FDT: Table 18; Celsa: Table 20). Each table is organised in the same way. From left to right, the columns deal with the following aspects:

- Process Stages: specifies which production process stage/s is/are affected
- Affected jobs: specifies which jobs are affected related to specific process stages
- Current tasks: brief description of main aspects of current tasks related to affected jobs
- New/ altered tasks after ALCHIMIA roll-out: brief description of new and/or altered aspects of tasks related to use of ALCHIMIA system
- Training need: provides a three-level (low, medium, high), assessment of anticipated training needs. The assessment is fairly vague in the sense that 'low' roughly translates into 'requires hours', 'medium' into 'requires days' and 'high' into 'requires weeks'. The actual training time depends on actual choices training products chosen by companies.
- Potentially suitable training forms: provides recommendations about potentially suitable modes of training delivery, e.g. on-the job or short-courses etc.
- Suggested training frequency/intensity: provides recommendations regarding the recurrence and depth of anticipated training requirements
- Types and (Sub-Types) of required competence: specifies the required types and sub-types of transversal competences are required
- Specific competences: specifies the required transversal competences

Fonderia Di Torbole (FdT), IT

In the context of automotive parts manufacturer FdT, the ALCHIMIA system will optimise production processes through improved quality outcome predictions. Accurate and early quality predictions are important and potentially useful because there is a significant time lag of 3 to 5 hours between the casting of parts and the final confirmation of quality outcomes. Instead of waiting for several hours before finding out whether parts do indeed meet the stringent quality thresholds, predictions, provided they are reliable and accurate, can speed up decision-making and thus increase the efficiency of production. Currently, the quality of a batch is established using an array of different testing methods. Most of these tests can only be performed after parts have cooled down for several hours. If the tests reveal irredeemable quality issues, the whole batch is scrapped. While the material used for the faulty batch can be reused, costs for energy, staff time and moulds will be lost. The ALCHIMIA system can minimise these losses as it will be able to predict final quality outcomes based on data related to the characteristics of the liquid metal just before pouring begins.

ALCHIMIA operates mainly in the background because almost all of the required data are automatically collected and available in digitalised form. Moreover, because ALCHIMIA will only be used to predict outcomes it therefore only has a very limited direct impact on current tasks and processes that constitute the FdT production process.[15] In fact, the

[15] The complete FdT production process has been described in Table 2, p.16-17of ALCHIMIA Deliverable D2.1 (Weinel et al. 2023).

current production process is likely to change in only two ways that affect 4 out of the 8 process stages[16] (see Table 17 in Appendix A1).

While the tasks of the vast majority of production-based workers will remain unaffected by the introduction and operation of ALCHIMIA, it is likely that some employees' tasks will be indirectly affected by the introduction of ALCHIMIA (see Table 18 in Appendix A1). This is mainly due the importance of continuous measurements and data generation, without which the optimal functioning of the ALCHIMIA system cannot be guaranteed.

As FdT organises production-based workers in poly-functional teams where each team member is expected to competently perform all tasks assigned to a team, additional training has to cover all team members.

CELSA

The main functions of the ALCHIMIA system when applied to EAF steel making is to optimise receipt selection and furnace operation. In the specific use cases, ALCHIMIA will work in conjunction with other digital innovations, such as an automated scrap metal classification system (I-SCRAP, currently tested in Barcelona), digitalised scrap yard inventories and a scrap market monitoring system (in the proposal, but not in operation), to produce better steel while using less energy and generating less waste. Considering ALCHIMIA in isolation, it again is likely to specifically affect only very few tasks and processes at three out of the four broad production process stages (see Table 19 in Appendix A2).[17]

The specific indirect effects of deploying the ALCHIMIA system in the context of EAF steelmaking affect are also relatively contained despite a much wider influence of the AI-based system on the production system in this case study compared with the other case study (see Table 20 in Appendix A2). The reason is again the backgrounded nature of the system in conjunction with an automated data collection infrastructure that requires very little human intervention beyond maintenance.

Celsa also organises production-based workers in poly-functional teams where each team member is expected to competently perform all tasks assigned to team. Thus, all additional training efforts must cover all team members.

4.5 Pillar 3: Competence Requirements to operate ALCHIMIA system

While considerations regarding the competence requirements to operate the ALCHIMIA system in industrial contexts is outside the scope of this Deliverable, this section briefly outlines Pillar 3, which focusses on the very specific competences required to operate the ALCHIMIA system in practice. As outlined in the previous section, the functionality of the ALCHIMIA system might vary to some degree – predicting product quality in the context of FdT and optimising production processes in the context of Celsa. Nonetheless, the operation of the system will in those two and other anticipated use contexts be relatively similar as operators will interact with the system via interfaces. Of course, the different

[16] The 8 production process stages are: Raw Material Acceptance, Cores, Moulding Sands, **Melting**, **Pouring in Mould**, **Hourly Control**, **Final Check** and Storing and Shipping (only the stages in bold are affected specifically by ALCHIMIA)

[17] The four broad process stages are: scrap purchasing, scrap processing, charging baskets, and EAF. A more detailed description of the complete production process can be found in Table 1, p.12-15 in ALCHIMIA Deliverable D2.1 (Weinel et al. 2023b). For the purposes of this report, the stage 'Charging Baskets' is sub-divided into recipe selection and basket loading as important specific effects of ALCHIMIA are likely to affect these sub-stages.

functionalities will mean very specific differences between interfaces deployed in different companies but on a less specific level, operators in all deployment contexts require a number of competences to control and manipulate the system via interfaces, whatever the specific functionalities of the system may be.

Our current understanding of how the final deployable ALCHIMIA systems will be operated suggests at least **four aspects related to specific competence requirements, which all relate to digital competences**. The list below moves from more theoretical to more practical competence requirements. Given that operators and end users are asked to engage with a new digital tool in addition to their current tasks, the acquisition of the competences outlined below benefits itself from transversal competences such as **adaptability**, **communication**, **learning to learn** and **critical thinking**.

First, a fundamental aspect is that operators require a good understanding as to how ALCHIMIA decision support is actually created by the system. This includes, among other things, possession of conceptual knowledge of Machine Learning in general and Federated Learning and Continual Learning more specifically, an understanding of what kind of production-related data is inputted into the system, an appreciation of the potentially limited accuracy of suggestions produced by the system and an awareness of potential sources of errors that might affect ALCHIMIA output. End users should also have understanding that the system uses Explainable AI (XAI), which in theory means that the system's recommendations should be understandable and trustworthy to them. These issues fall under the categories of methodological and digital competences and, more specifically, relate to **process knowledge/ understanding** and **data and information literacy**.

Second, end users require a comprehensive understanding of all available functionalities. This means they need to know what the system can and cannot do but they also need to be sufficiently familiar with the functionality of the system to recognise any potential issues or faults related to its workings and to react appropriately in such cases, either by resolving them or knowing where to get help to do so. These issues fall mainly under the categories of digital and social competences and, more specifically, relate to **data and information literacy**, **problem solving** as well as **process knowledge/ understanding** and **communication.**

Third, operators of the system need to be able to navigate and interact with ALCHIMIA interfaces while completing their routine work. In some application context, for example for EAF steelmaking, the use of the system is time-sensitive as decisions have to be taken relatively quickly. The ability to use the system needs to be deep enough to allow operators to react appropriately to potentially unexpected system behaviour such as, for example, glitches related to its functionality. These issues fall mainly under the categories of digital, social and personal competences and, more specifically, relate to **data and information literacy**, **problem solving**, **communication** as well as **adaptability**

Fourth, users of the system also need to be able to evaluate and interpret ALCHIMIA output as their further actions, such as whether to act upon or ignore recommendations issued by the system, depend on the views they form. What exact information will be displayed on various interfaces is still unknown as the interface design process is currently under way, but it can be anticipated that operator tasks will be more demanding as they will have to consider routinely available production-related data in conjunction with ALCHIMIA output to come to a view regarding the appropriateness, accuracy and reliability of ALCHIMIA's decision support. This requires digital, methodological and social competences, more specifically **data and information literacy**, **problem solving**, **critical thinking**, **process knowledge/ understanding** and **communication**.

Any required training needs to be undertaken before and during the implementation of the ALCHIMIA system to ensure its usability once installed. As there are no existing training products specifically related to the use of the ALCHIMIA system, they have to be developed by the ALCHIMIA consortium. The main element will be a handbook or manual detailing the functionalities of the ALCHIMIA system. This entails instructions regarding the configuration and routine use, via digital interfaces. This 'manual' can take different forms: it is conceivable as a printed or electronic 'book' or it could take the form of a video-based tutorial. Available AI tools such as NotebookLLM (Google), ChatGPT (Open AI), Co-Pilot (Microsoft) or Claude (Anthropic) could be used to transform written instructions into more engaging formats such as shorter summaries, FAQ documents, podcasts, AR/VR tutorials or even comic strips.

The ALCHIMIA project proposal also anticipates training workshops. These workshops can be utilised to both train prospective users of the system and to develop training materials that can be re-utilised in companies that want to adopt the ALCHIMIA system. Such workshops provide good opportunities to train users with regard to the system's functionalities, how to use interfaces and how to evaluate and interpret system outputs.

Table 15 summarises the identified competence requirements related to the operation of the ALCHIMIA system in industrial contexts.

Table 15: Summary of Pillar 3 training requirements

Additional requirements to operate system	Types and (Sub-Types) of required competence	Specific competence	Potentially suitable training forms
Acquire new competences related to operation of ALCHIMIA system	Transversal (Personal, Social, Methodological)	Adaptability; Communication; Learning to learn; Critical thinking	See Section 4.3
Develop conceptual understanding of how system works	Transversal (Methodological, Digital)	Process knowledge/ understanding; Data and information literacy	Handbook (and derived content, e.g. podcast or video tutorial) Workshops
Develop understanding of all available functionalities of system	Transversal (Social, Methodological, Digital)	Communication; Process knowledge/ understanding; Data and information literacy; Problem solving	Handbook (and derived content, e.g. podcast or video tutorial) Workshops
Develop ability to navigate and interact with ALCHIMIA interfaces	Transversal (Personal, Social, Digital)	Adaptability; Communication; Data and information literacy; Problem solving	Handbook (and derived content, e.g. podcast or video tutorial) Workshops On-the-job instructions

Develop ability to evaluate and interpret ALCHIMIA output	Transversal (Social, Methodological, Digital)	Communication; Process knowledge/ understanding; Critical thinking; Data and information literacy; Problem solving	Handbook (and derived content, e.g. podcast or video tutorial) Workshops On-the-job instructions

5 Recommended Training Programme

The whole of the recommended potential training programme is summarised in Table 16 below. The recommendations are based on the best possible understanding we could obtain through empirical research in the companies, discussions within the project consortium and extensive desk research which includes considering output from highly topical recent European research projects. It is, however, possible – mainly due to the fact that the development of the ALCHIMIA platform is still ongoing and not all aspects have been finalised yet, that some potential competence requirements have not been included here.

The summary Table 16 is organised in the following way, starting at the most left-hand column:

- Pillar: states which pillar content of row in the table refers to
- Aspect: details what Pillar of training programme is covering
- Who: suggests which staff groups might require training
- When: suggest timing of training provision
- Why: justifies need for training
- Competence Type: details broad competence type
- Sub-Category: details competence sub-category
- Specific Competence Requirements: details specific competences; competences displayed in bold relate to senior staff
- Details: refers to parts of Report D2.3 where more details regarding aspects are provided

As for the use of the proposed training programme, we suggest that companies treat it foremost as a check-list to evaluate to what extent and depth the mentioned competence requirements are already met by their staff.

The programme binds into project objectives at a broader level by providing recommended training for 'user' engagement in ALCHIMIA and the operation of AI/digital tools, and specifically to Objective 4 *Guarantee the highest levels of trust, safety and seamless collaboration between workers and AI-powered industrial solutions* and the KPI ALCHIMIA Skills Development Strategy.

Table 16: Summary of recommended ALCHIMIA Training Plan

Pillar	Aspect	Who	When	Why	Competence type	Sub-Category	Specific Competence Requirements	Details
1	Working in a company using ALCHIMIA system (and other digital technologies)	All staff	Before/ during/ after insertion	Ways of working that indirectly contribute to optimal use of ALCHIMIA system	General Transversal Competences	Personal Social Digital Methodological Environmental	Adaptability; **Strategic Thinking**; **Leadership** Communication; Team Work; **Project Management** Information/ Data Literacy; Problem Solving; **Cybersecurity** Process knowledge/ understanding; Learning to Learn; **Regulatory compliance** Sustainability; **Corporate Sustainability**	Section 4.3 (Tables 2-13)
2	Interacting with parts of production system directly affected/ controlled/ impacted by ALCHIMIA system	All staff whose work directly affects ALCHIMIA system output	Before/ during insertion	Ways of working that directly contribute to optimal use of ALCHIMIA system	Technology-Specific Transversal Competences	Personal Social Digital Methodological	Adaptability Communication; Team Work Information/ Data Literacy; Problem Solving Process knowledge/ understanding; Learning to Learn	Section 4.4 (Tables 17-20)
3	Practical operation and use of ALCHIMIA system	All staff operating ALCHIMIA platform via interfaces	Before/ during insertion	Optimal use of ALCHIMIA system	Technology-Specific Transversal Competences	Digital Environmental	Information and data literacy; Safety; Problem Solving Sustainability	Section 4.5 (Table 15)

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A.1 Effects of ALCHIMIA system on FdT production process

Table 17: Specific direct effects of ALCHIMIA system on FdT production process

Process Stages	Affected jobs	Current tasks	New/ altered tasks after ALCHIMIA roll-out	Training need	Potentially suitable training forms	Suggested training frequency/ intensity	Types and (Sub-Types) of required competence	Specific competence
Melting; Pouring in Mould; Hourly Control; Final Check	Production Manager, Production engineers, Production Supervisors	Planning, executing and monitoring melting processes from raw ingredients to pouring liquid metal into casts	Same tasks as before but additional production-related data available on ALCHIMIA interface	Low	On-the-job; short courses (F2F or online)	One-off	Transversal (Personal, Digital)	Adaptability; Information and Data Literacy
Pouring in Mould	Ladle Furnace Operators	Temperature measurements of metal just before it enters mould every 30 mins; manual recording of temperatures; taking material samples every 30 mins	Same but frequency of measurements and sampling might be increased; Company explores ways to automatise temperature entries to reduce potential for missing or wrong data	Low	On-the-job; short courses (F2F or online)	One-Off	Transversal (Personal, Methodological))	Adaptability; Process knowledge/ understanding

Table 18: Specific indirect effects of ALCHIMIA system on FdT production process

Process Stages	Affected jobs	Current tasks	New/ altered tasks after ALCHIMIA roll-out	Training need	Potentially suitable training forms	Suggested training frequency/ intensity	Types and (Sub-Types) of required competence	Specific competence
ALL	Process Engineers; Maintenance teams	Optimising and maintaining production facilities and infrastructure (including mainly automatised sensor infrastructure)	Increased importance of maintenance (and possibly expansion) of sensor infrastructure to keep data flow running; more frequent inspections and/ or the refinement of already existing predictive maintenance regimes	low	On-the-job; short courses (F2F or online)	One-Off	Transversal (Personal, Social, Methodological, Digital)	Adaptability; Communication; Learning to Learn; Process knowledge/ understanding Problem solving
ALL	IT staff	maintaining databases and ensuring error-free transfer, storage and processing of data increases in importance	Increased importance of accuracy and completeness of data; greater cooperation with production engineers and maintenance staff	low	On-the-job; short courses (F2F or online)	One-Off	Transversal (Personal, Social, Methodological)	Adaptability; Communication Team Work; Process knowledge/ understanding
Hourly Control;	Quality Controllers	Performing a variety of quality	Increased importance and frequency of some quality tests to	low	On-the-job; short courses	One-Off	Transversal (Personal, Social, Methodological)	Adaptability; Communication

Final Check [Quality Control]	(laboratory staff)	tests using a range of methods at different stages of production	aide early intervention		(F2F or online)			Process knowledge/ understanding

A.2 Effects of ALCHIMIA system on Celsa production process

Table 19: Specific direct effects of ALCHIMIA system on Celsa production process

Process Stages	Affected jobs	Current tasks	New/ altered tasks after ALCHIMIA roll-out	Training need	Potentially suitable training forms	Suggested training frequency/ intensity	Types and (Sub-Types) of required competence	Specific competence
ALL	Process Engineers/ Maintenance staff	Optimising/ maintaining production facilities and infrastructure (including mainly automatised sensor infrastructure)	Increased importance of maintenance; possible need to expand sensor infrastructure; more frequent inspections and/ or the refinement of already existing predictive maintenance regimes	low	On-the-job; short courses (F2F or online)	One-off	Transversal (Personal, Social, Methodological, Digital)	Adaptability Process knowledge/ understanding; Problem Solving
ALL	IT staff	Maintenance of databases and ensuring error-free transfer, storage and processing of data;	Increased importance of accuracy and completeness of data; Increased importance of collaboration with other key personnel to react to any potential issues with Alchimia system	low;	On-the-job; short courses (F2F or online)	continuous	Transversal (Personal, Social, Methodological, Digital)	Adaptability; Communication Team Work Learning to learn Problem solving

			ensuring long-term compatibility between ALCHIMIA system and other production-relevant hard- and software systems					
Scrap Purchasing	Scrap buyers	Buying scrap on local, regional and global markets; Maintaining working relations with network of scrap sellers	Potential changes to scrap requirements might affect buying strategies and practices	low; One-Off; On-the-job			Transversal (Personal, Social, Methodological)	Adaptability; Communication; Process knowledge/ understanding;

Table 20: Specific indirect effects of ALCHIMIA system on Celsa production process

Process Stages	Affected jobs	Current tasks	New/ altered tasks after ALCHIMIA roll-out	Training need	Potentially suitable training forms	Suggested training frequency/ intensity	Types and (Sub-Types) of required competence	Specific competence
ALL	Process Engineers/ Maintenance staff	Optimising/ maintaining production facilities and infrastructure (including mainly automatised	Increased importance of maintenance; possible need to expand sensor infrastructure; more frequent inspections and/ or	low	On-the-job; short courses (F2F or online)	One-off	Transversal (Personal, Social, Methodological, Digital)	Adaptability Process knowledge/ understanding; Problem Solving

		sensor infrastructure)	the refinement of already existing predictive maintenance regimes					
ALL	IT staff	Maintenance of databases and ensuring error-free transfer, storage and processing of data;	Increased importance of accuracy and completeness of data; Increased need for collaboration with other key personnel to react to any potential issues with Alchimia system ensuring long-term compatibility between ALCHIMIA system and other production-relevant hard- and software systems	low	On-the-job; short courses (F2F or online)	continuous	Transversal (Personal, Social, Methodological, Digital)	Adaptability; Communication Team Work Learning to learn Problem solving
Scrap Purchasing	Scrap buyers	Buying scrap on local, regional and global markets; Maintaining working relations with network of scrap sellers	Potential changes to scrap requirements might affect buying strategies and practices	low	On-the-job	One-Off;	Transversal (Personal, Social, Methodological)	Adaptability; Communication; Process knowledge/ understanding;

A.3 Further examples of training products

Table 21: Further examples of training products for Personal Competences

Adaptability and Resiliency | Coursera;	Beginner level, 8-hour course, covering: 'knowledge and tools to become more adaptable and resilient in your workplace and in your life'.
Building Adaptability in the Age of AI | LinkedIn Learning	Beginner level, online videos, covering developing an adaptable and growth-centered mindset; building resilience; navigating change; enhancing flexible thinking; learning and upskilling effectively; and, cultivating mental agility.

Table 22: Further examples of training products for Social Competences

Example training products	Description of training product
Teamwork Skills: Communicating Effectively in Groups | Coursera	Beginner level, 11-hour course, covering: Learning how to communicate to resolve or diffuse group conflicts; Making better decisions about using technology for group work based on key practical and conceptual considerations.
Communication within Teams | LinkedIn Learning	Beginner level, 45-minute course, covering: essential elements of team communication; and, how to best communicate with your team in different settings.
Communication: Online Courses, Training and Tutorials | LinkedIn Learning	Lists over 800 communication courses.

Table 23: Further examples of training products for Methodological Competences

Example training products	Description of training product

Critical Thinking Skills for the Professional | Coursera	Beginner level, 7-hour course, covering: applying critical thinking skills to complex problems; applying a model for solving problems; and, posing questions to further understanding of specific problems.
Solving Problems with Creative and Critical Thinking | Coursera	Beginner level, 3-hour course, covering: critical and creative thinking to solve issues; 5-step process of effectively solving problems.; analyzing a problem and identifying the root cause; exploring possible solutions and employing them in problem-solving process.
Critical Thinking and Problem Solving | LinkedIn Learning	Beginner level, 2-hour course, covering: how to critically assess the source of information; how to determine the right approach to take; strategies for approaching simple and complex problems; taking your team through the entire life cycle of a challenging decision; common traps people fall into when solving problems, both individually and as a team.
Learning How to Learn: Powerful mental tools to help you master tough subjects Course (Deep Teaching Solutions) | Coursera	Beginner level, 15-hour course, covering: how the brain uses two very different learning modes and how it encapsulates ("chunks") information; illusions of learning; memory techniques; dealing with procrastination; and, best practices to master tough subjects.
Top Critical Thinking Courses - Learn Critical Thinking Online (coursera.org)	Lists over 1000 critical thinking courses.

Table 24: Further examples of training products for Digital Competences

Example training products	Description of training product
MAN0202 – Digitalization towards the learning steel plant - steeluniversity	Beginner level, 1-hour lecture, covering: overview of digitalization for the steel industry; and, an example of a success story of the implementation of a technology and the optimization produced in the steel industry.
MAN0201 – Industry 4.0 as enabler to realise a Smart Steel Industry - steeluniversity	Beginner level, 1-hour lecture, covering: an overview of what Industry 4.0 means specifically for the steel industry; and, practical examples of I4.0 in the steel industry.

Introduction to Machine Learning (steeluniversity.org)	Beginner level, 4-hour course, covering: fundamental concepts of machine learning; learning to design and implement a variety of ML algorithms in a variety of real-world scenarios.
ID Cert Digital Competence Framework | Digital Skills and Jobs Platform (europa.eu)	The only Italian specialised certification built entirely on the DigComp 2.1 Framework, consisting of five areas of expertise, which mirror the competence areas outlined in DigComp 2.2
Sustainable AI in Business - Agoria | Digital Skills & Jobs Platform (europa.eu)	Beginner level, less than 2-hour course, aimed at management, covering: the societal impact of AI; general overview of organisational, legal and ethical aspects that need to be taken into account when implementing AI within a business context; key aspects to sustainability, such as ethics, safety and meeting SDGs.
CYBERWISER Primer | Digital Skills & Jobs Platform (europa.eu)	Covers main themes and concepts, which underpin cybersecurity technology.

Table 25: Further examples of training products for Environmental Competences

Example training products	Description of training product
SUS0203 – Climate Change Fundamentals - steeluniversity	Beginner level, 35-minute course, covering: key fundamentals around climate change.
Steel: The permanent material in the circular economy - steeluniversity	Beginner level, 1-hour course covering: The reason and benefit for shifting from linear to circular economy; the role of steel in the CE; the advantages of CE.
Sustainability in EAF steelmaking (steeluniversity.org)	Beginner level, 1.5-hour course, covering: energy/resource efficiency; carbon footprint and sustainability of EAF steelmaking,
Sustainable EAF steelmaking (steeluniversity.org)	Beginner level/'masterclass', 1-hour course, covering: energy/resource efficiency; carbon footprint and sustainability in EAF steelmaking,