ERASMUS+ Programme Key Action2: Strategic Partnerships
'Circular Economy in Metal Industries VET`
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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

EXECUTIVE SUMMARY

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.

The main goal of this document 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:

1. Disclosing the existing practices of the re-design or improvement of welding work process, which follow the principles of circular economy.
2. Identifying the skills/competence needs brought by the application of the principles and practices of circular economy.
3. 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).

1. 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):

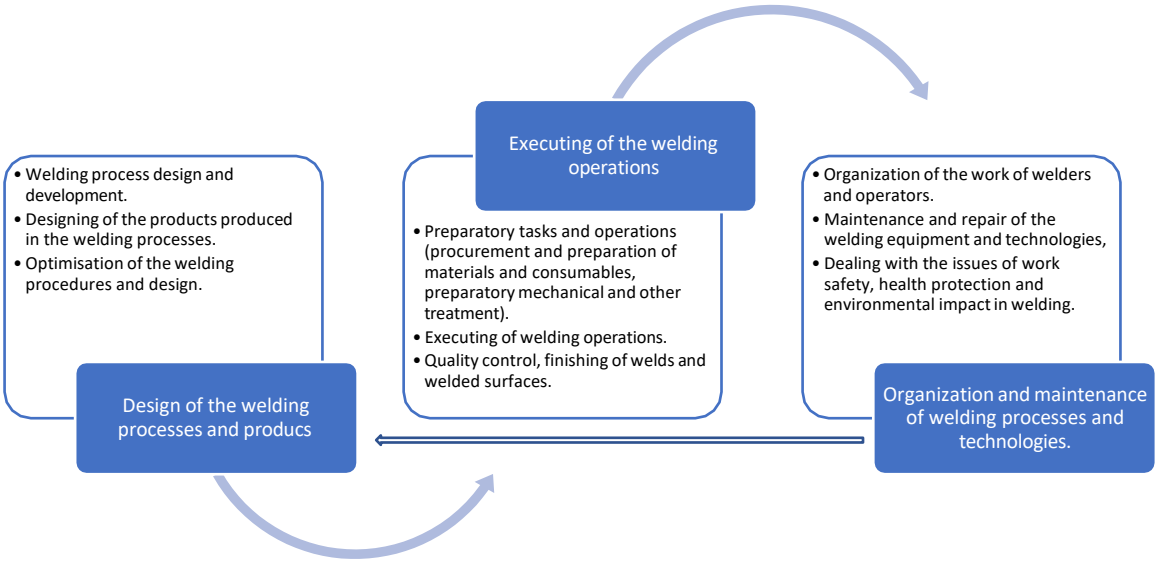

Figure 1. Structure of the work processes of welding

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).

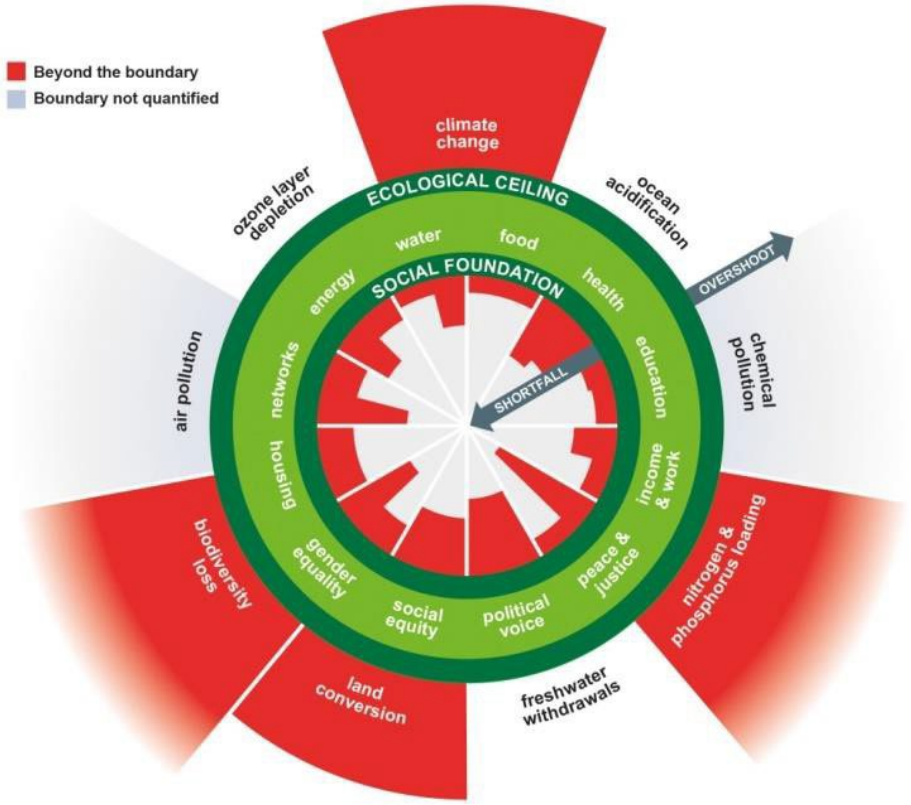

Figure 2. The Daughnut of social and planetary boundaries (Raworth, 2017).

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.

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.

2. 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.

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.

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.

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 entail 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 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 greener and more 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 regard 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

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

Table 2: Overview about interview partner in the countries analysis

The findings of this study together with the study of the available documents stipulating work processes of welding and related environmental requirements served as a basis for design oft he competence matrix oft he sustainable execution of work processes of welding.

3. COMPETENCE MATRIX OF THE SUSTAINABLE EXECUTION OF WORK PROCESSES IN THE FIELD OF /AND RELATED TO WELDING

This competence matrix is developed on the basis of the above provided findings of the work and learning station analysis of welding in the project partner countries. It describes the main competence areas and competence development steps related to sustainable, environment friendly and 'circular' execution of the work processes of welding. It can serve as a reference for development of the new and updating of the existing training modules in the initial and continuing VET. Each competence development step can be regarded as separate training module. Provided competence matrix "aggregates" the competence development steps of the whole technological and work processes of welding defined in the Figure 1. In order to identify the competence steps applicable for the different qualifications of the welding specialists, they are marked with the different colors of the matrix "boxes":

Competence areas	**Competence development steps**				
Following the design and maintenance of sustainable work process and products	To read the drawings and understand the symbols and technological information in order to avoid mistakes and non-conformities.		To discuss the technological requirements and possible practices of sustainable technological work regimes (using of materials, applying welding regimes, preparation of materials) with designers and engineers.	To apply the instructions and suggestions of sustainble usage of materials and consumables in the welding practice.	
Sustainable and circular preparation, maintenance and design of the workplaces in welding	To keep the workplace tidy (e.g. putting scrap metal in the designated place).	To execute periodic control of the aeration/ventillation systems of the welding areas by following internal regulations and rules of the enterprise, using control sheets of filtering systems .	To sort and dispose the waste at the workplace according to defined waste management procedures and systems (ISO etc.), internal rules of waste management, environmental guides.To evaluate each waste produced at the workplace and its suitability for further use.	To execute and ensure the traceability of the used materials in ensuring economic usage oft he main materials (metal sheets) by moving the remaining materials to the warehouse and using them in further production.	To execute the regular control and maintenance of the welding equipment in seeking to verify its efficiency, to control the temperature cycles and times.

Sustainable and circular execution of the technological operations in the field of welding.	To execute quality control of the materials and executed welds: visual control of the metal sheets and workpieces before the welding in order to spot and remove dirt, slags, rust and other deficiencies potentially having harmful effect on quality and volume of used materials; to execute the self-inspection of weld by using inspection gauges, as prevention of non-conformities.	To follow strictly quality management procedures, requirements of the WPS and welding instructions.	To apply savy procedures of the preparation of raw materials for welding permitting to save on the surface treatment operations after welding (metal and sand blasting); to follow the technological requirements and guidelines for selecting and fine-tuning of the composition of welding consumables : shielding gases, welding wire, electrodes etc.; to execute the preparation of the surface and edges of ther workpieces and sheets before welding by using	To apply technological solutions of welding regimes that allow for the reduction of subsequent work expenditure on cleaning the connection; while executing welds to keep within the limits of thermal impact defined in the welding procedure; to execute welds in applying savy regimes, such as pulse regime helping 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; to apply submerged-	To apply higher pace in executing welding operation in seeking to use fewer materials and save emissions (only for highly experienced welders, not compromising the quality) .	To ensure proper quality of cleaning of surface after welding (remaining slags before pickling requires additional pickling operations with negative environmental implications); to follow strictly the requirements of the need of the volume of paint and other surface surface treatment materials by referring to the corrosiveness of the environment of product usage.	To develop practical skills of welding by using simulator before executing the real operations, practicing; to use test equipment of the alternative methods, e.g. safety-relevant bolting, tightening torques and bolted connections by hand.

			cutters, grinding plates instead of abrasive materials (where possible); to execute the edge preparation in the ways which help to optimize the volume and instesiveness of the welding /joining and to minimize the zones of weld area.	arc welding or combination of welding regimes with submerged arc welding for the welding of high thickness metal sheets, what permits to reduce the number of welding passes; to apply contact welding (point welding) instead of full joint welding, where possible; to use the CNC machines (plasma cutters, lasers) in seeking to limit the harmful impact of welding processes on the operation of other stations (machining in a closed machine space).			
Sustainable and circular organization of work in welding	To control issuing of the materials and welding consumables for welders by disciplining the welders and	To ensure the proper division of tasks amongst the welders in the workplaces by referring to	To define clear goals and clear work plan of welding process; to support transparent and constant	To organise teamworking of welders with different levels of qualifications, incl. the organisation of	To establish and maintain tense collaboration between production preparation and		

	signalling / discussing of the cases of excessive consumption of materials and consumables of welding; to organize 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; to select and use less „contaminating" welding consumables, like, for example, solid welding wires which produce much less emissions that when using „powder" based welding wire.	the fit of their qualifications to the quality requirements related to he complexity of welding processes individual workplaces; to ensure the right following of the sequence of welding operations defined by the technological specifications; to plan all the working operations in the holistic way by taking into consideration their interdependencies.	cooperation between welding engineers, technologists, experienced welders and welding operators regarding requirements and environmental preferences; to plan the work and control of work by methods and times to avoid unnecessary tasks.	work of experience welders and beginners operators; to execute the mentoring of welders by providing suggestions and recommendations on how to apply more sustainable and economic ways of working in executing different welding operations; to exchange practical and theoretical know-how on the sustainable, circular approaches and ways of welding betw. welders, welding operators and engineering staff; to collect and evaluate the suggestions from welders on the improvement of sustainability of the welding processes.	programming units in the field of sustainable optimisation of the welding processes.
Sustainable and circular digitalization of the work processes in the field of welding.	To use welding robots and CNC 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).	To monitor and mitigate the consumption of the materials and energy in operating welding robots at the initial stages of their implementation by seeking to deal with possible increases in this consumption.	To optimise accessibililty and communication of the production data between the welding cobot, operator and design specialist in seeking to reduce the volume of welding seams and to reduce the volume of emissions.		

Sustainable and circular design of welding processes and products (welding technicians, engineers and designers, EQF 5-7)	To apply know-how of the welding quality requirements for the different constructions and products when deciding about sufficiency (not excessive) of these requirements for welding process; to evaluate possibilities to optimise of yield strengths of the steels in the welding process; to minimise the volume of welded joints in the design of products, taking into consideration the volume of waste and it's management options resulting from the design; to optimise the weld joint design.	To select the most economic and environmently friendly welding processes, regimes and procedures 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); to control the selection of welding regimes in order to avoid applying excessive regimes in terms of thermal impact.	To combine the theoretical know-how and engineering expertise with the practical (tacit) know-how of welding processes possessed by welders and welding operators, especially when making decisions about optimal technological processes, procedures, regimes and design; to engage in consultations with welders when preparing technical documents and procedures, collecting of their feedback and practical recommendations on the optimisation of welding processes	To design clear and transparent order in the field of collecting, sorting and processing of wastes and prevention of emissions of the welding processes; to develop the transparent and clear technical documentation for welding (drawings and technical specifications) leaving a minimal room for interpretation of data by the welder.	To evaluate the possibilities for applying alternative procedures of welding; to consider and foresee partial replacement welding with other technological processes having lower impact on environment (e.g. screwing and riveting), where possible.	To design the customer-oriented and environmentally friendly welded products, leading to Co2 savings; to consider the increasing of repairability of products in the design process (USP special vehicle construction, vertical range of manufacturing, applying lightweight design and modular construction of products (vehicle units).

*Table 3: Overview about competence areas and development steps for skilled welders and welding operators (EQF levels 2-4, in **yellow fields**, Welding supervisors and technicians (EQF level 5, in **green fields**, welding process engineers and product designers (EQF levels 6-7, in orange fields))*

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