Co-funded by the
Erasmus+ Programme
of the European Union

NR: 2020-1DE02-KA202-007578
Duartion: 1.09.2020 - 31.08.2023
Financed by European Union

CEMIVET

ERASMUS+ Programme Key Action2: Strategic Partnerships
'Circular Economy in Metal Industries VET`
2020-1-DE02-KA202-007578

IO1 Analysis of the welding work process in seeking to identify the potential of application of the principles of circular economy and their implications for the competence needs

REPORT

ibbf · Mi4 MetalIndustry4 · Centrum Promocji Innowacji i Rozwoju · Verslo konsultacinis centras · Vytauto Didžiojo Universitetas · REI Reindustria Innovazione

Table of content

1. INTRODUCTION

Application of the principles of circular economy in the work processes and related re-design of work processes are important factors which define dvelopment of circular economy in the different sectors, especially in the industry.

Work, aside to consumption, is one of the key sources and areas of different impacts on environment and society. Dealing with the environmental challenges and related socio-economic implications also involve significant change in the design of the work processes, especially technological, ergonomic, anthropological, organizational – managerial dimensions of the work. Implementation and development of the principles of circular economy require pro-active and constructive approach to the work process including critical analysis and adjustment of the different parameters of work process, such as technologies, work organization, objects of work (products and services), requirements to work processes imposed by the enterprises, consumers, public authorities, attitudes of the work performer, communication at work, etc. In turn, there emerge new requirements of competence which have to be considered in the design of the vocational curricula both in the initial and continuing vocational education. Again, implementation of the principles of circular economy in the work processes should be considered an open and very diverse phenomenon, which can take different forms. For example, circular economy principles can be introduced because of the pressure of the legislation and public regulation of economic activities, or because of the different financial and fiscal incentives initiated by the public authorities (top-down), as well as by the corporate social responsibility initiatives of the enterprise, as well as by the personal initiatives of the employees (bottom-up). There can also exist different hidden or tacit practices of work execution, which „fit" to the principles of circular economy, but are not recongized as such by the enterprise or work performer, for example, the usage of such principles of circular manufacturing (Muirhead), like modularity, open standards of design, open source of design , open data and transparency are applied by following economic or marketing goals and not recognized as valuable practices of work with positive implications for the environment and society. Disclosing of such practices and making them explicit could serve as a source of know-how and inspiration for the improvement and development of the work process design.

Referring to the above, the main goal of this work package is to identify the possibilities of application of the principles of circular economy in the work process of welding. This goal will be attained by:

- Disclosing the existing practices of the re-design or improvement of welding work process, which follow the principles of circular economy.
- Identifying the skills/competence needs brought by the application of the principles and practices of circular economy.
- Drafting of the related competence profile which can serve as source for design and adjustment of the VET curricula (both for initial and continuing VET).

2. IMPLEMENTATION OF THE CIRCULAR ECONOMY PRINCIPLES IN THE WORK PROCESS OF WELDING: THEORETICAL FRAMEWORK

The work process of welding is defined as a complex work process which involves all occupations, jobs and qualifications related to welding in metalworking and engineering industry, such as skilled welder (EQF level 3), highly skilled welder/welding operator (EQF level 4), highly skilled and specialist welder or welding operator, e.g., operator of automatic and robotized welding (EQF level 5), welding technicians and engineers (EQF levels 6 and 7). There can be suggested the following structure of the work processes of welding to be followed in the analysis (Figure 1):

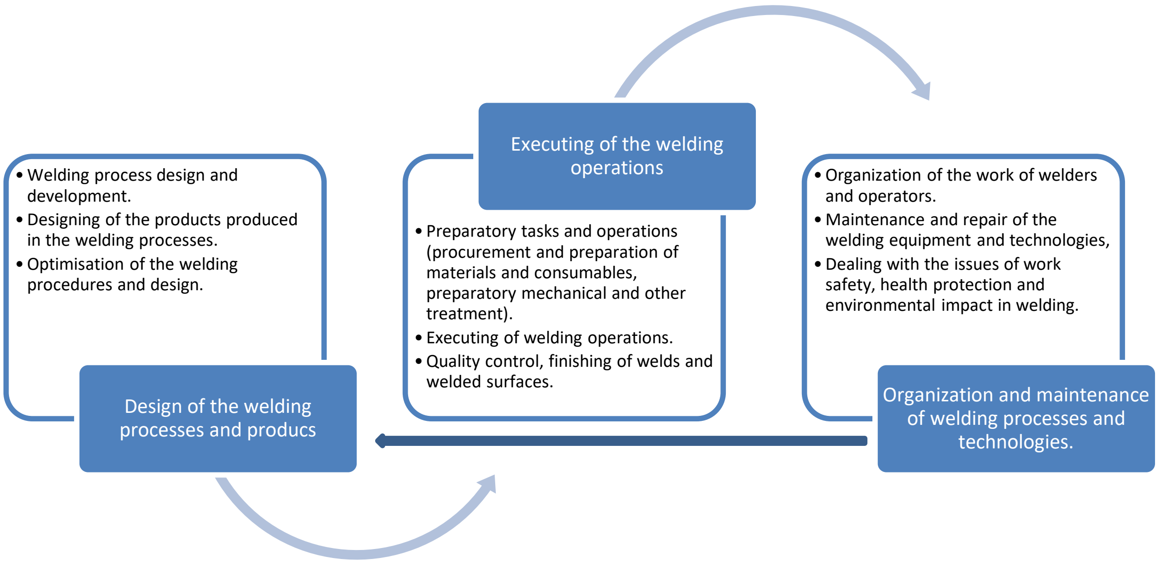


Figure 1. Structure of the work processes of welding

The methodology of this analysis is based on several key theoretical models. One of these models is „Daughnut model of social and planetary boundaries“ suggested by the Oxford University economist Kate Raworth (2017). This model seeks to frame the challenge of balancing between meeting the life‘s essential needs (shortfalls) from one side, and dealing with the collective overshooting the pressure of economic activities on the fundamental Earth‘s life-supporting systems, such as stable climate, fertile soils, biodiversity etc (Figure 2).

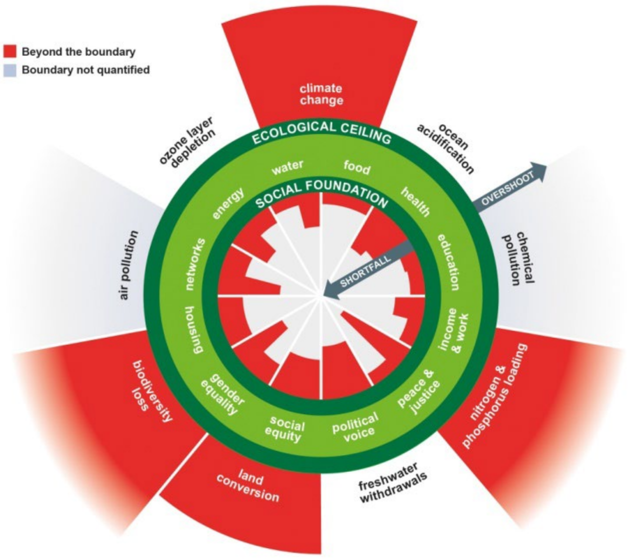


Figure 2. The Daughnut of social and planetary boundaries (Raworth, 2017).

This model claims, that it is necessary to re-adjust the economic and social activities and systems in order to fit them in the space between the social boundaries defined by the minimum social standards, or social foundation from the one side, and the environmental ceiling consisting of key planetary boundaries.

To what extent and how this model is suitable for the analysis of the industrial work processes? The Daugnut model can serve as reference for the exploration of the balancing between the social foundations (shortfalls) and ecological ceiling at the level of work process. In this regard the safe and sustaibnable design of the work process should satisfy the social foundations of work related to objective human needs (access to occupation, employment safety, remuneration, work safety and health protection) and subjective needs (dignity of work, meaningfulness of work, contribution of work to personal development and self-realization) from the one side, and to contribute to coping with overshooting the ecological ceiling of work process - polluting the environment, reducing biodiversity, wasting and depleting non-renewable resources, contributing to the irresponsible and wastefull consumption of products produced in the work process, favouring unsustainble work culture (Figure 3).

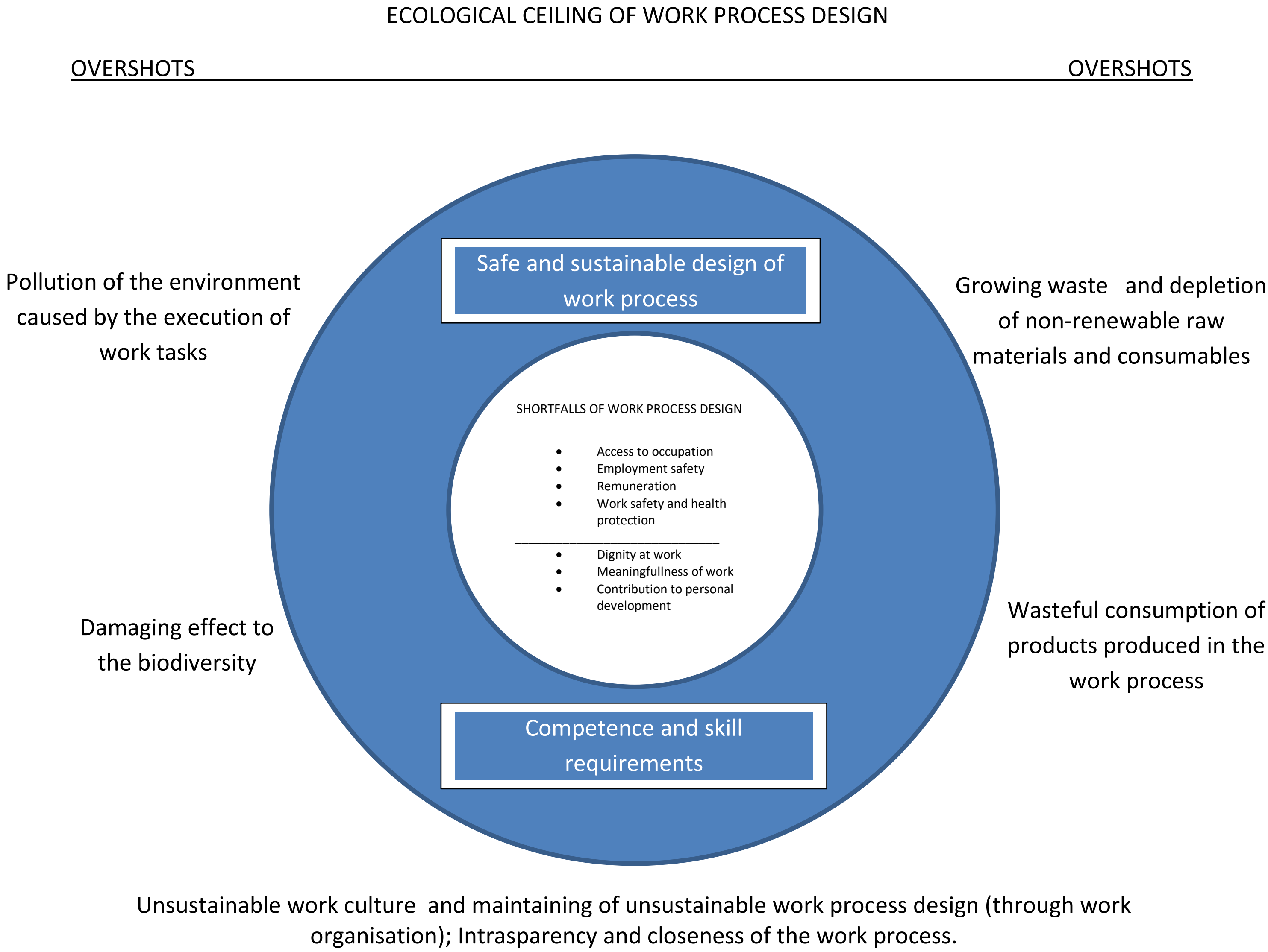


Figure 3. Environmental and social-economic boundaries of industrial work process design

Here it is important to take into consideration, that both social foundations (shortfalls) and ecological ceiling of the work process can be different and case specific, depending on the economic, ergonomic, technological, organizational and socio-cultural specificities of a given work process. One of the key challenges in creating and developing such safe and sustainable design of work process is to enable strong synergy between the respecting/sustaining of the ecological ceiling from the one side, and keeping/protecting the social foundations of the work process. For example, there could be established synergy between the application of the technologies and modes of work organization which eliminate or reduce the pollution or waste of raw materials from the one side, and contribute to the work effectiveness, safety and satisfaction of customers from the other side. These categories of work process will be taken into consideration in the analysis of the work process of welding.

3. WORK PROCESS RESEARCH IN SEAKING TO DISCLOSE THE POSSIBILITIES OF IMPLEMENTATION OF THE CIRCULAR ECONOMY PRINCIPLES IN THE WORK PROCESSES OF WELDING AND RELATED COMPETENCE NEEDS: RESEARCH METHODOLOGY

The analytical approach applied in this research is based on the Work and Learning Station Analysis (WLSA). WLSA presents by itself an instrument to analyse different aspects of work processes in their relationship with work-based learning (WBL). This instrument was developed jointly by trainers from Airbus Germany and researchers from the Bremen University approximately 15 years ago and has been widely used for the analysis of industrial work processes in the different ERASMUS+ projects like "Apprentsod", "DualTrain", "metals", "ICSAS", and others. This instrument helps to evaluate learning potential of work processes by taking into consideration different specificities or specific aspects of work. It helps to identify and to describe apparent good practice of work process execution, to disclose related competence requirements and to indicate the potential of these practices to be used in the WBL and other forms of VET.

Execution of the WLSA can be divided into three main stages: preparation of the analysis, accomplishment of the analysis, analysing and documentation of findings.

3.1 Preparation of the WLSA analysis

Preparation of the WLSA analysis starts form the identification of the occupations and job positions to be analysed. The proposed model-structure of the welding work process (Figure 1) can be used as a reference for such identification. Other information sources are lists of existing occupations and qualifications, existing occupational standards in the field of welding, training curricula, descriptors of jobs developed by the enterprises.

It is recommended to analyse at least several jobs or occupational positions per partner country:

- skilled welders (EQF 3),
- highly skilled welders (EQF 4),
- highly skilled welding operators and technicians, including the welding operators of automatized/robotised welding (EQF 5).

Once the occupations/job positions for analysis are identified and selected, the potential informants should be selected and their participation in the analysis agreed with the enterprises and informants themselves.

WLSA is executed by organizing structured workshop (or focus group interview) which can last up to few hours. Ideally, such workshop (focus group interview) should involve at least 2 experienced employees with different qualifications/competence profiles, for example, skilled welder or welding operator, and welding technician or welding engineer. Participation of the welding specialists with higher qualifications (such, as welding engineers, production managers responsible for welding operations) is very helpful, because these specialists can provide important information about the technological and organizational aspects of more sustainable and environmentally friendly welding process. There should also be involved experienced VET teachers and trainers working in the training programmes which provide qualifications of welders. By participating in these workshops, VET teachers and trainers can provide their insights about the competencies, which are necessary for the accomplishment of sustainable and "circular economy"- oriented work processes of welding.

Before the workshop/focus group discussion there could be executed ***the desktop analysis of the information materials*** about work processes of welding, their environmental implications and existing good practices of application of circular economy principles in the field of welding. This analysis should provide the answers to the following questions:

1. What are the key negative environmental implications of the welding processes and technologies in terms of pollution, waste of non-renewable raw materials and consumables, work safety and health protection of employees? To what extent and how these implications are taken into consideration by the enterprises, social partners, governments and civil society? Sources of information: articles in the specialised press and professional websites, reports of the professional associations and groups.
2. What are the key challenges of the social and occupational welfare of welding occupations in our countries (remuneration, work safety, employment stability and career, learning opportunities, etc.)? How are these challenges and problems being solved? Sources of information: articles in the specialised press and professional websites, reports of the professional associations and groups, occupational standards.
3. What process and product innovations in the field of welding are being experimented, implemented or developed in order to deal with the before identified negative environmental implications? Sources of information: articles in the specialised press, websites of the projects, websites of the professional associations and organizations of welders and welding engineers.
4. To what extent and how the issues of environmental impact of welding are reflected in the existing VET curricula and training materials? What kind of "green skills" and competencies are suggested to deal with the challenges of sustainability of welding processes and technologies? Sources of information: national VET standards and VET curricula.

Partners analyse the materials for the desktop research available in their national languages and covering the projects and practices in their countries.

Apparent good practices identified during the desktop research are chosen as the targets for workshops of WLSA: the representatives or experts of enterprises and VET schools from these cases are invited to participate in the workshops.

3.2 Organisation of the WLSA workshops /interviews

The workshops or focus groups of WLSA analyse the daily work of skilled worker but are not focused on the evaluation of individual performance of skilled workers. The participants of the workshop or interviews should proofread and give their consent for the publication of the data of the WLSA.

The workshops were organized by using online platforms of communication (Zoom, MS teams and others). In case, if the organization of workshop was not possible because of the limited availability of participants or inconsistencies in their agenda's, the workshop, or focus group discussion was replaced with the individual interviews. However, individual interviews entails some important limitations, because some respondents, especially welders with lower qualifications (EQF 3 and 4) can be rather limited in answering the questions. For this reason such interviews involved only higher skilled welders or specialists, such as welding technicians, engineers or production managers.

The workshops / interviews carried out by using the below provided questionnaire, translated in the native language of respondents and delivered them before the workshop/interview.

Analytical category	Central questions
General features of work process (welding)	- Which products are manufactured? - Where do pre-products come from? - Where in the further process are the products used? - Which industries are the clients / customers of the service/product?
Workplace characteristics	- Where is the analysed workplace located (inside/outside)? - Prevailing climatic conditions (heat, cold, radiation, ventilation, gas, vapours, fog, dust)? - What are the key emissions/ sources of pollution of the executed welding process to the workplace environment (pollution of air, water, soil, etc.)? - What kind of protective measures are used in order to prevent negative implications of emissions and pollution at the workplace for the welder/welding operator, other employees and external environment? - What kind of waste is produced at the workplace? What is the average quantity of this waste? - Are there any procedures of collecting and recycling of waste produced at the workplace? What are these procedures? - What are the possible good practices in the collecting and processing of the waste at the workplace? - Are welders /welding operators incentivised to follow the recommendations or requirements about processing of the waste at the workplace? How?
Subjects and methods of sustainable work	- What are the key tasks being executed in the work process of welding (preparation of materials, executing of welded joints, quality control, finishing of the welded surfaces)? - What kind of welding regimes are applied? - What kind of emissions are produced during the preparatory stage, executing of welded joints, quality control and finishing of the surface? How these emissions are being further treated? - What kind of practices / methods are applied to reduce the volume of emissions at the each stage of work process? - What kind of practices/ methods are applied to reduce the volume of main materials (e.g. metals) and consumables in the welding process? - To what extent and how the existing quality requirements and procedures of welding permit and enhance to apply such welding regimes, which generate less emissions and create less waste of materials and consumables? - To what extent and how the welders/ welding operators can adjust the working methods and regimes in the ways which reduce emissions and consumption of materials and consumables? Do the welders and welding operators receive any support from the engineering staff in this field?

Tools / equipment of sustainable work	- Which tools and equipment are used to perform the welding task (machines, tools, devices, software)? - To what extent and how the tools and equipment permit to apply the working methods, regimes and procedures that reduce the pollution and waste of materials and consumables? What knowledge and skills are needed to use these functionalities?
Organisation of sustainable work	- How the work of welders/welding operators is being organised (e.g. individual work or group work, division of labour)? - What problems or shortages of work organization contribute to the increasing pollution, usage of materials and consumables, as well as increase of waste in the process of welding? - What kind of cooperation and interfaces between the welders/welding operators and other workplaces/specialists are critical in order to make welding processes more green and sustainable (to reduce pollution, consumption of raw materials and consumables and volume of produced waste)? - What are the possible good practices of work organisation, which enable reduction of pollution, optimal use of materials and consumables and recycling of produced waste (co-operation between the different departments, teams of welders with different qualifications and specialization, team-working between welders and representatives of the engineering staff, etc.) ?
Environmental requirements of sustainable work	- Which national/European standards, laws and specifications of environment protection need to be considered in the work process of welding ? - Are there any operational environmental requirements or standards initiated and suggested by the enterprise? If so, what are they? - Which demands are placed by the customer? To what extent the demands of customers comply with the operational environmental requirements to welding processes? What are the biggest challenges in this regards and how these challenges are being met?
Implications for the VET curricula (questions to the involved VET teachers and trainers)	- What competencies related to the sustainability of work process have been discovered in the workshop? - Are these competencies included in the current VET curricula? If not, how the existing curricula can be updated? - What key sources of information and learning are needed for the provision of these competencies? - What are the most suitable training methods and approaches for development of these competencies?

Table 1: Guiding questions for the interviews/focus groups of Work and Learning Station Analysis

The workshop or interviews have been registered.

There were conducted workshops and interviews in the project partner countries by involving the following informants

Country	Categories of informants		
	Welders and welding operators, technicians	Engineering and man agerial staff of enterprises	VET teachers and trainers
Lithuania	-	12	5
Germany	5	2	2
Italy	2	1	2
Spain	-	5	1

3.3 Analysis of the findings

The findings of interviews were inserted by partners in the template below. On the basis of the provided desktop analysis reports and templates from the partner countries countries there has been prepared the synthesis (comparative) report and the competence matrix for development of circular economy related skills and competencies in the work process of welding.

Description	**Work process / occupation** **Date**	
Location / site	**Corresponding VET qualification/programme**	
General features of work process (welding)	Type of product/service	
	Internal supplier of pre-products	
	Further / direct user of product/service	
	Client of product/service	
Workplace	Location of workplace	
	Prevailing climatic conditions (heat, cold, radiation, ventilation, gas, vapours, fog, dust)	
	The key emissions/ sources of pollution of the executed welding process to the workplace environment (pollution of air, water, soil, etc.)	
	Protective measures used in order to prevent negative implications of emissions and pollution at the workplace for the welder/welding operator, other employees and external environment	

	Waste produced at the workplace – types and quantities.	
	Availability of procedures of collecting and recycling of waste produced at the workplace: yes/ no. If yes, the types of procedures.	
	Possible good practices in the collecting and processing of the waste at the workplace.	
	Applied incentives for welders/welding operators to follow the recommendations or requirements about processing of the waste at the workplace.	
Subjects and methods of sustainable work	Key tasks in the work process of welding (preparation of materials, executing of welded joints, quality control, finishing of the welded surfaces).	
	Applied welding regimes.	
	Emissions produced during the preparatory stage, executing of welded joints, quality control and finishing of the surface. Treatment of emissions.	
	Practices/methods applied to reduce the volume of emissions at the each stage of work process.	
	Practices/ methods applied to reduce the volume of main materials (e.g. metals) and consumables in the welding process.	
	The most important synergies and/or trade-offs between the quality requirements and more “green” (environmentally friendly) approaches and methods in the process of welding.	
	Autonomy of the welders/ welding operators to adjust the working methods and regimes in the ways which reduce emissions and consumption of materials and consumables. Availability of support for welders and welding operators from the engineering staff.	

Tools / equipment of sustainable work	Tools and equipment used to perform the welding tasks (machines, tools, devices, software).		
	Functionalities of the tools and equipment enabling to apply the working methods, regimes and procedures that reduce the pollution and waste of materials and consumables.		
Organisation of sustainable work	Modes of work organisation (e.g. individual work or group work, work in shifts, hierarchy).		
	Problems or shortages of work organization contribute to the increasing pollution, usage of materials and consumables, as well as increase of waste in the process of welding.		
	The ways of cooperation and interfaces between the welders/welding operators and other workplaces/specialists, which are critical to make welding processes more green and sustainable.		
	Possible good practices of work organisation, which enable reduction of pollution, optimal use of materials and consumables and recycling of produced waste.		
Environmental requirements of sustainable work	National/European standards, laws and specifications of environment protection need to be considered in the work process of welding.		
	Operational environmental requirements or standards initiated and suggested by the enterprise.		
	Demands by the customer and their compliance with the national/operational environmental requirements to welding processes.		
Implications for vocational training curricula	Newly identified competencies related to the sustainability of work process.	Key sources of information and learning are needed for the provision of these competencies.	Suggested training methods and approaches for development of these competencies

4. WELDING WORK PROCESSES IN GERMANY, ITALY, SPAIN, POLAND AND LITHUANIA: GENERAL REQUIREMENTS AND ROLE OF CIRCULAR ECONOMY PRINCIPLES

This part provides a short overview of the overall structure and content of the welding work processes and their regulations in the project partner countries, by paying attention to the role and place of the circular economy principles and to the related problems or shortages.

4.1 Germany

The main negative environmental impacts of welding processes and technologies in terms of pollution, waste of non-renewable raw and auxiliary materials, occupational safety and health protection of employees

The environmental impacts of welding extend to several environmental media. They are recorded, legally assessed and influenced by various procedures. The demand for energy, for example, is viewed[1] critically because of the electricity mix currently available in Germany and its contribution to the climate crisis. The basic and auxiliary materials required, as well as those of the tools, consist of finite raw materials, whose growing need for imports is critically assessed:

"... around 79 billion euros in 2018 - were accounted for by metals and their intermediate and semi-finished products. This sum underlines the high economic importance of a secure and competitive supply of metallic raw materials for Germany. " [2]

The welding process itself releases gaseous emissions, particles, heat, noise and light with a high risk potential for the health of welders and contributes to the climate crisis. Against this background, there are many legal rules and standards for welding. Emissions from welding processes are classified as hazardous substances in relation to humans and environmental media. The particles are inhalable and can cause severe respiratory diseases and cancer. Therefore, there are rules of occupational health and safety of employees. They are set out in laws whose scientific basis is kept up to date through research. A re-evaluation of welding fumes describes possible neurotoxic and carcinogenic effects and describes consequences for applicable workplace limits. The researchers see a need for innovations, for example, in the form of torch-integrated extraction systems, emission-reducing shielding gases and welding rods, as well as information campaigns[3]. Such research results are discussed by the executive with the social partners (employers, works councils, trade unions, professional associations, insurance companies), who have rights of participation and control. They work together on the sub-legislative regulations. This

---

[1] Petra Icha, Development of specific carbon dioxide emissions of the German electricity mix in 1990 - 2017, CLIMATE CHANGE 11/2018, https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2018-05-04_climate-change_11-2018_strommix-2018_0.pdf

[2] Federal Ministry for Economic Affairs and Energy (BMWi), Rohstoffstrategie der Bundesregierung Sicherung einer nachhaltigen Rohstoffversorgung Deutschlands mit nichtergetischen mineralischen Rohstoffen, 2019, p.18 https://www.bmwi.de/Redaktion/DE/Publikationen/Industrie/rohstoffstrategie-der-bundesregierung.pdf?__blob=publicationFile&v=4

[3] Martin Lehnert, Wolfgang Zschiesche, Anne Lotz, Thomas Behrens, Thomas Brüning, Gesundheitsschutz beim Schweißen - Aktuelle Herausforderungen, IN: IPA-Journal 01/2020, https://www.ipa-dguv.de/medien/ipa/publikationen/ipa-journale/ipa-journale2020/ipa-journal2001/ipa_journal_2001_schweissen.pdf

includes, for example, TRGS 528 "Welding work", which was revised in 2020. It describes protective measures:

- *"Selection of low-hazard processes and filler materials - substitution*
- *Ventilation measures - recording emissions*
- *Organisational and hygienic measures - avoidance of contact, inhalation*
- *Personal protective measures - Wearing of respiratory protection".* [4]

Fluorine emissions are reported in the Framework Convention on Climate Change[5].

The main challenges of the social and professional well-being of the welding professions (remuneration, job security, employment stability and career, learning opportunities, etc.)

In general, it can be said that remuneration, job security, employment stability, career and learning opportunities in craft and industrial occupations where welding is part of the job profile have steadily improved. There were approximately 79,800 employees subject to social insurance contributions in welding and joining occupations in Germany in 2018. Welding is remunerated differently in the sectors, depending on experience, company size, etc. from €12.50 to €20 per hour. On average, the hourly wage for welders is about 17 € per hour. This corresponds to about 68% of average earnings in Germany across all occupations.

Occupational safety is trained during training and also monitored later, so that the number of occupational accidents is continuously decreasing. In 2019, the fewest occupational accidents in Germany's industrial history were recorded nationwide. Of these, 2,870 occupational accidents occurred during joining activities such as welding and screwing. In Germany, all employees have the right to 30 working days of recreational leave and an additional 5 days of educational leave.

Overall, career and learning opportunities vary from region to region, but are at least satisfactory to good throughout Germany. Sometimes the distances to vocational schools, public transport connections and the demographic situation in rural areas, e.g. declining birth rates and rural exodus, especially of women, are problematic.

Today, the local economy lacks not only skilled workers but also those willing to train. Young people lack the necessary experience in the modern world of work at the end of their schooling. But only on the basis of their own experiences strengthen decisions about apprenticeship occupations and apply to companies for a training place. The existing guidance and counselling services are not effective enough

---

[4]Federal Institute for Occupational Safety and Health (BAuA) The advisory body of the Federal Ministry of Labour and Social Affairs (BMAS)Committee on Hazardous Substances (AGS), TRGS 528 Welding work, Technical Rule for Hazardous Substances, 2020, https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRGS/pdf/TRGS-528.pdf?__blob=publicationFile

[5] Federal Environment Agency UBA, Inventory determination of F-gases 2017/2018 - Data of HF(C)KW, HFC, SF6, NF3, SF5CF3, H(C)FE and PFPMIE, Emissions reporting under the Framework Convention on Climate Change, 02/2021, https://www.umweltbundesamt.de/publikationen/inventarermittlung-der-f-gase-20172018, p. 38, 40, 43, 102

for this. That is why every year more training places remain unfilled than before, even fewer girls enter dual training, while youngsters who start training drop out too often. [6]

Today, digital and technical skills are needed in combination, especially in SMEs. The requirements continue to rise. At the same time, the work of many SMEs contributes to sustainable development and thus to securing the future. However, this is unknown to young people today. The attractiveness of metal professions in particular seems to be declining for young people - compared to other craft and industrial professions. This threatens SMEs in sparsely populated and structurally weak regions, where demographic changes have a strong impact. The biggest social challenge for companies there is to find young professionals and to keep young people in the company longer after their training. Another challenge is the lack of willingness to take over.

For several years now, there have been initiatives that address these challenges. These include the federal funding programmes "JobStarter" [7]and "Jugendbauhütten[8]", but also the increasingly popular dual courses of[9] study that combine practice and study, or even trial courses of study that include a vocational dual education, a bachelor and a German Meister degree[10].

Process and product innovations in the field of welding to address the previously identified environmental impacts

It is fundamental for the economic future of the metal industry that all metal products, their machining processes, including the welding processes, require finite and thus critical raw materials. The "Climate Protection Handbook" was compiled from 300 current scientific studies. It discusses the contributions of steel production and metal processing to total greenhouse gas emissions as well as the medium-term shortage of raw materials and formulates possible solutions: *"The industrial sector with the most emissions today is the iron and steel industry - even though steel production in Germany has been declining in terms of volume for years. The high emissions are due to the fact that coal is burned as a reducing agent in the blast furnaces in order to be able to separate iron from the remaining rock. In future, the reduction of iron is to be carried out with green hydrogen instead. ... In a circular economy, energy consumption in the production of metals can be reduced because it takes less energy to process old metal than to produce it anew. …*“. [11]This is seen as an important impulse also for metal processing. Research and testing of the industrial combination of production and use of hydrogen is currently underway.

---

[6] Federal Institute for Vocational Education and Training (ed.), Datenreport zum Berufsbildungsbericht 2020, Informationen und Analysen zur Entwicklung der beruflichen Bildung, Bonn 2020, https://www.bibb.de/dokumente/pdf/bibb_datenreport_2020.pdf, p. 9 et seq.
[7] Federal Ministry of Education and Research, The JOBSTARTER plus funding programme, https://www.jobstarter.de/de/english.html
[8] German Foundation for Monument Protection, Youth Refuges, https://www.denkmalschutz.de/denkmale-erleben/denkmal-aktiv.html?&L=1
[9] Hofmann, Silvia; Hemkes, Barbara; Leo-Joyce, Stephan; König, Maik; Kutzner, Petra; AusbildungPlus in Zahlen. Dual study 2019. Trends and Analyses, https://www.bibb.de/dokumente/pdf/06072020_AiZ_dualesStudium-2019.pdf, p. 22 et seqq.
[10] Handwerkskammer Oberfranken, Für leistungsstarken Nachwuchs, https://www.hwk-oberfranken.de/artikel/fuer-leistungsstarken-nachwuchs-das-triale-studium-handwerksmanagement-b-a-start-oktober-2021-72,1164,2565.html
[11] Karl-Martin Hentschel, Handbuch Klimaschutz : wie Deutschland das 1,5-Grad-Ziel einhalten kann, oekom Verlag, Munich, 2020, ISBN: 9783962387563

The German Institute for Standardisation (DIN) has the NAS Standards Committee for "Welding and Allied Processes". This committee presented the "NAS Sustainability in Joining Technology" for the first time in 2019. Led by Prof. Dr.-Ing. M. Rethmeier, DIN SPEC 3523 "Sustainability in welding technology - Life cycle assessment of welding processes" is being developed. The publication is planned for May 2021. It will be taken into account in the course of ***CEMIVET***. The standards project is a collaboration between engineers and researchers from Fraunhofer IPK and the Federal Institute for Materials Research and Testing BAM. With the life cycle assessment method (ISO 14040, 14044), inputs and outputs of products or services - here a 1m weld - and associated environmental impacts are recorded in order to compare and evaluate processes.

These activities go back to a fundamental work from 2015 and[12]subsequent work[13]. This provides both examples of how to determine the environmental impacts of selected welding processes and guidance on how to conduct such analyses. Material, energy and gas consumption as well as auxiliary materials were recorded as key inputs. The associated environmental impacts were compared for four welding processes (MMAW, LAHW, GMAW standard+modified) in these impact categories:

- Global Warming Potential (GWP),
- Eutrophication potential (EP),
- Acidification potential (AP) and
- Photochemical ozone creation potential (POCP).

The LAHW method showed the best result in the impact assessment. The study did not consider the necessary equipment (welding equipment, robots, beam sources, etc.). Therefore, further research is needed to discuss and improve welding technologies.

Innovative laser material processing methods are described in several present publications in Germany like these of UBA, the environmental research institute of the government[14] and of the German Association for Welding and Allied Processes e.V. conferences[15].

Reflecting the issues of environmental impacts of welding reflected in existing VET curricula and training materials

In Germany, skills such as welding are usually acquired through dual vocational training, e.g. as a plant mechanic, and further training to bring them up to date. ***Occupational safety, health, accident prevention*** and ***environmental protection*** are mandatory components of all welding courses and

[12] Gunther Sproesser, Ya-Ju Chang, Andreas Pittner, Matthias Finkbeiner, Michael Rethmeier, Life Cycle Assessment of welding technologies for thick metal plate welds, Journal of Cleaner Production, Volume 108, Part A, 2015, Pages 46-53, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2015.06.121.

[13]WORKING DOCUMENT ON Potential Ecodesign R equirements for Welding Equipment and Machine Tool products, BAM, 2017, https://netzwerke.bam.de/Netzwerke/Content/DE/Downloads/Evpg/Industrie/405_workdoc_2017-10_notes.pdf?__blob=publicationFile

[14] Sarah Hackfort, Melanie Degel, Edgar Göll, Kai Neumann, Die Zukunft im Blick: Sozio-ökonomische und sozio-kulturelle Trends der Ressourcenschonung, Umweltbundesamt UBA-Texte, 2019, https://www.umweltbundesamt.de/sites/default/files/medien/421/publikationen/uba_klirex_fachbroschuere.pdf

[15] DVS Media, Berichte, Band: 367, Innovative Verfahren der Lasermaterialbearbeitung, https://www.dvs-media.eu/media/pdf/Bericht_366_Inhalt5f759a968d191.pdf

training, which are also tested. Digital media are used to illustrate hazards and protective measures. Companies provide information and training on occupational health and safety[16]. The rules for 250 processes for joining, cutting and coating metallic and non-metallic materials and material composites are available to all in freely accessible portals[17].

In 2019, the training regulations were changed. Now all training regulations contain modernised minimum requirements for the areas:

- Organisation of the training company, vocational training, labour and collective bargaining law,
- Safety and health at work,
- Environmental protection and sustainability and
- digitised world of work.

These four so-called ***standard occupational profile positions will*** apply to all training occupations from August 2021. Therefore, these new competences are described and teachers are currently receiving further training. For example, trainees should contribute to ***environmental protection and sustainability by***:

- *"Identify opportunities for avoiding operational burdens on the environment and society in one's own area of responsibility and contribute to their further development.*
- *Use materials and energy in work processes and with regard to products, goods or services under economic, environmental and social aspects of sustainability.*
- *comply with environmental protection regulations applicable to the training company*
- *Avoid waste, recycle and dispose of substances and materials in an environmentally friendly way.*
- *Develop proposals for sustainable action for their own area of work*
- *work together in compliance with company regulations in the sense of economic, ecological and socially sustainable development and communicate in a manner appropriate to the target group".*
- *Trainees should be much more competent in the field of safety and health at work.*
- *"Know the rights and duties arising from occupational health and safety and accident prevention regulations and apply these regulations.*
- *Check and assess hazards to safety and health at the workplace and on the way to work.*
- *explain safe and healthy working practices*
- *take technical and organisational measures to avoid hazards as well as mental and physical stress for themselves and others, also preventively*
- *Observe and apply ergonomic working methods*
- *Describe behaviour in case of accidents and initiate first measures in case of accidents*

[16] Schweisshelden, Linde Schweisstechnik GmbH, https://www.schweisshelden.de/fachwissen/schweissen-loeten-fuegen/arbeitsschutz-beim-schutzgasschweissen

[17] German Welding Society, Portal with the complete technical set of rules https://www.dvs-regelwerk.de/en

- *apply company-related regulations of preventive fire protection, describe behaviour in case of fire and take first measures for fire fighting".*

The fact that trainees are learning in a future-proof way, that professions are being transformed, is the result of negotiations between research and social partners. Concrete specifications for activities such as welding are in the pipeline.[18]

4.2 Italy

Key negative environmental implications of the welding processes and technologies in terms of pollution, waste of non-renewable raw materials and consumables, work safety and health protection of employees.

A first environmental impact of the welding processes is manifested in the fumes they emit. The most significant risk associated with welding fumes is represented by the presence, in the fumes, of metals in the state of vapor or fine particles (iron in a preponderant quantity; manganese, nickel, chromium in significant percentages; zinc, lead, silicon, titanium, aluminum, cadmium, molybdenum, vanadium, niobium, cobalt, tungsten, copper, beryllium, antimony in very low quantities or only in trace amounts). These and many other chemicals still produced today metal welding is certainly **one of the most critical activities for the health of the worker**[19].

The volatility of polluting particles such as industrial fumes, oil mists and aerosols, whether solid or liquid, involves and creates various problems for engineering companies, operators and machine tools. First of all, **they negatively affect the health of the air and the health and hygiene conditions of the operators**, in particular at the **respiratory level**, since particles smaller than 0.3 microns can reach the pulmonary alveoli, compromising the respiratory tract. Not only that, in contact with the epidermis, they create skin irritation, dermatitis and redness.

From a purely productive point of view, the pollution in the factory deriving from micro powders and oily mists considerably reduces the productivity of the plant and in particular the efficiency of the machine tools, since the stratification of pollutants affects the precision and tolerance of the instruments of measurement, with the costly consequence of having to increase maintenance interventions on the most delicate components. Dust, oil mist and aerosols, if not filtered and purified, make the floor slippery, dirty the surfaces of the machine tools and the walls of the shed, on which they are deposited.

These implications are taken into consideration at national and regional level through the provision of specific regulations. Example of measures and prevention of chemical and carcinogenic risk provided for by Legislative Decree 81/08[20] are:

---

[18] Federal Institute for Vocational Education and Training BIBB: Standard Berufsbildpositionen, 2020; Available in English at P. 10-12, https://www.bibb.de/dokumente/pdf/20200829_Publikation_Standardberufsbildposition_2020_Web.pdf

[19]https://www.vegaengineering.com/linea-guida-vademecum-per-il-miglioramento-della-sicurezza-e-della-salute-dei-lavoratori-nella-attivita-di-saldatura-metalli-a-cura-di-regione-lombardia--383.pdf

[20] http://www.cip.srl/documenti/Testo%20Unico%20Salute%20e%20Sicurezza%20sul%20lavoro%20-%20D.lgs.%2081-2008.pdf

- the replacement, when possible, of a substance or preparation with one of lesser toxicity;
- minimize the formation of fumes that may arise during processing;
- Ventilation of work environments;
- Localized extraction systems.

However, it can be said that the main arc welding processes are processes with a low environmental impact. Both the production of welding fumes and the disposal of packaging and waste of the materials used are aspects that affect modest quantities. Generally then the welding fumes are filtered before being discharged into the air.
From the point of view of health and safety, welding processes require particular protections as regards the following aspects:

- the production of welding fumes harmful to inhalation;
- the generation of ultraviolet radiation that can produce burns due to prolonged skin exposure and eye damage if in direct contact with the electric arc;
- the production of dust, projected metal fragments and noise above the safety threshold due to mechanical operations on the joints (grinding, chiselling, etc ...)[21].

With regard to PPE, the Italian legislation provides that in general all workers involved in the various stages of the production cycle must be equipped and use suitable personal protective equipment (PPE) such as:

- Protective clothing (full overalls, or long trousers with long-sleeved shirt or shirt);
- Safety footwear with non-slip sole;
- Gloves;
- Eye and face protection (mechanical and ultraviolet radiation).

The Lombardy Region, to improve the protection of the health and safety of workers in the sector, has issued Decree no. 10033 of 9/11/2012 concerning "Targeted prevention plan: Vademecum for improving the safety and health of workers in the metal welding activity"[22] in which it refers to the following areas on which to pay attention to safety:

- Use of machines and equipment;
- Work environment;
- Load handling with machines.

Therefore, both the environmental impact and the aspects related to health and safety at work are commonly further mitigated by measures such as the **filtration of fumes before release into the**

[21] Courtesy of Giancarlo Canale, Commercial Director - IIS Group
[22] https://www.vegaengineering.com/linea-guida-vademecum-per-il-miglioramento-della-sicurezza-e-della-salute-dei-lavoratori-nella-attivita-di-saldatura-metalli-a-cura-di-regione-lombardia--383.pdf

environment, the **differentiated disposal of waste**, the use of **inactinic screens** and protective goggles, the use of filter masks, noise protection and heat and ultraviolet radiation resistant clothing for welders[23].

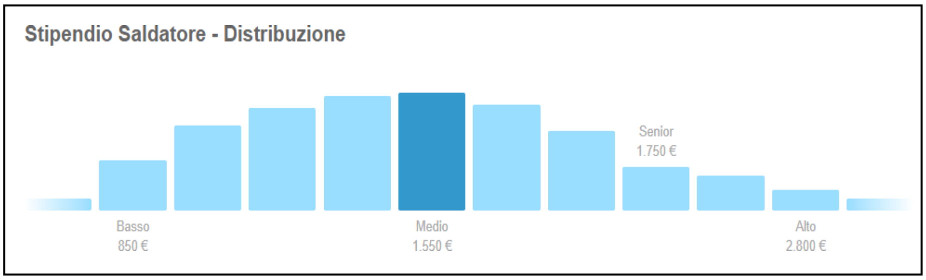
Key challenges of the social and occupational welfare of welding occupations

In Italy the profession of the welder is a very popular profession, in fact recent surveys by Sole24[24] show the professional profile of the welder among the **ten most requested professions among specialized workers and plant and machine operators**; they are also among the top professionals for whom demand is much higher than supply. Although this is a **tiring job** and although in many areas there is a **redirection towards robotic applications**, still today many welds in industry, especially in the sector of medium and large constructions, are performed manually and **the professionalism of the welder has a decisive impact on quality of products** and the competitiveness of the production process. Despite being a profession that provides excellent salary levels, there is a problem of the **low availability of young people** to deal with a mainly manual activity to be carried out in the workshop or construction site and the scarcity of training opportunities in the area[25].

In effect, the World Manufacturing Foundation, at the 2018 World Manufacturing Forum, made 10 key recommendations for improving the sector[26]. One of the main challenges of the engineering sector is to **cultivate and promote a positive image and perception of the manufacturing chain**.

In these terms, even the welding sector is not exempt from the need to subvert the common thinking that paints this sector as unhealthy and unattractive for the new workforce.

Then, taking into consideration the variables that affect the social well-being and the employment data of the professional figure of welder, it is clear that in Italy the average salary of an operator involved in welding processes is equal to € 1,550 net per month (approximately € 28,500 gross per year), in line with the average monthly salary in Italy. The salary of a welder can start from a minimum salary of € 850 net per month, while the maximum salary can exceed € 2,800 net per month[27].



Source: www.jobbydoo.it/stipendio/saldatore

According to Istat data relating to the three-year period 2014-2016 in Italy about **110 thousand people**

[23] Courtesy of Giancarlo Canale, Commercial Director - IIS Group
[24] https://www.ilsole24ore.com/art/alla-ricerca-90mila-lavoratori-entro-fine-dell-anno-ecco-30-figure-piu-richieste-ADzYLP3
[25] Courtesy of Giancarlo Canale, Commercial Director - IIS Group
[26] https://www.worldmanufacturingforum.org/copia-di-wmf-report
[27] www.Jobbydoo.it

are employed in professions related to welding. Of these, 75% work as employees in companies of various sizes, while 24% are self-employed. Most, 64%, are over 40 years of age[28].

Unioncamere data reveal that the **welder is a figure difficult to find** on the job market in Italy. In particular, Italian companies find it difficult to find people specialized in electric welding (difficulty of finding = 44%) due to the lack of candidates (73.2%) and inadequate preparation and training

26.8%). In fact, for about 80% of companies, further training in this area is required, perhaps by attending specialization courses to obtain the license. The problems associated with welders and flame cutters are more minor. In fact, this is a figure that is not particularly difficult to find, but who still needs additional training courses for 50% of companies.[29]

The Excelsior research[30] shows that in 2019 the difficulty in finding specialists in electric welding in Lombardy was 71% for the following reasons:

- For lack of candidates 39.2%
- Inadequate preparation 51.2%
- Other reasons 9.6%

Furthermore, what most denotes the welding sector is that it is an environment purely characterized by **male profiles**. For the Lombardy region alone, the data show that 82% of employees are male[31].

Again from the data that emerged from the Excelsior research in Italy, the contractual forms for the profession of the technician specialized in electric welding are characterized by:

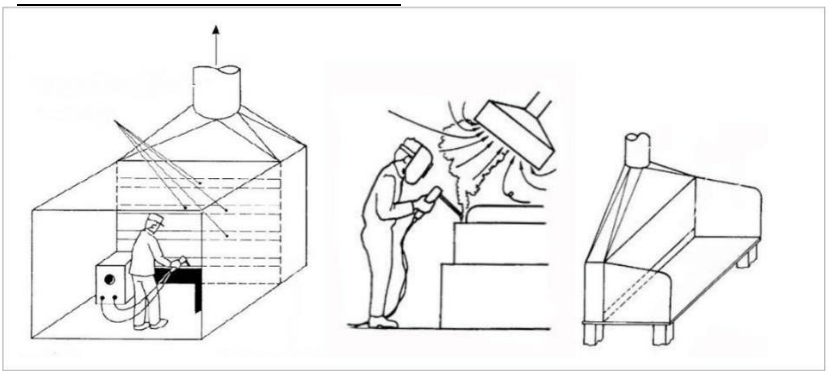
- 70% fixed-term contracts;
- 23% permanent contracts;
- 7% vocational apprenticeships.

A feature that makes the field of welding unattractive is that the activities related to it expose subjects to a wide range of risk factors and numerous pathologies[32] including:

- musculoskeletal system: upper limb tendinopathies, lumbar discopathies;
- respiratory system: bronchial asthma, chronic obstructive pulmonary disease, fever from metal fumes;
- integumentary system: allergic dermatitis, irritative dermatitis;
- intoxications: oxycarbonism;
- neoplasms: lung, nasal and sinus tumors, melanoma, ocular melanoma.
- accident risk: burns, cuts, ocular foreign body, etc.

[28] http://professioni.istat.it/sistemainformativoprofessioni/cp2011/index.php?codice_1=6&codice_2=6.2&codice_3=6.2.1
[29] http://assoservizi.eu/culture-blog/saldatore/
[30] https://excelsior.unioncamere.net/banca-dati-professioni/bdprof_scheda.php?cod=6.2.1.7.0&r=0103
[31] https://excelsior.unioncamere.net/banca-dati-professioni/bdprof_scheda.php?cod=6.2.1.7.0&r=0103
[32] https://www.repertoriosalute.it/rischi-nella-saldatura-strumenti-azioni-prevenzione/

To cope with these risks, the Lombardy Region, through the "Targeted prevention plan: application of the Vademecum for the improvement of the safety and health of workers in stainless steel welding activities" of 2012, indicated the suction methods and tools. In fact, during the welding phases, localized aspiration must always be provided, with the collection element positioned in the operating area.



Source: Presentation by Ing. Andrea Caridi, "The extraction systems", Prevention and Safety of Workplaces Service, Brescia 7 December 2016

Experimented, implemented and developed process and product innovations in the field of welding

The innovations in the welding sector mainly concern the evolution of processes in improving performance, quality and productivity, with an increasing use of hybrid processes that combine the prerogatives of different applications. Furthermore, there is a **strong push towards robotization**. As regards the environmental implications, innovation concerns the development of increasingly performing systems in terms of efficiency and optimization of the resources used[33].

Reflecting of the issues of environmental impact of welding in the existing VET curricula and training materials.

The training courses for the professional figure of welder are very differentiated according to the proposing entities. Since this is a professionalism intended for manual activities, a fundamental role is played by the **practical part of the training**. There are often also **theoretical parts** and the parts dedicated to **health and safety** are certainly part of the training programs[34].

In Italy to be able to practice the profession of welder it is necessary to have the so-called license for **welder**. It is in fact mandatory, from 1 July 2014 according to UNI EN ISO 9606-1: 2017[35], for those who work within companies and workshops to be in compliance with European legislation. In this way, the certified welder demonstrates that he knows how to manipulate the electrode, the welding torch or the torch, creating a weld of acceptable quality in any manual and semi-automatic fusion welding

[33] Courtesy of Giancarlo Canale, Commercial Director - IIS Group
[34] Courtesy of Giancarlo Canale, Commercial Director - IIS Group
[35] http://store.uni.com/catalogo/index.php/catalog/product/view/id/270284/s/uni-en-iso-9606-12017/category/849/?josso_back_to=http://store.uni.com/josso-security check.php&josso_cmd=login_optional&josso_partnerapp_host=store.uni.com

process. The certification has a maximum **duration of two years**.
Each license is linked to a specific welding technique (WPS) and belongs to the company as much as to the operator. In fact it has no validity if used in another context other than the one in which it was obtained.

From the survey carried out by the Excelsior Project "Green skills"[36], promoted by Unioncamere, 10 professions emerged that require a high degree of sensitivity and "aptitude for energy saving and environmental sustainability". The profiles inherent to the technical sphere have a higher impact percentage than the other figures considered, as shown in the table below:

Le 10 professioni per cui l'attitudine al risparmio energetico e sensibilità alla riduzione dell'impatto ambientale delle attività aziendali sono richieste con un grado elevato di importanza* (% sul totale delle entrate)

*Sono state considerate le professioni con almeno 3.500 entrate programmate/previste. Inoltre, per queste professioni sono state considerate esclusivamente le entrate per cui le imprese hanno segnalato per tale competenza un grado di importanza medio-alto e alto.

Fonte: Unioncamere – ANPAL, Sistema Informativo Excelsior, 2017

It is clear that the skills in environmental sustainability and green economy also impact the world of training, where only the teachers of vocational training have declared for 51%[37] that specific skills related to sustainability issues can only be part of their baggage cultural.

As regards the training contents in the field of sustainability, the sector is committed to limiting energy consumption and the quantities of consumables, gas, flows and filling materials. These latter issues are often present in training courses dedicated to welding coordination figures, with technical or managerial responsibilities such as the International Welding Technologist or the International Welding Engineer[38].

The new skills for the welding technician profile will have to include:

[36] https://www.cliclavoro.gov.it/Barometro-Del-Lavoro/Documents/2018/Excelsior-competenze-green.pdf
[37] https://www.cliclavoro.gov.it/Barometro-Del-Lavoro/Documents/2018/Excelsior-competenze-green.pdf
[38] Courtesy of Giancarlo Canale, Commercial Director - IIS Group

- circular economy
- attention to the sustainability of processes and products with a view to safeguarding the environment;
- 4.0 technologies and innovation.

4.3 Poland

The key negative environmental implications of the welding processes and technologies in terms of pollution, waste of non-renewable raw materials and consumables, work safety and health protection of employees

In 2015-2019, the financial result from the sale of products, goods and materials in the industrial processing sector increased by approx. 17.1%, with a simultaneous increase in electricity consumption by 14.4%[39].It is one of the many manifestations of the implementation of pro-ecological assumptions in the Polish economy. However, limiting the consumption of raw materials and energy must go hand in hand with reducing the amount of pollution and waste generated. Manufacturing techniques using welding and related processes, in most cases, do not cause large emissions of gases or dust, and the environmental fees applicable in Poland for this reason do not cause a significant financial burden for companies. The problem is the handling of settling the amount of emissions, especially in small companies and in the case of outdoor welding work and unorganized gas and dust emissions.

The emissions depend on the type of welding technologies used. Gaseous substances generated in an electric arc (nitrogen oxides, carbon monoxide), metal dust, and shielding gases (carbon dioxide, helium) are taken into account. Meeting the minimum requirements set out in the Environmental Protection Law[40] requires the enterprise to calculate the amount of such emission, submit information about it and assess whether the determined value exceeds the threshold for the obligation to pay the relevant fees. Such an impact can be determined, for example, using specialized computer software[41] or on the basis of guidelines contained in guides[42]. At the same time, when applying for an environmental decision, it is also important to take into account the production of productive waste (e.g. sheet metal cutting waste, welding wire waste) from the welding process itself, as well as during the preparatory work of such a process, e.g. pre-treatment, grinding, deburring. There is also a problem with waste that could normally be classified as municipal waste, but it is generated in production halls and is not related to the production technology, but to the activities of employees, e.g. beverage packaging, dust and sludge from cleaning workplaces. Packaging in which components and parts used in products as well as operating fluids, cleaning cloths and paint waste are also becoming more and more important.

[39] Materiały statystyczne udostępniane przez GUS: https://bdl.stat.gov.pl/BDL/start
[40] https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20200001219/U/D20201219Lj.pdf
[41] J. Matusiak, J. Wyciślik, A. Pilarczyk: i-EkoSpawanie – internetowy system doradczy wspomagający obliczanie emisji zanieczyszczeń pyłowych i gazowych przy spawaniu i procesach pokrewnych. 58 Konferencja spawalnicza „Technologie XXI wieku", Instytut Spawalnictwa, Polskie Spawalnicze Centrum Doskonałości, 18-20.10.2016r. Sosnowiec.
[42] J. Matusiak; B. Rams; S. Machaczek: Emisja zanieczyszczeń pyłowych i gazowych przy procesach spawania i lutowania metali : katalog charakterystyk materiałów spawalniczych pod względem emisji zanieczyszczeń, Gliwice : Instytut Spawalnictwa : Wydaw. WAM, 2004.

Important issues include the management of water used to fill the bathtubs, e.g. when cutting with hydroabrasive or plasma cutters (in preparatory processes).

The main hazards at the welder's position are[43]: electric shock, exposure to welding dust and gases, UV, Vis, IR radiation noise and electromagnetic field (especially high-frequency). The medical literature mentions the appearance of manganism and the symptoms of Parkinson's disease in welders[44]. Scientific research confirms the link between manganese exposure in welders and Parkinson's disease[45]. Disease symptoms were found in workers after exposure to manganese at a concentration of 0.14 mg / m3 with the applicable standard of 0.2 mg / m3.

A new problem to be solved is the formation of nanoparticles during welding and their impact on human health and the environment[46]. Toxicity, the mechanism of their action and impact on the body, as well as the pathomechanism of many respiratory diseases remain unknown, therefore there is a growing interest in a comprehensive risk assessment[47].

The key challenges of the social and occupational welfare of welding occupations in our countries (remuneration, work safety, employment stability and career, learning opportunities, etc.)

A welder is one of the five professions that have been at the top of the list of the most wanted professions in Poland for years. According to information from April 2021, collected from job offers posted on websites[48] and specialist forums[49], a beginner TIG welder in Poland can count on earnings from PLN 3,500 gross, while experienced - valued from PLN 5,000 gross (average earnings are PLN 4.3 thousand[50]) gross with the average gross salary in the enterprise sector in 2019 - PLN 5169). However, young welders' expectations as to wages may be even twice as high. Job offers abroad are much more attractive, which further reduces the supply of employees on the domestic market. Most welders in Poland are employed under employment contracts, and employers offer them additional private medical care, swimming pool passes, gyms or cultural packages. The earnings of a welder in Poland are often inadequately low in terms of risk to health and life. The most advantageous offers for specialists in this industry are offered by temporary employment agencies.

The cost of a certified welder's course in TIG technology is PLN 6,500, the MMA welding - PLN 7,200. PLN and MIG / MAG - 8 thousand. PLN. It is also possible to participate in free courses organized by employment agencies. Often the costs of training are covered by the employer, provided that the costs

[43] M. Skiba, J. Frymus: Wpływ środowiska pracy spawacza na jego zdrowie i życie, Studia i Prace WNEIZ US nr 51/2 2018, s97-107.
[44] G.R. Evans, L.N. Masullo: Manganese Toxicity. 2020 Jul 15. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan–. PMID: 32809738.
[45] S. R. Criswell, S. S. Nielsen, M. N. Warden, and others: MRI Signal Intensity and Parkinsonism in Manganese-Exposed Workers. Journal of occupational and environmental medicine (2019), 61(8), 641–645. https://doi.org/10.1097/JOM.0000000000001634
[46] H. Langauer-Lewowicka, K. Pawlas: Nanocząstki, nanotechnologia – potencjalne zagrożenia środowiskowe i zawodowe, medycyna Środowiskowa - environmental medicine 2014, Vol. 17, no. 2, 7-14
[47] M. Hurbánková, D. Hrašková, and others: Nanoparticles from welding and their effects on health. Pracovni Lekarstvi (2015). 67. 12-17.
[48] https://pl.jooble.org/praca-zarobki-spawacz access April 2021
[49] https://www.gowork.pl/forum/wynagrodzenia-pracownikow/wynagrodzenie-na-stanowisku-sp access April 2021
[50] https://businessinsider.com.pl/twoje-pieniadze/praca/zawody-deficytowe-w-polsce-2021-pandemia-nasilila-trendy/hmnh2zz access April 2021

incurred are paid off. The research conducted by the Welding Institute shows that in Poland over 4,000 people have international or European diplomas in the field of welding, and over 8,000 people have confirmed NDT qualifications. Of the 200 surveyed companies using welding technologies, each had at least one specialist with an international diploma[51]. According to the Polish Agency for Enterprise Development (PARP), based on the Study of Human Capital[52] in Poland, more than half of Polish companies see their competitive advantage in the competences and experience of their employees.

Changes in the method of production and the introduction of robotization of welding processes raise concerns about employment, but also raise hopes for improving working conditions among welders. Based on the research, it can be concluded that the employment structure changes most often as a result of robotization, employees are delegated to other duties, and the decline in employment occurs less frequently (approx. 20%), 65% of companies showed no changes in employment for this reason. Due to the improvement of the company's competitiveness and the increase in production obtained thanks to robots, in some companies the need to create new jobs appeared, almost 20% of the surveyed companies declared such a need[53]. Replacing workers with robots in positions where working conditions were harmful to them or in particularly monotonous and burdensome work, resulted in an increase in the general level of occupational health and safety[54].

Experimented, implemented or developed process and product innovations in the field of welding in order to deal with the before identified negative environmental implications

The need to reduce the consumption of energy and raw materials as well as reducing the amount of waste entails the constant modernization of the machine park and the search for more and more innovative technologies that reduce the consumption of energy and raw materials or significantly improve the quality of work performed, at a similar level of expenditure. One can mention research on welding with micro-cooling[55] or the development of CMT technology[56]. The National Center for Research and Development (NCBiR) is currently co-financing several scientific and research projects related to welding. Projects: POIR.01.01.01-00-0440 / 19, POIR.01.01.01-00-0779 / 18, POIR.04.01.04-00-0119 / 19 directly or indirectly fit into the assumptions of the circular economy, especially in the areas of increasing the work safety of welders, reducing pollutant emissions and reducing energy consumption in processes.

---

[51] M. Restecka, R. Wolniak: Doskonalenie jakości procesów spawalniczych w wyniku wdrożenia robotyzacji, Instytut Spawalnictwa, Oficyna Wydawnicza Stowarzyszenia Menedżerów Produkcji i Jakości, Częstochowa 2017

[52] https://www.parp.gov.pl/storage/publications/pdf/30---Raport-z-badania-pracodawcow_200129.pdf access April 2021

[53] M. Restecka: Struktura zatrudnienia a ekonomia w robotyzacji procesów spawalniczych, PRZEGLĄD SPAWALNICTWA Vol. 87 5/2015

[54] J. Fundowicz, K. Łapiński, B. Wyżnikiewicz: Wpływ robotyzacji na konkurencyjność polskich przedsiębiorstw. III Edycja, Instytut Prognoz i Analiz Gospodarczych, 2019

[55] T. Węgrzyn, J. Piwnik i inni: Innowacyjność procesowa w spawaniu laserowym z wykorzystaniem technologii chłodzenia mikro-jet. [W:] red. Knosala R., Innowacje w zarządzaniu i inżynierii produkcji. Tom 1, Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2016, s. 126-134.

[56] T. Węgrzyn, J. Piwnik i inni: Innowacyjność procesowa w spawaniu laserowym z wykorzystaniem technologii chłodzenia mikro-jet. [W:] red. Knosala R., Innowacje w zarządzaniu i inżynierii produkcji. Tom 1, Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2016, s. 126-134.

Welding sources for cooperation with robots, combined with the kinematics and control of the welding robot, allow the implementation of new technologies and processes, applications with TIG, CMT, brazing, laser and plasma welding processes are more and more common. The conducted analyzes indicate that robotization, although inevitable, is progressing very slowly in Poland. The number of robots in the years 2003-2013 increased from 2 to 14 machines per 10 thousand. people employed in industry[57], and ~~by~~ in 2019. has grown to 46 (the world average is 113) [58,59].

The issues of environmental impact of welding reflected in the existing VET curricula and training materials

The selected results of the Study of Human Capital Balance[60] (BKL Study) indicate that the key criterion in the selection of an employee for most employers is education (83%), then experience - 69% of respondents' indications, 25% of employers require the candidates at work to be primarily diligent, meticulous and precise. , responsibility, work discipline, honesty and reliability.

The analyzed curricula and welding course programs contain information blocks on the identification and causes of welding non-conformities as well as information on safety and accident prevention. The information contained therein concern: the welding environment, types of hazards in welding works, pollution and hazards related to dust and gases, hazards related to arc radiation, electromagnetic field and noise, and increased risk of electric shock[61]. The analyzes show that environmental issues and issues related to sustainable development are marginal. It is mainly related to the demand of the labor market, where the deficit of welders with basic skills is still visible.
The trainings that can meet the challenges related to the sustainable development of welding processes and technologies are addressed mainly to qualified employees of welding supervision and welding engineers. The modules related to the production and quality assurance in production contain content referring to the methods of searching for means optimizing the production of welded joints, economic and technological criteria for welding repairs or ways to reduce costs in the welding process[62].

4.4 Lithuania

Education and training of welders

The training programes of welders and welding operators are offered in many VET centres of Lithuania. In 2017 there was established a modern sectoral practical training centre for welding in Vilnius equipped with the modern welding technologies and offering a wide range of initial and continuing VET

[57] M. Restecka, R. Wolniak: Doskonalenie jakości procesów spawalniczych w wyniku wdrożenia robotyzacji, Instytut Spawalnictwa, Oficyna Wyd. Stowarzyszenia Menedżerów Produkcji i Jakości, Częstochowa 2017
[58] J. Fundowicz, K. Łapiński, B. Wyżnikiewicz: Wpływ robotyzacji na konkurencyjność polskich przedsiębiorstw. III Edycja, Instytut Prognoz i Analiz Gospodarczych, 2019
[59] https://evertiq.pl/news/26467 access April 2021
[60] M. Kocór, J. Górniak, P Prokopowicz, A.Szczucka: Zarządzanie kapitałem ludzkim w polskich firmach, obraz tuż przed pandemią, Bilans Kapitału Ludzkiego 2019, Raport z badania pracodawców w obszarze zarządzania kapitałem ludzkim, Warszawa 2020
[61] http://www.tdt.pl/component/rubberdoc/doc/307/raw access April 2021
[62] https://www.tuv.com/poland/pl/lp/tuv-rheinland-academy/specjalista-spawalnik-t%C3%BCv.html#AdditionalInformation access April 2021

programmes. Welding sector practical training center is so far the only such center in Lithuania and the most modern trining centre for welding in the Baltic countries, where welders are trained according to an accredited international training program for welders. This training center is established at the Vilnius Jerusalem Labor Market Training Center and is equipped with unique equipment that allows to train highly qualified international welders and other employees related to metal processing. Vilnius Jerusalem Labor Market Training Center has the necessary material for the training of welders, constantly updates and supplements it. Modular training programs have been developed: for the training of welders, plumbers, locksmiths. An informal program of non-formal training courses for employees performing welding work against the protection of electric PK, VK has been prepared. Achievement assessment tests and tasks have been prepared. Equipped with training workshops for welding and metal cutting using flammable gas and manual and robotic electric arc welding. The Center provides training according to 3 formal training programs and 5 non-formal training programs. It implemented the project “Welder Training Quality development (WTQuality)” (2015-2017) during which it acquired the status of ATB (Authorized Training Body) - accredited to train welders in accordance with the requirements of the international welders' associations IIW and EWF.

Experimented, implemented or developed process and product innovations in the field of welding in order to deal with the before identified negative environmental implications

There are several start-ups in Lithuania which develop and implement different innovations of the welding technologies. Here is one example.

Tenth of millimeters of thickness metal structures are welded by laser devices. This is the new welding method offered by Kaunas start-up LAR Technologies, which has opened up opportunities for manufacturers of metal decorations and sheet steel products. The traditional arc method currently used to weld sheet metal products has many disadvantages when it comes to precisely welding thin metals, as heat-exposed thin metals deform and a lot of time and effort is required to process the seam. "The complexity of the latter's software and the relative" clumsiness "of the devices have led to the search for a more convenient and easier way to adapt," says Naglis Ausman, CEO of the company. Lasers with a weld seam that is almost twice as narrow as an arc weld are connected to a device that simulates human movements. Companies purchasing such equipment can weld small quantities or unit sheet products directly or at any 360-degree angle. Thinner seams halve the time of their scrubbing and chemical bleaching. “The main innovation of our solution is adaptability. We connect a manual laser welding machine to the equipment we are developing, which communicates with the laser and acts as a common system that repeats smooth movement, "notes N. Ausmanas. The Lithuanian solution has already been implemented by Lithuanian companies specializing in sheet steel structures - from chimneys to kitchen equipment. Startup developers are very interested in companies, as there are many advanced engineering manufacturers in Lithuania, investing in innovations, looking for advanced, flexible and inexpensive technological solutions. Scandinavian and Western European peroducers also tend to choose technologies offering a wider range of welding and processing methods with the least possible invasion.

Source: *https://www.delfi.lt/mokslas/technologijos/isrinkite-geriausia-2019-metu-lietuviu-isradima-turime-ideju-kurios-sudomino-silicio-sleni.d?id=82873153*

There are working innovative suppliers and developers of the innovative laser welding technologies, like the following: *https://www.tmtrobotics.com/about-our-company/; https://protozauras.lt/en/about-us/.*

The issues of environmental impact of welding in the existing VET curricula and training materials.

The Occupational Standard of the Manufacturing of Welded and Soldered metal products (excluding machines and equipment) and of Transport Means (excluding motorized) and Equipment approved in 2020 defines the occupations and qualifications of this sector (Dėl virinamų ir lituojamų metalo gaminių (išskyrus mašinas ir įrenginius) bei transporto priemonių (išskyrus variklines) ir jų įrangos gamybos ir remonto sektoriaus profesinio standarto patvirtinimo, 2020, *https://www.e-tar.lt/portal/lt/legalAct/a5b50380a18411ea9515f752ff221ec9).*

The subsector of the production and repair of welded and brazed metal products (excluding machinery and equipment) include:

- manufacture of structural metal products, consisting of the manufacture of metal structures and parts thereof and the manufacture of metal doors and windows;

- the manufacture of metal tanks, reservoirs and containers, consisting of the manufacture of central heating radiators and boilers and the manufacture of other metal tanks and containers, the latter being subdivided into the manufacture of metal containers with compressed or liquefied gas;

- treatment and coating of metals, machining, manufacture of steel drums and similar containers and manufacture of light metal containers.

The above mentioned occupational Standard foresees the following qualifications of the subsector of the production and repair of welded and brazed metal products:

Title of qualification	Level of qualification according to the Lithuanian Qualifications Framework	Level of qualification according to the European Qualifications Framework for Lifelong Learning (EQF)
Contact welding operator	II	II
Brazing solder	II	II
Welder	II	II
Welder of plasma arc welding	II	II

Operator of thermal treatment plant for welded joints	II	II
Contact welding machine operator	III	III
Brazing solder	III	III
Operator of mechanized, orbital and robotic welding equipment	III	III
Industrial painter	III	III
Laser welding, cutting and surface treatment plant operator	III	III
Welder	III	III
Welder of plasma arc welding	III	III
Operator of thermal treatment plant for welded joints	III	III
Contact welding machine operator	IV	IV
Operator of mechanized, orbital and robotic welding equipment	IV	IV
Laser welding, cutting and surface treatment plant operator	IV	IV
Welding quality inspector-assistant	IV	IV
Welder	IV	IV
Welder of plasma arc welding	IV	IV
Supervisor of contact welding	V	V

Supervisor of mechanized, orbital and robotic welding	V	V
Welding quality inspector	V	V
Supervisor of laser welding, cutting and surface treatment	V	V
Welder supervisor	V	V
Welder supervisor	V	V

Analysis of the descriptors of the above indicated qualifications aimed to identify the content of competencies related to applying of the principles of circular economy, disclosed the following facts:

- Qualifications of the welders and welding operators (LTQF/EQF levels 2-4) do not contain competencies which are explicitly focused on the application or following of the principles of the circular economy in the work process. Descriptors of qualifications include the introductory unit of qualification defined as preparation of the workplace of welder. This unit contains a wide range of learning outcomes including the knowledge of the environmental requirements of the welder‘s work: basic and general requirements for the profession of welder, occupational risk assessment, occupational safety and health and environmental protection, professional ethics, as well as provisions of the Labor Code of the Republic of Lithuania and the Law on Safety and Health of Workers of the Republic of Lithuania directly related to the interests of employees.
- The level of autonomy of qualifications of welders and welding operators at the EQF levels 2-3 do not foresee autonomy of operators in decising about the parameters of the technological work process relevant for the application of the principles of circular economy. The welders of these qualifications have to follow descriptors of welding procedures.
- Welders and welding operators at level 4 enjoy higher autonomy in the broader fields of activities, including decision making in the fields which are relevant for the implementation and applying of the principles of circular economy, such as optimisation of the welding processes, planning of the welding systems, setting-up of the welding equipment, monitoringo of the working regimes and effectiveness of the welding systems, design of the welded constructions, design of the welding tooling and fixtures, autonomous selection of the welding materials, consumables and process parameters, quality control of the welded joints.
- The qualifications of welding specialists referenced to the level 5 (supervisors and foremen) include wide range of units and competencies related to the implementation and application of the principles of circular economy, such as: quality assurance of welded joints and quality control in the process of welding, managing of the quality control documentation, taking care about the welding productivity and economy of materials and consumables in the welding processes, analysis of the welding practices and drawing of know-how from the failures, taking care about the environmentally-friendly execution of welding operations and controling related

parameters, taking care about training of separate welders, operators or the group training activities in seeking to improve productivity, quality of product (dealing with non-conformities), savings of materials and meeting requirements of the evironment protection.

5. WORK AND LEARNING STATION ANALYSIS OF THE WELDING WORK PROCESSES : FINDINGS

This part presents the findings of the comparative analysis of the work and learning station analysis of the welding work processes aimed to identify the potential of implementation of circular economy principles and related competence requirements.

Work process/occupation: welding of metals.
Corresponding qualifications /VET programmes: welder, welding operator, welding supervisor (EQF levels 2-5).
General features of welding work process:
Types of product/service: • Truck trailers and bodies, trough & roll-off trailers for waste disposal companies , NF superstructures. • Sheet metal assemblies, housings, subracks • Products for exhaust systems, made of stainless steel and titanium • Equipment for processing and utilization of waste (food waste) • Aluminum helicopter tubular structures (frames) • Facilities for events • Furniture of steel and stainless steel • Agricultural machinery, cultivating aggregates; • Various steel structures made of profiles (e.g. structures of warehouse halls), laser cutting, welding of profiles, trusses; • Warehouse carts, hydraulic lifts, devices for internal transport, aluminum stairs, cabinets • Racks, stands, mounting systems for LCD / LED screens • Metal components for the machinery and transport industries, rail vehicles • Constructions and equipment for Oil and Gas industry, Industrial Plants installations (Shutdowns, Modules, Tanks), Marine Energy equipment (Anchor Piles, Jackets, etc.), tubes with extended surface and prefabrication of heat recovery systems, heat exchangers • Stainless steel tanks and equipment for food, beverage, chemical industries, energy sector • Welded steel structures for electric energy networks and installations: wind energy components, different constructions and elements for the nuclear power plants.
Internal suppliers of pre-products:

• Suppliers of materials and semi-products, like flat profiles, wheat profiles in a wide range of variants. • Industrial companies supplying components. • Wholesalers of the steel products in the vicinity. • Steel mills for sectional steels. • Procurement of assemblies from the nearby areas. • Steel suppliers from domestic markets and EU. • Welding consumables suppliers from EU. • A concern for companies using the services of existing suppliers in connection with the introduction of the principles of a closed loop economy is whether the components they use in their products will continue to meet quality and durability requirements in the future (by subsequent assumptions, e.g. 10 years of service).
Further / direct users of product/service: • Other departments of production for further processing of welded elements, parts, units. • Direct delivery of welded assemblies (some self-manufactured) and their assembling (bolted, welded). • Sometimes companies are subcontractors to other manufacturers, their components are used in the transport, automotive and construction industries (brackets, frames, handles, running elements, truss structures). • Maintenance of industrial, mining (oil), processing equipment and storage appliances, power generation industry. • Used as industrial components.
Clients of product/service: • municipal companies dealing with municipal waste management • medical technology, audio industry companies • aerospace sector enterprises • exhibition sector enterprises • catering companies (bars and restaurants) • individual farmers and companies providing services to agriculture (agriculture sector) • enterprises dealing in the production of steel structures • shipyards • refineries • advertisement industry (multimedia, offices and promotional departments) • production plants in the metal industry, transport companies, carriers • food and beverage producers • chemical and petrochemical industry • energy sector enterprises

• paper mills, mining industry.
Workplace characteristics:
Locations of workplace: • indoor and outside • approved work and training places defined according to standards • spacious production halls, separated by walls; several welding ends at workplace with protective walls • a grinding room for the preparation of the seams • working at customer sites to demonstrate the equipment used with the welding source, to execute training of qualified and certified welders at the customer's site.
Prevailing climatic conditions (heat, cold, radiation, ventilation, gas, vapours, fog, dust): • light, heat radiation, uv radiation, ventilation, noise, vapours, dust , electro-magnetic radiation and mechanical vibration • heated and ventilated facilities, in summer draught with fans. • ventilation of working spaces according to requirements of the EN ISO 15012-4: 2016.
The key emissions/ sources of pollution of the executed welding process to the workplace environment (pollution of air, water, soil, etc.): • industrial gases, aerosols and dust generated during welding processes: argon gases when welding with TIG, NOx, CO,CO2 PM2.5 and PM10 suspended dust, total dust with separated compounds MnO2, FexOy, CuO2, NiO2, cromium particles from welding of austenitic steel, nitric acid vapours from the chemical pickling of welds, Al2O3 in case of welding of aluminium. • UV radiation, dusts, noise, especially at plasma or gas cutting stations, welding fumes, metal active gas in case of MAG welding • waste after cleaning of chemically treated wastewater from the pickling process (neutralised sludge with coagulated heavy metal particles and grinding remains) • cutting with waterjet cutters also generates water pollution and large amounts of abrasive used.
Protective measures used in order to prevent negative implications of emissions and pollution at the workplace for the welder/welding operator, other employees and external environment: • extraction of gases and dust at the workplace: automatically functioning systems that extract, extraction per workplace with trunk, which is movable, using local exhausts with a filter of > 99% efficiency, purified air being recirculated to the hall and through general ventilation of the welding room

• welding booths: limitation of light emissions, separating walls shield electric arcs (only rarely with splashes thanks to conversion to electronics technology) • electronic spark prevention • mobile partitions against electric arcs • personal protective equipment: helmet with automatic lens,double visors, overpressure prevents entry of gases, respirators, leather gaiters, noise-reducing measures, adapted hearing protectors, fireproof protective clothing • weighing of the welded pieces • important voluntary decision of all employees to improve workplace quality.
Waste produced at the workplace: • non-hazardous waste: scrap metal, iron scrap, paper/cardboard of packing, wood, industrial waste type 1, metal residues, grinding residues, dusts, electrode rods and electrode welding rod caps, welding wire, tungsten welding needles, protective clothing, spare parts of the welding machines, grinding discs and other grinding tools, • hazardous waste: waste oil, packaging that has contained RP, rags or material soaked in RP, WEEE, used batteries, spare parts of the welding machines.
Procedures of collecting and recycling of waste produced at the workplace, the types of applied procedures: • implemented waste management system in the enterprise, persons delegated responsibilities for the collecting and sorting of waste in production, having register for waste (national environmental registers for packing waste and chemical materials) • resources for training and competence development of employees in the field of waste collecting and recycling • waste is disposed of according to defined procedures, there are used services of specialized waste collecting companies assisting in the disposal of hazardous filter residues • general waste management procedures, controlled internal notes with information on waste management, environmental guides • general waste management procedures, controlled internal notes with information on waste management, environmental guides • procedures on the sequence of work operations: if cut out, then being deburred, bended, welded • procedures for collecting of the different types of materials: steel CR17, magnetic steel, stainless steel; collection containers per different types of waste • procedures of programming the CNC machine in economic regimes • dust filtered via extraction and disposed of properly , grinding dust swept up at the site (mixing normal dirt) and disposed of professionally; the issues of calculating the amount of dust and metals emissions as well as matters related to environmental fees and the

collection and disposal of waste, including scrap can be outsourced to specialist external companies. • usage of wood waste as biofuel.
Good practices in the collecting and processing of the waste at the workplace: • various recycling practices • if a metal sheet is not used in full, it goes to the warehouse together with information about the cut distribution and the material specification, then it can be used for cutting in the future; the material is prepared for current production and, if the sheet is not used, to cut out details for planned future needs (in the warehouse) - related problem of the lack of storage space reserved for this purpose (especially with small production series) • using the leftover raw material for by-production, for example, the openwork created from cutting is used for fencing elements • applied incentives for welders/welding operators to follow the recommendations or requirements about processing of the waste at the workplace: welders encouraged to evaluate each waste and its suitability for further use; they are supposed to keep the workplace tidy (e.g. putting scrap metal in the designated place); they are trained to use the material economically and to use it intensively, by taking into consideration economic factor • training and information through established channels, included in the training curricula and times necessary for waste collection and treatment, specific tasks created from planning, communications to staff on World Environment Day, Recycling Day, annual awards • applied ISO 9001 material flows standards.
Subjects and methods of sustainable work in welding
Key tasks in the work process of welding: • material control before the production: sheets in small/medium/large are checked for surfaces on delivery; production preparation involves comparison of individual orders with each other to ensure material utilisation; dimensional accuracy checked with VQC machine and checked on the first piece • preparation of parts for welding: laser or plasma cutting of sheets and profiles, edge processing after cutting, deburring, grinding, vibro-abrasive machining; grafting; removal of burrs caused by lasers and punches - deburring on Grinding Master, grinding plates and rollers with the conveyor belt; bending of parts; cold forming, parts taken from large sheets are cut with digitally controlled cutting laser equipment • executing of welded joints: welding studs, welding of parts, welding for joining applied in the mix with other welding verbalisations; applying special arc EWM forf welding of steel does not require preparation of materials for welding

• intermediate checking the dimensional accuracy, non destructional quality control of welds: visual control, penetration liquid method, ultrasonic control and magnetosocpy • quality control: welding process specifications and quality control procedures are defined according to various standards and certifications (ISO standards, TÜV certifications), different destructive and non-destructive methods of quality control of welds applied - breakage test, seam check ; the welders and last years VET students/apprentices are expected to carry out the quality control by themselves (EQF 3-5); welded pieces which are broken for testing purposes are treated as scrap metal; possibly test pieces are also separated in order to be able to be reused. • post-processing if necessary: cleaning of welds, grinding, vibro-abrasive machining; in the case of large dimensions and inaccessible places, it is done manually (hand-held power tools) in rooms with extraction, smaller elements are being cleaned in continuous shot blasting chambers or in vibratory abrasive devices; outsourcing the preparation of materials for welding and the cleaning of welds (cutting and pre-treatment, deburring, grinding, cleaning); grinding and polishing of welds, brushing with the stainless steel brushes, pickling and passivation of the welds and whole surface (for stainless steel products), varnish coatings increasingly being carried out in-house using powder coating; the galvanic coatings made by the cooperators.
Applied welding processes: • TIG - depending on material thickness and gap size, the manual dexterity, it is possible to apply without further reworking for steel, stainless steel, aluminium • welding in the vacuum, with electrode, electric arc welding • submerged arc welding • MAG - requires continuous material application, post-processing only for steel, wedling of stainless steel; MAG active gas welding at 99 • MIG (isolated) for aluminium • MIG-MAG • SAW, SMAW, GTAW • gas for outdoor welding • MMA welding - only outdoor installation or in hard-to-reach places • flame, laser and plasma cutting • usage of welding robots for all processes referring to the volume of production • pulsed laser welding used for filigree parts • spot welding (cost-effective regime) • stud welding (mechanised) with tip ignition • orbital welding, welding using tractors • welding regimes depend on the product requirements (TA of vehicle construction) and defined in the drawings (sequence, rising/falling seams, root seam)

• welding regimes sometimes are defined and approved by the certification bodies (certification oft he welding procedures and welders if it is required by the contract) • for some welding processes, the installation techniques are not available • submerged acr welding generates more melted metal from the same input of energy, thus enabling energy savings.
Emissions produced during the preparatory stage, executing of welded joints, quality control and finishing of the surface, treatment of emissions: • waste from the preparation process or remnants of cutting openings (most often treated as segregated scrap, depending on the shape and dimensions, also used for secondary production, e.g. fences); noise, spark, splash, grinding dust, solvents. • dust and swarf from the grinding and cleaning process are collected by extractors and filters, and then transferred for disposal to external companies • welding phase emissions: smoke, light, waste, slag, projections; smoke is filtered with filters containing cleaning bags that are separated by compressed air, dust is disposed of; the extraction units are regularly checked by dealers and replaced if necessary. • after-welding processing emissions: griding and polishing material residues, emissions from the heat treatment furnace, sand and metal blasting residues, surface pickling and passivation materials, residues of painting lines. • problems with a large amount of plastic, cardboard and wood waste in the form of various types of packaging, damaged pallets, oils and consumables (collected by external companies); cardboard used as a filling and protective material when packing own products • in case of deficiencies, companies using ISO quality assurance standards have procedures in place for non-conforming products (repair, disassembly, scrapping); importance of economic account - more costly components are repaired, e.g. dimensions are changed and mating parts are adjusted; non-compliant products are either repaired or scrapped, depending on the type of deficiency and the dimensions of the item.
Practices/methods applied to reduce the volume of emissions at the each stage of work process: • at the stage of the design of welded products and constructions: minimising the volume of joints, taking into consideration the volume of waste and it's management options resulting from the design; positioning of the workpieces for cutting from the sheets; registering and ensuring traceability of the remaining sheet materials after cuttting for usage in the production of other parts and products; optimisation of the weld joint design • at the stage of the selecting of technological process of welding: selecting the most economic and environmently friendly welding processes for the each case by taking into consideration technological and product requirements (not compromising quality but avoiding excessive welding regimes, e.g. very often use of submerged arc welding for thick sheets helps to economise on the preparatory edge cutting of sheets and to reduce emissions

from this process); excessive requirements to welding in the design stage often become the core source of increased polution and waste; very often these overshoots in the design and technological preparation of welding process occur because of the speedy / hasty execution of the design, lack of „patiency" and time for high quality calculations of the needed volume of materials

- suitable and optimal selecting of the welding regimes according to the technological requirements of the concrete case; optimal selection of the welding procedures and regimes according to the required types of joints, control of the selection of welding regimes and avoiding applying excessive regimes in terms of thermal impact; while executing welds keeping within the limits of thermal impact defined in the welding procedure
- executing proper quality control of the metal sheets, avoiding the practices of economising on the quality of the metals by using cheap and low quality materials (rusted, contaminated, low-quality), what requires additional preparations and involves additional emissions; choosing and using less „contaminating" welding consumables, like, for example, welding with solid welding wires produces much less emissions that when using „powder" based welding wire
- applying savy procedures of the preparation of raw materials for welding and optimal welding regimes also permit to save on the surface treatment operations after welding (metal and sand blasting)
- strict quality control of the worksheets in order to prevent non-conformities before welding
- reducing the usage of abrasive materials for surface treatment of welds by using more cutters, grinding plates
- minimising the volume of welding work by maintaining high quality of welding (avoiding repairs of welds); emission reduction is sought by improving the quality of welds, by selecting and fine-tuning the composition of shielding gases and welding wires
- optimisation of the volume and intensiveness of the welding processed by the edge preparation before the welding proces, usage of the X welds, minimisation of the zones of weld area
- choosing the welder of the right profile and level of qualification for the foreseen welding processes: usage of competence frameworks of welders aligned with the levels of complexity of welded constructions/objects
- solutions that allow for the reduction of subsequent work expenditure on cleaning the connection; the shift to work with the use of welding robots and laser cutters (especially fiber type), allowing a greater use of the starting material and reducing waste through optimized nesting; the robots perform welds in a repeatable manner, which, with the right choice of means and parameters of the technological process, leads to the reduction of defects
- for MAG welding: usage of protective gas (mixed gas: argon [own silo] 92%+ Co2 & oxygen helps to avoid of spattering and gives better burn-in; focused arc (1000 degrees)

avoids radiated heat on the workpiece; temperature rise 1-2 degrees at a distance of 30 cm from the body • favouring „faster“ welding in seeking to use fewer materials and save emissions (entails the risks of mistakes and non-conformities what can increase the usage of materials, consumables and waste of welding process) • wire welding allows the operator to use only the amount of material necessary for processing, without producing waste due to the use of metals exceeding the actual production needs • usage of CNC machines (plasma cutters, lasers) significantly limit the harmful impact of welding processes on the operation of other stations (machining in a closed machine space) • strictly following quality management procedures, approval of the WPS and preparation of the welding instructions, executing test pieces of welding, certification of applied welding processes and welders in the company with the approved international/national audit and certification bodies, standard DIN 15085 -2 (incl. 3834) • favouring individualised methods and approaches in reducing the volume of emissions, depending on the individual experience of welder/apprentice • control of the furnace, periodical maintenance to verify its efficiency, study of the thermal treatments for their effectiveness, control of the temperature cycles and times • partially replacing welding with screwing and riveting • the quality and environmental impact of pickling of welds highly depend on the quality of cleaning of surfce after welding (remaining slags before pickling requires additional pickling operations with negative environmental implications) • surface treatment by painting requires optimal calaculation of the needed volume of paint and choosing optimal painting system (C2, C3, C4, C5) according to the corrosiveness of the environment of product usage, avoiding excessive painting • using metal blasting is more environmentaly friendly compared to sand blasting because of repetitive use of abrasive materials • periodic control of the aeration/ventillation systems of the welding areas by following internal regulations and rules of the enterprise (usualy executed by the responsible foremen and supervisors of the welding units), using control sheets of filtering systems.
Practices/ methods applied to reduce the volume of main materials (e.g. metals) and consumables in the welding process: • concentration of purchases of raw materials, integration of materials from engineering to make the most of raw materials • applying lightweight design and modular construction of products (vehicle units); work parameters of the performed process in the welding device are registered • Finite element design and product performance simulation technicques permit not to oversize the weld seams and the extent of the welds themselves. As a result, savings are generated on the amount of metal deposited, energy consumed, etc.

• larger amounts of waste and increased material consumption occur in the case of small series, where the cut details do not occupy the entire surface of the sheet; free spaces are then filled with elements for future orders; the arrangement of items on the sheet also takes into account the placement of smaller elements inside the holes punched in larger details; what can no longer be used in the production process is sometimes used for "by-product" production • unused sheets and profiles are labelled (steel grade, order) and sent to the warehouse, where they are taken from with the next order • sorting of the remaining waste of metals and welding consumables according to the type of materials. • defects arising in the production process are each time analyzed in terms of the cause of non-compliance and assigned to specific welders and stations • developing of practical skills of welding by using simulator before executing the real operations, practicing; possessing practical experience and availability of tools, using test equipment of the alternative methods, e.g. safety-relevant bolting, tightening torques and bolted connections by hand. • permanent security measures are also used, e.g. seals on gas regulators installed after setting the process conditions and various levels of access to the machine process settings • circular usage of the filtered wastewater of the pickling units and baths.
The most important synergies and/or trade-offs between the quality requirements and more “green” (environmentally friendly) approaches and methods in the process of welding: • compliance of the goals of quality assurance with the environmentaly friendly approaches of the organization and execution of work processes in welding; the quality of weld preparation is of critical importance for reduction of emissions and economies of materials • some customers (CEE countries) favour quality and durability of the welded products but still ignore the factor of sustainability of manufacturing; other customers (Nordic countries) prioritise the environmental aspects of welding processes in making decisions about orders and apply audit and certification practices • importance of following environmental requirements and having “green” welding processes as a part of strategy in promoting expoprts and entering of new demandive markets.
Autonomy of the welders/ welding operators to adjust the working methods and regimes in the ways which reduce emissions and consumption of materials and consumables, availability of support for welders and welding operators from the engineering staff: • clear and transparent order in the field of collecting, sorting and processing of wastes and prevention of emissions, very clearly transmitted to the welders (importance of training and awareness raising of welders on why the concrete practices are applied and how these practices contribute to wellbeing at work, health and environment); importance of the

transparent and clear technical documentation for welding (drawings and technical specifications) leaving a minimal room for interpretation of data by the welder • ergonomic convenience for welder to comply to the waste management and minimisation of emissions at the workplace: availability and functionality of the necessary infrastructure (e.g. for sorting of waste, protection of environment from emissions) • using surveillance, including video monitoring for control of the work of welders • competence of welders cannot compensate the lack of quality of the engineering and design stage • detailed prescription of the working tasks, welder must comply to the technical documentation and specifications; welding is highly complex work process, especially attaining the quality requirments ivolves a lot of efforts, thus, the responsibility of welder has to be clearly delimited and cannot be broad; limited autonomy, because main decisions are made by designers of products • welders receive detailed guidelines on the welding procedure specification (WPS); corrections made by an employee are possible, e.g. within the permissible range (e.g. 10%) of a parameter change; if employees perform work in certain ranges, they do not have to inform technologists about changes; in the case of piecework, welders cannot change any process parameters on their own, and each such fact is registered in the welding equipment control system in order to prevent the tendency of welders to "accelerate" their work by excessively increasing parameters (e.g. welding current) and, consequently, increasing the volume of non-conformities, such cases are usually foreseen in the WPS. • welders have to possess competence enabling autonomous preparation of the welds • where the robot operators are non-welding employees, only experienced technologists can change the operating parameters of welding proces, while an employee may only correct the robot's work path (to a limited extent) after obtaining the consent of the technologist • welders are encouraged to come up with initiatives regarding efficiency, quality and reduction of waste / scrap, but cannot interfere with the process technology themselves – this is more the role of welding supervisors • consultations with welders when preparing technical documents and procedures, collecting of their feedback and practical recommendations on the optimisation of welding processes • communication between decision-makers (wedlding supervisors and coordinators, engineers and designers) and welders is crucially important to ensure quality with the least possible workload.
Tools / equipment of sustainable work
Tools and equipment used to perform the welding tasks (machines, tools, devices, software): • welding machines (semi-automatic welding machines equipped with inverter sources, welding in MIG/MAG and TIG technology) • welding robots equipped with software enabling the control of the manufacturing process are being used to an increasing extent; it is also possible to track and save parameters of the

welding process in real time; the software includes features to automatically correct errors in case of undesirable interactions with the environment; Solidworks software; automation of the cutting and welding proces, individually adapted to the customer's needs • clamping tables to fix the assemblies and welding gauges in place, clamps, heavy duty clamps, gantry & slewing cranes (optimum relief); no forced positions (possible for repairs) • laser and plasma cutters to cut metal sheets, pipes and profiles, as well as cutting holes of various shapes, secator for thermal cutting, flame cutting and fusion cutting processes with motorised drive • chambers and equipment for sand and metal-blasting of the welded surfaces • tools for surface treatment: grinding discs and plates, polishing belts and tools, bleaching equipment and tools • baths and equipment for the pickling and passivation of the welded surfaces of stainless steel products.
Functionalities of the tools and equipment enabling to apply the working methods, regimes and procedures that reduce the pollution and waste of materials and consumables: • using/ benefitting from the competition of the providers of welding equipment in seeking to offer more energy –saving solutions; taking into consideration of the energy demands of welding machines when purchasing new welding equipment • pulse regime in welding helps to control the thermal input and to regulate the volume of energy, using of synergetic regimes of welding which help to control and optimise the energy consumption • usage of submerged-arc welding or combination of welding regimes with submerged arc welding for the welding of high thickness metal sheets (e.g. in welding 100 mm sheets the root of weld is welded by semi-automatic welding, the remaining weld- with the tractor of submerged arc welding by using the wire of 4 mm diameter), what permits to reduce the number of welding passes • wider usage of contact welding (point welding) instead of full jodint welding, where possible • robots replace welding sources in seeking to reduce or eliminate ineffective and energy-intensive operations, are applied where there is a shortage of skilled workers, helps to eliminate resource-consuming activities, e.g. manual grinding of inferior quality welds or manual tacking • automation permits to reduce the volume of rejects and to increase the efficiency and repeatability in welding and cutting - CNC cutters use software that optimizes the distribution of elements on the sheet and facilitates the management of material and cut orders • pollution reduction is manifested in equipping the workshops with local exhausts integrated with the burner, which eliminates the need to use large exhaust fans

• internal quality assurance, with 4 eyes principle, worker self-inspection by using inspection gauges and the quality control by the QM representative, who is a welder himself • accurate cutting with a secator helps in reducing the volume of grinding; using of cutting machines for preparation of edges instead of grinding; special base discs for grinding are expensive, but they create fewer emissions and residual materials • current wire welding equipment does not waste material because it allows the operator to work very precisely; the latest generation machinery optimize work and are more efficient than the instruments of the past • changing the mechanical valves to electronic ones helps to reduce consumption of gases by 1/3! • usage of custom-made EWM, hose packages (4-6.5m) on gallows makes welding process safer, causes less damage (no ground contact) • necessity of introductory special briefings and training sessions for wedlers/apprentices on these issues; welders being trained for welding with different materials, the functional skills are necessary to keep up to date; in the training process preparation of the pieces is always done manually, because the welders must prove that they are able to do this task; virtual welding simulation with computers for practical training are still too expensive, moreover one cannot simulate the material properties completely.
Organisation of sustainable welding work process
Modes of work organisation: • individual workplaces; welder executes single work in a shift; in the case of small series and on the customer's order production, the welds are placed by individual welders with appropriate qualifications • welder works together with the operator of mechanical treatment (in pairs) in order to ensure optimal productivity of welding operations • welder works in team with the operator of mechanical treatment who also can make the point welding of the sheets/parts to prepare for joining as well as to make intermediate surface treatment of welds (polishing) • critical importance of the right following of the sequence of welding operations defined by the technological specifications – very important to plan all the working operations in the holistic way by taking into consideration their interdependencies; supervision of the following of welding procedures by executing welding tasks made by the supervisor of the welding unit • two-shift system organised in teams, tasks being assigned according to the skills of the employees, possibly with handover to the next shift; a teamwork of qualified and experience welders and (easier to get) operators without welding skills allows to learn, select optimally and test of process parameters • rotation teams; divided teamwork • decided by the production manager

• some of the work is performed by robots and operators without welding qualifications, some by welders with permissions • controlled issuing of the materials and welding consumables for welders – monitored consumption plays the role of disciplining the welder; signalling and discussing of the cases of excessive consumption of materials and consumables of welding; the presence of the welding coordinator and one or more internal welding inspectors as elements of the organizational model
Problems or shortages of work organization which contribute to the increasing pollution, usage of materials and consumables, as well as increase of waste in the process of welding: • communication problems - failures in defining clear goals and clear work plan of welding process - customer, designer and welder must have the joint responsibility to understand and implement the order correctly; lack of a transparent and constant cooperation between the technological department (welding engineers, technologists), experienced welders and welding operators; a shortage of sharing information between the marketing department, which is familiar with the customer's requirements and environmental preferences, and the welders department, which focuses primarily on the quality of the product; the question of the scope and manner of such an exchange remains to be resolved • lack of concentration, lack of will, insufficient motivation of welders in performing of work • problems typical for handling individualised production processes - handling differences of the working time needed to produce standard products and specially designed ones (classical chassis could require 8h, special construction -up to 3 weeks); in case of individualised production customers often request changes and adjustments, whereas introduction of new parameters in the welding process can lead to undesired effects, while learning to handle them may require volume of production and time • problems caused by the defects of materials, what requires control by procurement and QC departments • ensuring the quality of processes in the initial phase of robotization implementation; employment of welding operators (with a shortage of welders) to operate robots may lead - during the implementation period - to an increase in the consumption of materials and energy (higher shortage rate), nevertheless, the implementation of supervision and the control of the process which are led by experienced welders is the reason to increase the efficiency and quality of production.
The ways of cooperation and interfaces between the welders/welding operators and other workplaces/specialists, which are critical to make welding processes more green and sustainable: • concentration of purchases to make use of materials for several orders where possible, use of raw materials (material integration sheets) • planning of work and control of work by methods and times to avoid unnecessary tasks

- quality and control of work to avoid repairs and further consumption of raw materials by segregating waste to be able to recycle (steel scrap, for example)   - production preparation units make arrangements with the welders depending on the situation   - cooperation between welder - welding robot and design specialist and welding coordinator help to optimise accessibility of production data reduces the volume of welding seams and ensures lower emissions   - exchange of know-how and competence between different welding specialists is systematically pursued: to ensure proper competence development the experienced welders work together with the novices (in pairs)   - welding engineers execute mentoring of welders by providing suggestions and recommendations on how to apply more sustainable and economic ways of working in executing different welding operations   - training projects that promote cooperation/teamwork; training is more focused on the overall learning effect and less about aspects like how much material is used, how many emissions are produced
Possible good practices of work organisation, which enable reduction of pollution, optimal use of materials and consumables and recycling of produced waste: - welders directly on the stands (smaller plants) verify the needs and the use of the remains of flat bars, bars, etc. to perform subsequent production orders; systematically making samples of welds for qualitative tests (continuous verification of skills); assessment of samples by an independent institution   - the welder's maintenance of good quality welds is taken into account; the employee gets promotion offers or, for example, financing new attractive courses and qualifications   - when operators of robots are skilled welders they are being trained by providing a new knowledge in the field of robotic workstations; training of welding technologists and operators (new unskilled workers) to work with welding robots; the operators of robotic welding stations can be without qualifications or even without welding skills, what allows welders to be directed to other tasks that could not be done without them   - qualified employees supervise the work of robot operators and control the quality of the process   - establishing tense collaboration between production preparation and programming units   - rotation of welders in the teams ensures enrichment and development of their competence and is usually well accepted by welders themselves   - collecting of the suggestions for improvement from the welders by the QM team, analysis and decision making about implementation, what could lead to investments, awarding of good proposals; using of the feedback from the customer service providing it to QM team   - error-causing components being reported to the design department, error reports and complaints are handled in the same way

<table>
<tr><td>

- usage of robotics requires better planning (no flexibility in the welding process itself).

</td></tr>
<tr><td>Environmental requirements of sustainable work in welding</td></tr>
<tr><td>

National/European standards, laws and specifications of environment protection need to be considered in the work process of welding:

- legal regulations regarding the protection of environment which are connected with the emission of dust and metals pollutants; national and regional standards and technical rules, national emission control regulations, especially those related to dust filter and protection from the noice; DIN 3834 standard, DVS leaflets; Learning Shot Ordinance; MAK values - maximum workplace concentration
- companies trying to implement environmental standards and are taking action in this direction by adjusting the current production processes; QM 9001 energy and environmental management according to the rules of the company; enterprise standards of the product design (lightweight, modular construction); procedural instructions, work instructions, WPS, welding consumables catalogues, references to the specific quality standards of welding, such as UNI EN ISO 3834 etc.
- regulations from the professional associations.

</td></tr>
<tr><td>

Operational environmental requirements or standards initiated and suggested by the enterprise:

- pro-environmental activities undertaken by companies are one of the ways to increase their competitiveness on the market; awareness of companies that the price of their products may not be competitive in relation to the offer of Asian markets and puting emphasis in their offer on the quality of products and the company's environmental policy, thus increasing importance that production takes place with care for the environment and resources
- use of energy-saving welding equipment and technologies that are less harmful to the environment - companies invest in their own photovoltaic power plants and sewage treatment plants; the replacement of the machinery park, the introduction of fiber laser cutters and welding robotization seeking to increase the productivity with the same level of energy consumption.
- usage of modern extraction systems (e.g. in welding holders), dust removal installations equipped with recuperators, which allow to save the energy needed to heat the halls; warm air from the compressor room is used to heat production rooms in winter
- customers 'inquiries about environmental policy are very rare, domestic recipients do not ask such questions, but it may be due to the fact that this information is already included in companies' brochures.
- current standards and regulations are defined by law; in some cases there are no special environmental requirements as pollutants are not carried outside, noise also remains indoors

</td></tr>
</table>

• pro-active approaches: setting goals beyond legal requirements.
Requirements of the customers and their compliance with the national/operational environmental requirements to welding processes: • growing environmental and sutainability requirements and demands from the public and municipal sector customers; customers demonstrate interest in the technologies used and the company's machine park; the welding sources used, extraction and filtering installations, and air vents are assessed; the terms of verification of the company (manufacturer or subcontractor), the production process and acceptance are set individually between the parties; customers are interested in the implementation of ISO environmental standards (Environmental management - ISO 14000 series standards) at their subcontractors and producers of the products they buy; before the cooperation/orders the welding processes of manufacturers are audited; marketing departments analyze information about customer expectations as to environmental requirements, but welding departments are not informed about such requirements or suggestions • sometimes customer requirements contradict the principles of circular and environmentally friendly manufacturing of welded products – requirements of the food/beverage and chemical industries to execute pickling of the whole surface of stainless steel equipment and tanks • handling with customer requirements according to EN 15085, EN/ISO 9001 ff & 14001, KBA-certifiications • preparation of the annual environmental impact reports by the quality management department.
Implications for vocational training curricula
Newly identified competencies related to the sustainability of work process: • practical experience for young welders (especially in the case of workers hired to perform responsible welded joints) and need of knowledge, especially visible when welding various materials (other than popular steels) and the sequence of activities in the welding process as a whole • possessing of the vocational/professional qualifications of welders, welding coordinators and inspectors • practical technological skills of welders needed for the preparation of materials and worksheets for welding • skills to properly design and perform a welding by selecting the method and parameters, and in the case of constructions - the lack of necessary and optimal accuracy; know-how of the techniques and technologies usied in renovation and repair (e.g. using welding and hardfacing);

• competencies of the welding engineers and design specialists: the posessing of know-how of the welding quality requirements for the different constructions and products by the welding engineers, especially when decising about sufficient (not excessive) quality requirements for welding process; understanding of the alternative procedures of welding by the designer; competencies of design demanded by the customer-oriented and environmentally friendly manufacturing, such as lighter weight vehicles, leading to Co2 savings and increasing possible load capacity; competencies needed to increase repairability of products (USP special vehicle construction, vertical range of manufacturing; competencies for optimisation of yield strengths of the steels in the wedling process; competencies on the alternation of welding and screwing by referring to the resilience and reliability of the joining; importance for welding engineers to have practical skills and practical (tacit) know-how of welding processes, especially when making decisions about optimal technological processes, procedures, regimes and design • competencies for welding supervisors and masters: strongly following the competence framework of welders linked to the levels of complexity of welded products or constructions; quality management knowledge and skills of welders focused on the level of work process of welding and products; also understanding by welders of quality management principles of organisation are important • holistic understanding of the product characteristics • understanding of the proces of waste management at the workplace and work proces levels • abilities of welders to read the drawings • ability to assess the usefulness of the remaining material (e.g. what remains after cutting) for subsequent processes; • digital skills for working with software of automated /robotized welding for programmers and operators; the operators of robotic welding stations may be persons without welding qualifications • competencies needed to verify the service credibility of producers and suppliers of welding equipment; competencies of servicing and maintenance of the devices beyond the warranty period; abilities to test new welding devices by welders in companies • specific functional skills and competencies of welding emerging in executing each new project and enhanced by customer demands have to be provided to welders • competencies on the welding quality and safety management.
Key sources of information and learning are needed for the provision of these competencies: • training of welders and related operators provided by the suppliers of technologies and materials – bringing in new and more sustainable ways of working • the time phases for training of „sustainability“ competencies are too short, there is a lack of the modules of practical training of such competencies • framework curricula are not up-to-date enough and oriented only to covering of basic requirements

• occupational standards and curricula do not sufficiently cover digitalisation and sustainability-related skills and competencies • direct know-how transfer from networks by using databases • regular meetings with the welding experts, where you are informed about the latest innovations • regularly updated welding certifications • technical specifications of metals • events of national ans sectoral professional organizations and bodies • learning materials provided by the VET providers • participation in the trade fairs, studying brochures of technology providers and using their provided training services • cooperation projects between the enterprises and R&D centres of the universities.
Suggested training methods and approaches for development of these competencies: • certified welders acquire new knowledge in the operation of robotic workstations; growing shortage of welders requires to train welding technologists and operators (new unskilled workers) to work with welding robots; • tacit knowledge and practical skills in the field of reparability and also dismantlability of the superstructures acquired and exchanged by welders through their work experience • modern processes and current R&D results through VET student internships • mentoring of VET students and apprentices • practical tasks • individualisation of continuing training of welders • applying incentives for apprentices via bonuses, prospects (master craftsman course) • recruitment of young people with school tours.

REFERENCES

Criswell, S. R. , Nielsen, S. S., Warden, M. N. (2019) MRI Signal Intensity and Parkinsonism in Manganese-Exposed Workers. Journal of occupational and environmental medicine (2019), 61(8), 641–645. https://doi.org/10.1097/JOM.0000000000001634

DVS Media, Berichte, Band: 367, Innovative Verfahren der Lasermaterialbearbeitung, https://www.dvs-media.eu/media/pdf/Bericht_366_Inhalt5f759a968d191.pdf

Erasmus+ Project "Learning through experience is one of the fundamental rules of sustained learning." http://icsas-project.eu/

Evans, G.R. , Masullo, L.N. (2021) Manganese Toxicity. 2020 Jul 15. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan–. PMID: 32809738.

Federal Institute for Occupational Safety and Health (BAuA) The advisory body of the Federal Ministry of Labour and Social Affairs (BMAS)Committee on Hazardous Substances (AGS), TRGS 528 Welding work, Technical Rule for Hazardous Substances, 2020, https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRGS/pdf/TRGS-528.pdf?__blob=publicationFile

Federal Environment Agency UBA, Inventory determination of F-gases 2017/2018 - Data of HF(C)KW, HFC, SF6, NF3, SF5CF3, H(C)FE and PFPMIE, Emissions reporting under the Framework Convention on Climate Change, 02/2021, https://www.umweltbundesamt.de/publikationen/inventarermittlung-der-f-gase-20172018, p. 38, 40, 43, 102

Federal Institute for Vocational Education and Training (ed.) (2020), Datenreport zum Berufsbildungsbericht 2020, Informationen und Analysen zur Entwicklung der beruflichen Bildung, Bonn 2020, https://www.bibb.de/dokumente/pdf/bibb_datenreport_2020.pdf, p. 9 et seq.

Federal Ministry for Economic Affairs and Energy (BMWi), Rohstoffstrategie der Bundesregierung Sicherung einer nachhaltigen Rohstoffversorgung Deutschlands mit nichtergetischen mineralischen Rohstoffen, 2019, p.18 https://www.bmwi.de/Redaktion/DE/Publikationen/Industrie/rohstoffstrategie-der-bundesregierung.pdf?__blob=publicationFile&v=4

Federal Ministry of Education and Research, The JOBSTARTER plus funding programme, https://www.jobstarter.de/de/english.html

Fundowicz, J, Łapiński, K., Wyżnikiewicz, B. (2019) Wpływ robotyzacji na konkurencyjność polskich przedsiębiorstw. III Edycja, Instytut Prognoz i Analiz Gospodarczych

German Foundation for Monument Protection, Youth Refuges, https://www.denkmalschutz.de/denkmale-erleben/denkmal-aktiv.html?&L=1

German Welding Society, Portal with the complete technical set of rules https://www.dvs-regelwerk.de/en

Hackfort, S., Degel, M., Göll, E., Neumann, K. Die Zukunft im Blick: Sozio-ökonomische und sozio-kulturelle Trends der Ressourcenschonung, Umweltbundesamt UBA-Texte, 2019, https://www.umweltbundesamt.de/sites/default/files/medien/421/publikationen/uba_klirex_fachbroschuere.pdf

Handwerkskammer Oberfranken, Für leistungsstarken Nachwuchs, https://www.hwk-oberfranken.de/artikel/fuer-leistungsstarken-nachwuchs-das-triale-studium-handwerksmanagement-b-a-start-oktober-2021-72,1164,2565.html

Hentschel, K.-M. (2020) Handbuch Klimaschutz : wie Deutschland das 1,5-Grad-Ziel einhalten kann, oekom Verlag, Munich, 2020, ISBN: 9783962387563

Hofmann, S.,Hemkes, B., Leo-Joyce, S., König, M., Kutzner, P. (2019) AusbildungPlus in Zahlen. Dual study 2019. Trends and Analyses, https://www.bibb.de/dokumente/pdf/06072020_AiZ_dualesStudium-2019.pdf, p. 22 et seqq.

Hurbánková, M. , Hrašková, D. (2015) Nanoparticles from welding and their effects on health. Pracovni Lekarstvi , 67. 12-17

Icha, P. (2018) Development of specific carbon dioxide emissions of the German electricity mix in 1990 - 2017, CLIMATE CHANGE 11/2018, https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2018-05-04_climate-change_11-2018_strommix-2018_0.pdf

Kocór, M., Górniak, J., Prokopowicz,P., Szczucka, A. (2020) Zarządzanie kapitałem ludzkim w polskich firmach, obraz tuż przed pandemią, Bilans Kapitału Ludzkiego 2019, Raport z badania pracodawców w obszarze zarządzania kapitałem ludzkim, Warszawa

Langauer-Lewowicka, H., Pawlas, K. (20014) Nanocząstki, nanotechnologia – potencjalne zagrożenia środowiskowe i zawodowe, medycyna Środowiskowa - environmental medicine 2014, Vol. 17, no. 2, 7-14

Lehnert, M., Zschiesche, W., Lotz,A., Behrens, T., Brüning, T. (2020) Gesundheitsschutz beim Schweißen - Aktuelle Herausforderungen, IN: IPA-Journal 01/2020, https://www.ipa-dguv.de/medien/ipa/publikationen/ipa-journale/ipa-journale2020/ipa-journal2001/ipa_journal_2001_schweissen.pdf

Matusiak, J., Ram, B., Machaczek, S. (2004) Emisja zanieczyszczeń pyłowych i gazowych przy procesach spawania i lutowania metali : katalog charakterystyk materiałów spawalniczych pod względem emisji zanieczyszczeń, Gliwice : Instytut Spawalnictwa : Wydaw. WAM

Raworth, K. (2017). Doughnut Economics: Seven Ways to Think Like a 21st-Century Economist. London: Penguin Random House

Restecka,M., Wolniak, R (2017). Doskonalenie jakości procesów spawalniczych w wyniku wdrożenia robotyzacji, Instytut Spawalnictwa, Oficyna Wydawnicza Stowarzyszenia Menedżerów Produkcji i Jakości, Częstochowa 2017 https://www.parp.gov.pl/storage/publications/pdf/30---Raport-z-badania-pracodawcow_200129.pdf access April 2021

Restecka, M. (2015) Struktura zatrudnienia a ekonomia w robotyzacji procesów spawalniczych, Przegląd spawalnictwa Vol. 87 5/2015

Saniter, A., Lopez, A.E., Carballo-Cruz, F. (2015). DualTrain: Building A Sustainable Approach To The Dual Vocational Training System In the Shoe Sector In Portugal, Spain And Germany. https://eera-ecer.de/ecer-programmes/conference/20/contribution/36510/

Schweisshelden, Linde Schweisstechnik GmbH, https://www.schweisshelden.de/fachwissen/schweissen-loeten-fuegen/arbeitsschutz-beim-schutzgasschweissen

Skiba, M., Frymus, J. (2018) Wpływ środowiska pracy spawacza na jego zdrowie i życie, Studia i Prace WNEIZ US nr 51/2 2018, s97-107.

Sproesser, G., Chang, Y-J., Pittner, A., Finkbeiner, M., Rethmeier, M. (2015) Life Cycle Assessment of welding technologies for thick metal plate welds, Journal of Cleaner Production, Volume 108, Part A, 2015, Pages 46-53, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2015.06.121.

Węgrzyn, T., Piwnik, J. (2016) Innowacyjność procesowa w spawaniu laserowym z wykorzystaniem technologii chłodzenia mikro-jet. [W:] red. Knosala R., Innowacje w zarządzaniu i inżynierii produkcji. Tom 1, Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole 2016, s. 126-134.

Working document on Potential Ecodesign R equirements for Welding Equipment and Machine Tool products, BAM, 2017, https://netzwerke.bam.de/Netzwerke/Content/DE/Downloads/Evpg/Industrie/405_workdoc_2017-10_notes.pdf?__blob=publicationFile

.

Co-funded by the
Erasmus+ Programme
of the European Union

CEMIVET

ibbf
MetaIndustry4
Centrum Promocji Innowacji i Rozwoju
Verslo konsultacinis centras
VYTAUTO DIDŽIOJO UNIVERSITETAS
REI Reindustria Innovazione