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

Project title:

Creating knowLedge and skilLs in AddItive Manufacturing

CLLAIM

Reference number:
2017-3309/591838-EPP-1-2017-1-ES-EPPKA2-SSA

3.1 European AM Designer, Specialist, Operator and European AM Inspector's Occupational Standards / 3.2 LOs' Guideline for the AM Qualifications

Guideline - General information for the public and organizations that implement these qualifications

European DED–Arc Operator

LEGAL NOTICE

Index

1. Preface

The present document consists in European Operator DED-Arc Guideline, developed in the framework of an European project “Creating KnowLedge and SkilLs in AddItive Manufacturing / CLLAIM“.

This guideline, for the European education, training, examination and qualification of additive manufacturing personnel, has been developed and approved by all partners involved in the project: EWF, CESOL, DVS, FhG, LZH, Lloyd’s Register, IDONIAL, TWI. Contains general information for the public and organisations that implement this qualification.

This guideline was developed with a close relation to industry and standardization bodies. The guideline was validated in workshops directed to industry and education centres. Moreover, the guideline was validated by experts from EWF’s International Additive Manufacturing Qualification Council and was built with close relation to ISO and ASTM.

Furthermore, this guideline englobes Occupational Standards and Learning Outcomes for the qualifications identified by the Industry as more relevant: Operator, Designer, Supervisor and Inspector.

Copies of this document can be downloaded from CLLAIM website: cllaimprojectam.eu or requested from European Union dissemination platform.

2. Routes to Qualification

Three distinct routes to gaining the qualifications described in this document have been agreed to all AM profiles developed under project CLLAIM scope.

1. The Standard Route
2. Blended Learning Route
3. Alternative Route

2.1 The Standard Route

The Standard Route requires successful completion of AM approved courses which are designed to meet all the requirements in this Guideline. This is the route recommended, as offering the fastest, most comprehensive manner in which the detailed knowledge may be covered.

2.2 Blended Learning Route

The Cross-Cutting Competence Units (theoretical knowledge and skills) may be taught using Distance Learning Programs under the control of European harmonized system and all the Functional Competence Units (practical knowledge and skills) must be taught at the facilities of a Training Centre that has the capacity to do so.

2.3 Alternative Route

The alternative route allows those who have gained relevant knowledge and skills in a particular job function through formal, informal and non-formal means of education to proceed to examination without a compulsory attendance of an approved training course or specific Competence Unit addressed by it. The alternative route encompasses two possibilities for the validation of knowledge and skills, through: the direct recognition of the Competence Unit.

3. Guideline for Metal AM Operator DED - Arc

3.1 Introduction to Metal AM Operator DED - Arc

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	EO-DED-Arc	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 01: DED-Arc Process	14	28
CU 02: Quality Assurance (QA) in DED-Arc	7	14
CU 03: Health, Safety and Environment (HSE) in DED-Arc	7	14
CU 04: Fit and set-up of DED-Arc systems	21	42
CU 05: Manufacturing of DED-Arc parts	7	14
CU 06: Post processing of DED-Arc parts	7	14
CU 07: Maintenance of DED-Arc systems	14	28
TOTAL	84	168

* Recommended Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Expected Workload is calculated in hours, corresponding to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Although the hours indicated in the above table are merely recommended, it is mandatory that in total the qualification has a minimum of 40 contact hours.

Within CLLAIM project's qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Sectoral Systems Framework levels (see Appendix I). On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills. Recommended contact hours are distributed between theoretical (A), assigned pro-jects/exercises (B), practical workshop training (C), etc., as shown in the following example:

Qualification: Example 1	
CONTACT HOURS	X= (SUM A:C)
Subject Contents	A + B + C

3.2 Occupational Standard

EO DED-Arc are the professionals with the specific knowledge, skills, autonomy and responsibility to operate metal AM machines using DED-Arc Process. His/her main tasks are to:

- Operate arc based DED machines for AM, including, fitting and setting up, maintenance and repair.

He/She will be able to:

- Verify arc related parameters and positioning in DED-Arc machines for AM;
- Self-manage the handling of feedstock (approval, storage, contamination, traceability);
- Develop solutions on basic and specific problems related with DED-Arc machines and processes for AM.

3.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to European Metal AM Operator Qualification admission are the following:

- National compulsory school diploma

3.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
EO DED–Arc	INDEPENDENT	Factual and broad concepts in the field of DED–Arc metal additive manufacturing process.	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific of DED–Arc manufacturing problems	Self-manage of professional activities and simple standard applications of of DED–Arc manufacturing in predictable contexts but subject to change.

3.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Operator DED-Arc is listed below.

3.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	14

Learning Outcomes – CU 00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – Directed energy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

3.5.2 Competence Unit 01: DED-Arc Process

CU01: DED-Arc Process SUBJECT TITLE	CONTACT HOURS
DED-Arc System (Hardware & Software)	5
DED-Arc Physical Principles, Processes and Parameters	5
DED-Arc Build platform, feedstock and other consumables	3
Post processing operations	1
Total	14
WORKLOAD	28

Learning Outcomes – CU01: DED-Arc Process	
KNOWLEDGE	Factual and broad of: – DED-Arc systems – Arc physics – Processable materials with DED-Arc – Processing atmosphere requirements with DED-Arc – Sensors and process controls with DED-Arc
SKILLS	Describe the DED–Arc systems, including the components and their functions Distinguish different types of feedstock Associate the interaction of the process heat source with the feedstock Recognise the DED–Arc parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED–Arc build platform, feedstock and other consumables Identify the problems associated with inadequate preparation and set-up of the build platform, handling and storage of feedstock and application of the gases used in DED–Arc

3.5.3 Competence Unit 02: Quality Assurance (QA) in DED-Arc

CU 02: Quality Assurance in DED-Arc SUBJECT TITLE	RECOMENDED CONTACT HOURS
General QA principles	3
AM Machine QA	2
AM Parts QA	2
Visual Inspection Overview	4
Total	11
WORKLOAD	22

Learning Outcomes – CU 02: Quality Assurance in DED-Arc	
KNOWLEDGE	Factual and broad knowledge of: – Quality Assurance in DED-Arc – Standard operating procedures – Overall overview of process flow from costumer purchase order to delivery of finished part – Receiving inspection of feedstock and build platform – Receiving inspection of non-consumable electrodes and constricting nozzles in DED-Arc – Material staging and preparation – Visual Inspection of DED-Arc
SKILLS	Recognise the broader use of QA within engineering Recognise the scope of the DED-Arc operator qualification within the AM industry Support the qualification and requalification procedures of DED-Arc equipment Identify the main procedures, equipment and their role Prepare test reports based on the requirements specified by the manufacturer Compare geometry and dimensions specified in the technical drawings with the as built parts Use simple measurement devices and techniques to carry out a basic visual inspection of the as built part Identify problems in the as build parts distinguishing between imperfections and defects Report defects suggesting either their removal with post processing operations or part disposal

3.5.4 Competence Unit 03: Health, Safety and Environment (HSE) in DED-Arc

CU03: HSE in DED-Arc	CONTACT HOURS
SUBJECT TITLE	
Health, Safety and Environment	7
Total	7
WORKLOAD	14

Learning Outcomes – CU03: Health, Safety and Environment (HSE) in DED-Arc	
KNOWLEDGE	Factual and broad of: – Health, Safety and Environment related to DED-Arc
SKILLS	Identify the main hazards and safety measures associated with DED-Arc systems Recall existing legislation and requirements on HSE procedures related to DED-Arc

3.5.5 Competence Unit 04: Fit and set-up of DED-Arc systems

CU04: Fit and set-up of DED-Arc systems SUBJECT TITLE	CONTACT HOURS
DED-Arc processes and systems requirements	5
Loading of files and Work Documentation	4
Operational Parameters	7
Materials handling and how it relates to the process	4
HSE procedures	1
Total	21
WORKLOAD	42

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Fit and set-up of DED-Arc systems	4 Independent	Fit and set-up the DED-Arc system	Verifying the DED-Arc system set-up the procedure determined by the machine manufacturer and required operational conditions (e.g. electric arc power supply, gas supply, cooling system, torch)	21	42
			Preparing and verifying the build platform and feedstock		
			Performing Additive Manufacturing file loading and build jobs specs verification based on the AM procedure specification (includes inserting/verifying process parameters if needed)		
			Verifying parameter specifications (e.g. voltage, current, wire feed speed, travel speed, contact tip to work distance, positioning of the substrate)		
			Following HSE procedures for the fit and set-up of the DED-Arc system		
			Following and completing work documentation created by the DED-Arc Engineer		

Learning Outcomes – CU04: Fit and set-up of DED-Arc systems	
KNOWLEDGE	Factual and broad of: – Variables of DED-Arc and related operational conditions parameters – DED-Arc Equipment Requirements – Materials used for DED-Arc – Type of files and Work documentation – HSE procedures under DED-Arc
SKILLS	Prepare the system for operation, according to the Additive Manufacturing Procedure Specification Verify if the machine is working in accordance with the job specification, in terms of process parameters Prepare the feedstock, build platform and the machine in accordance to the used material Verify if the DED-Arc machine complies with the machine manufacturer and/or internal specifications Load files to DED-Arc machine Comply with HSE procedures associated to a DED-Arc machines Interpret technical information related to the DED-Arc processes and machines

3.5.6 Competence Unit 05: Manufacturing of DED-Arc parts

CU05: Manufacturing of DED-Arc parts SUBJECT TITLE	CONTACT HOURS
Machine functionalities and monitoring systems	5
Documentation	1
HSE procedures	1
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Manufacturing of DED-Arc parts	4 Independent	Manufacturing of DED-Arc parts	Performing a dry run and machine calibration at the beginning of the production run	7	14
			Ensuring that the layers are manufactured according to the quality requirements (i.e. first layers and periodically)		
			Monitoring the machine and the manufacturing process		
			Following HSE procedures when manufacturing DED-Arc parts		
			Following and completing work documentation according to the quality requirements		
			Reporting issues and implementing corrective or preventive actions based on parts' requirements feedback from the Engineer		

Learning Outcomes – CU05: Manufacturing of DED-Arc parts	
KNOWLEDGE	Factual and broad of: – Manufacturing of DED–Arc parts – DED–Arc machine functionalities and monitoring systems
SKILLS	Set-up the clamping system for the build platform characteristics according to the clamping plan (e.g. shape, thickness, material) Perform manufacturing of parts according to the build instruction applying HSE procedures Identify the main reasons for failure during the manufacturing process Interpret technical documentation related to the requirements of the as built parts Prepare reports on the manufacturing process, including identified issues

3.5.7 Competence Unit 06: Post processing of DED-Arc parts

CU06: Post processing of DED-Arc parts SUBJECT TITLE	CONTACT HOURS
Post build cycle operations including manual tools and methods	3
HSE procedures	4
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Post processing of DED-Arc parts	4 Independent	Prepare DED–Arc parts for post processing	Providing information from monitoring data about critical areas for extended testing	7	14
			Unclamping the part		
			Performing basic verification of as built parts		
			Applying manual operations to parts (cleaning, subtractive & other post processing)		
			Handing parts for post processing operations		
			Following applicable HSE procedures		

Learning Outcomes – CU06: Post processing of DED-Arc parts	
KNOWLEDGE	Factual and broad of: – Manual tools and methods for post-processing operations
SKILLS	Remove the as built parts from the machine applying the necessary HSE procedures Carry out simple manual preparation of the as built part for different post-processing methods

3.5.8 Competence Unit 07: Maintenance of DED-Arc systems

CU07: Maintenance of DED-Arc systems SUBJECT TITLE	CONTACT HOURS
Periodic maintenance aspects	5
Mechanical parts maintenance	5
Gas supply system maintenance	2
Auxiliary elements maintenance	2
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Maintenance of DED-Arc systems	4 Independent	Maintain and repair DED-Arc systems	Implementing equipment manufacturer's maintenance routines	14	28
			Cleaning and replacing components (e.g. feedstock spool, electrode tip, nozzle, liner, coolant, gas supply components)		
			Reporting problems to the Engineer		
			Following applicable HSE procedures		

Learning Outcomes – CU 07: Maintenance of DED-Arc systems	
KNOWLEDGE	Factual and broad of: – Maintenance aspects associated with DED-Arc systems

Learning Outcomes – CU 07: Maintenance of DED-Arc systems	
SKILLS	Assess the need to perform maintenance operations in DED-Arc system Perform maintenance operations in a DED-Arc system Identify the consumables for the different machine parts Report the need to execute specific maintenance Support other technicians during system maintenance Verify monitoring and calibration status (e.g. CNC/robot encoders) Verify the level of wear of a mechanical component (e.g. nozzles, rollers, contact tips) Replace, clean and repair mechanical components according to manufacturer instructions Change filters in the shielding gas system Verify the welding gas and fume extraction system flows Verify the condition and make use of the personal protective equipment

4. Guideline for Metal AM Operator DED – LB

4.1 Introduction to Metal AM Operator DED - LB

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	EO DED-LB	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 08: DED-LB Process	14	28
CU 09: Quality Assurance (QA) in DED-LB	14	28
CU 10: Health, Safety and Environment (HSE) in DED-LB	7	14
CU 11: Fit and set-up of DED-LB systems	21	42
CU 12: Manufacturing of DED-LB parts	7	14
CU 13: Post processing of DED-LB parts	7	14
CU 14: Maintenance of DED-LB systems	14	28
Subtotal (without optional CUs)	63	126
CU 48: Powder Handling	14	28
CU 49: Laser Beam Characterisation	7	14
Total	84	168

* Recommended Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Expected Workload is calculated in hours, corresponding to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Although the hours indicated in the above table are merely recommended, it is mandatory that in total the qualification has a minimum of 40 contact hours.

Within CLLAIM project's qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Sectoral Systems Framework levels (see Appendix I). On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills. Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical workshop training (C), etc., as shown in the following example:

Qualification: Example 1	
RECCOMMENDED CONTACT HOURS	X = SUM (A:C)
Subject Contents	A + B + C

4.2 Occupational Standard

EO DED-LB are the professionals with the specific knowledge, skills, autonomy and responsibility to operate metal AM machines using DED-LB Process. His/her main tasks are to:

- Operate Laser based DED machines for AM, including, fitting and setting up, basic maintenance and repair.

He/She will be able to:

- Verify Laser beam measurement and positioning in DED-LB machines for AM;
- Self-manage the handling of feedstock (approval, storage, contamination, traceability);
- Develop solutions on basic and specific problems related with Laser based DED machines and processes for AM

4.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to European Metal AM Operator Qualification admission are the following:

- National compulsory school diploma

4.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
EO DED-LB	INDEPENDENT	Factual and broad concepts in the field of DED-LB metal additive manufacturing process.	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific of DED-LB manufacturing problems	Self-manage of professional activities and simple standard applications of DED-LB manufacturing in predictable contexts but subject to change.

4.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Operator DED-Arc is listed below.

4.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	14

Learning Outcomes – CU 00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – Directed energy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

4.5.2 Competence Unit 08: DED-LB Process

CU 08: DED-LB Process	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
DED-LB System (Hardware & Software)	5
DED-LB Physical Principles	2
DED-LB Parameters	3
Build platform, feedstock and other consumables	3
Post processing operations	1
Total	14
WORKLOAD	28

Learning Outcomes – CU08: DED-LB Process	
KNOWLEDGE	Factual and broad of: – DED-LB systems – Laser Characteristics – Build platform – Powder/wire – Gases – Processable materials with DED-LB
SKILLS	Describe the DED-LB systems, including the components and their functions Distinguish different types of feedstock Associate the interaction of the process heat source with the feedstock Recognise the DED-LB parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED-LB build platform, feedstock and other consumables Identify the problems associated with inadequate preparation and set-up of the build platform, handling and storage of feedstock and application of the gases used in DED-LB Recognise the basic principles of 3D CAD systems and machine control software

4.5.3 Competence Unit 09: Quality Assurance (QA) in DED-LB

CU 09: Quality Assurance (QA) in DED-LB	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
General QA principles	2
AM Machine QA	4
AM Parts QA	4
Visual Inspection Overview	4
Total	14
WORKLOAD	28

Learning Outcomes – CU09: Quality Assurance (QA) in DED-LB	
KNOWLEDGE	Factual and broad knowledge of: – Quality Assurance in DED-LB – Visual Inspection of DED-LB parts
SKILLS	Recognise the broader use of QA within engineering Recognise the scope of the DED-LB operator qualification within the AM industry Support the qualification and requalification procedures of DED-LB equipment Identify the main procedures, equipment and their role Prepare test reports based on the requirements specified by the manufacturer Compare geometry and dimensions specified in the technical drawings with the as built parts Use simple measurement devices and techniques to carry out a basic visual inspection of the as built part Identify problems in the as build parts distinguishing between imperfections and defects Report defects suggesting either their removal with post processing operations or part disposal

4.5.4 Competence Unit 10: Health, Safety and Environment (HSE) in DED-LB

CU10: Health, Safety and Environment (HSE) in DED-LB	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
Health, Safety and Environment	7
Total	7
WORKLOAD	14

Learning Outcomes – CU10: Health, Safety and Environment (HSE) in DED-LB	
KNOWLEDGE	Factual and broad of: – Health, Safety and Environment related to DED-LB
SKILLS	Identify the main hazards and safety measures associated with DED-LB systems Recall existing legislation and requirements on HSE related to DED-LB

4.5.5 Competence Unit 11: Fit and set-up of DED-LB systems

CU 11: Fit and set-up of DED-LB systems SUBJECT TITLE	RECOMENDED CONTACT HOURS
DED-LB process requirements and operational parameters	12
Materials knowledge and how it relates to the process	4
Type of files and work documentation	4
HSE procedures	1
Total	21
WORKLOAD	42

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Fit and set-up of DED-LB systems	4 Independent	Fit and set-up the DED-LB system	Verifying the DED-LB system set-up according to the procedure determined by the machine manufacturer and required operational conditions	21	42
			Preparing and verifying the build platform and feedstock		
			Performing Additive Manufacturing file loading and build jobs specs verification based on the AM procedure specification *(includes inserting/verifying process parameters if needed)*		
			Following HSE procedures for the fit and set-up of the DED-LB system		
			Following and completing work documentation created by the DED-LB Engineer		

Learning Outcomes – CU 18: Hardware, software and build file set-up for DED-LB	
KNOWLEDGE	Factual and broad of: – Variables of DED-LB and related operational conditions parameters – DED-LB Equipment Requirements – Materials used for DED-LB – Type of files and Work documentation – HSE procedures under DED-LB

Learning Outcomes – CU 18: Hardware, software and build file set-up for DED-LB	
SKILLS	Identify and set-up the clamping system for the build platform characteristics (e.g. shape, thickness, material) Load powder/wire following mandatory safety procedures Prepare machines for operation, according to the Additive Manufacturing Procedure Specifications Verify if DED-LB machines are working in accordance with job specifications, in terms of process parameters Prepare feedstock, build platform and machines in accordance to used material Verify if DED-LB machines comply with manufacturer and/or internal specifications Load files to DED-LB machines Comply with HSE procedures associated to DED-LB machines Interpret technical information related to the DED-LB process and machines

4.5.6 Competence Unit 12: Manufacturing of DED-LB parts

CU 12: Manufacturing of DED-LB parts SUBJECT TITLE	RECOMENDED CONTACT HOURS
Machine functionalities and monitoring systems	6
Documentation	1
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Manufacturing of DED-LB parts	4 Independent	Manufacturing of DED-LB parts	Ensuring that the layers are manufactured according to the quality requirements (i.e. first layers and periodically)	7	14
			Performing build cycle according to manufacturing instructions		
			Following HSE procedures when printing AM parts		
			Following and completing work documentation according to the quality requirements		
			Reporting issues and implementing corrective or preventive actions based on parts' requirements feedback from the Engineer		

Learning Outcomes – CU 12: Manufacturing of DED-LB parts	
KNOWLEDGE	Factual and broad of: – Manufacturing of DED-LB parts – DED-LB machine functionalities and monitoring systems

Learning Outcomes – CU 12: Manufacturing of DED-LB parts	
SKILLS	Perform parts manufacturing according to the build instruction applying HSE procedures Interpret technical documentation related to the requirements of the as built parts Identify the main reasons for failure during the manufacturing process Prepare reports on the manufacturing process, including identified issues Monitor and escalate errors of the build process

4.5.7 Competence Unit 13: Post processing of DED-LB parts

CU 13: Post processing of DED-LB parts SUBJECT TITLE	RECOMENDED CONTACT HOURS
Post-build cycle operations	3
Manual tools and methods for post-processing operations	4
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Post processing of DED-LB parts	4 Independent	Prepare DED-LB parts for post processing	Providing information from monitoring data about critical areas for extended testing	7	14
			Applying simple manual operations to parts (cleaning, subtractive & post processing)		
			Handing parts for post processing operations		
			Following applicable HSE procedures		

Learning Outcomes – CU 13: Post processing of DED-LB parts	
KNOWLEDGE	Factual and broad of: – Manual tools and methods for post-processing operations
SKILLS	Remove the as build parts and build platform from the machine applying the necessary HSE procedures Carry out simple manual preparation of the as built part for different post-processing methods

4.5.8 Competence Unit 14: Maintenance of DED-LB systems

CU 14: Maintenance of DED-LB systems SUBJECT TITLE	RECOMENDED CONTACT HOURS
General maintenance aspects	3
Optical elements	1
Parts maintenance	2
Gas supply system	1
Auxiliary elements maintenance	2
Application driven material change	1
HSE procedures	2
Calibration	2
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Maintenance of DED-LB systems	4 Independent	Maintain and repair the DED-LB system	Implementing equipment manufacturer's maintenance routines	14	28
			Cleaning and replacing materials components (e.g. filters, cover glass, powder containers, tubes, nozzles)		
			Reporting problems to the Engineer		
			Following applicable HSE procedures		

Learning Outcomes – CU14: Maintenance of DED-LB systems	
KNOWLEDGE	Factual and broad of: – Maintenance aspects associated with DED-LB systems

Learning Outcomes – CU14: Maintenance of DED-LB systems	
SKILLS	Change protective lens and clean the nozzle Assess the need to perform maintenance operations in DED-LB system Perform maintenance operations in a DED-LB system Identify the consumables for the different machine parts Report the need to execute specific maintenance Support other technicians during system maintenance Verify the cleanliness of the optic system Verify if the optical system is working correctly Monitoring and calibration status (e.g. CNC encoders) Verify the level of wear of a mechanical component Verify the system gas flow Adequate maintenance routines to the material type Verify the condition and make use of the personal protective equipment

4.5.9 Competence Unit 48: Powder Handling

CU 48: Powder Handling SUBJECT TITLE	RECOMENDED CONTACT HOURS
Overview of Powder Manufacturing Processes	3
Chemical Composition and Physical Properties	4
Particle Size Distribution	2
Powder storage, handling, ageing and documentation	3
Powder reusability	1
HSE procedures	1
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Power Handling	4 Independent	Manage powders for Metal AM	Implementing procedures for powder delivery and storage	14	28
			Preparing and analysing powder according to technical documentation		
			Performing powder reconditioning (e.g. sieving) after build cycle		
			Following HSE procedures		

Learning Outcomes – CU 48: Powder Handling	
KNOWLEDGE	Factual and broad of: – Powder handling, storage and reconditioning
SKILLS	Complete technical documentation related to powders for metal AM Characterise powders according to instructions from the engineer Ensure powder conditioning according to the AM Procedure Specification Control the reusability of powders Handle powders according to HSE procedures

4.5.10 Competence Unit 49: Laser Beam Characterisation

CU 49: Laser Beam and Characterisation SUBJECT TITLE	RECOMENDED CONTACT HOURS
Laser Beam parameters and conditions	2
Measurement Equipment	5
Total	7
WORKLOAD	1

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Laser Beam Characterisation	4 Independent	Verify Laser Beam	Checking of the Laser beam characteristics and properties	7	14

Learning Outcomes – CU 48: Laser Beam Characterisation	
KNOWLEDGE	Factual and broad of: – Laser Beam characterisation – Measurement equipment
SKILLS	Safely carry out power measurements including power stability Safely carry out beam profiling in different areas of the build platform Use other measurement equipment to determine other Laser beam properties Carry out measurement in accordance with existing standards and/or internal specifications

5. Guideline for Metal AM Operator PBF – LB

5.1 Introduction to Metal AM Operator PBF - LB

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	EO PBF-LB	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 15: PBF-LB Process	14	28
CU 16: Quality Assurance (QA) in PBF-LB	7	14
CU 17: Health, Safety and Environment (HSE) in PBF-LB	3,5	7
CU 18: Hardware, software and build file set-up for PBF-LB	14	28
CU 19: Monitoring and managing the manufacturing of PBF-LB parts	3,5	7
CU 20: Post-processing of PBF-LB parts	7	14
CU 21: Maintenance of PBF-LB systems	7	14
Subtotal (without optional CUs)	63	126
CU 48: Powder Handling	14	28
CU 49: Laser Beam Characterisation	7	14
Total	84	168

* Recommended Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Expected Workload is calculated in hours, corresponding to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Although the hours indicated in the above table are merely recommended, it is mandatory that in total the qualification has a minimum of 40 contact hours.

Within EWF´s qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Systems Framework levels (see Appendix I). On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills. Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical workshop training (C), etc., as shown in the following example:

Qualification: Example 1	
RECCOMMENDED CONTACT HOURS	X = SUM (A:C)
Subject Contents	A + B + C

5.2 Occupational Standard

EO PBF-LB is the professional with the specific knowledge, skills, autonomy and responsibility to operate metal AM machines using PBF-LB Process. His/her main tasks are to:

- Operate powder bed-based laser beam machines for AM, including fitting and setting up, maintenance and repair.

He/She will be able to:

- Remove parts and prepare them for post-processing steps;
- Verify Laser beam measurement and positioning in laser powder-bed machines for AM;
- Self-manage the handling of powder (approval, storage, contamination, traceability);
- Develop solutions on basic and specific problems related with laser powder-bed fusion machines

5.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to European Metal AM Operator Qualification admission are the following:

- National compulsory school diploma

5.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
EO PBF-LB	INDEPENDENT	Factual and broad concepts in the field of PBF-LB metal additive manufacturing process.	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific of PBF-LB manufacturing problems	Self-manage of professional activities and simple standard applications of PBF-LB manufacturing in predictable contexts but subject to change.

5.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Operator DED-Arc is listed below.

5.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	14

Learning Outcomes – CU 00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – Directed energy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

5.5.2 Competence Unit 15: PBF-LB Process

CU 15: PBF-LB Process SUBJECT TITLE	RECCOMMENDED CONTACT HOURS
PBF-LB Process Principles	2
PBF-LB System – Hardware and Software	4
PBF-LB Parameters	3
PBF-LB Feedstock	2
PBF-LB Consumables	2
Post Processing	1
Total	14
WORKLOAD	28

Learning Outcomes – CU15: PBF-LB Process	
KNOWLEDGE	Factual and broad knowledge of: – PBF-LB systems – Laser characteristics – Build platform – Powder – Gases – Processable materials with PBF-LB
SKILLS	Describe the PBF-LB systems, including the components and their functions Recognise the characteristics of the PBF-LB build platform, feedstock and other consumables Recognise the PBF-LB parameters and the influence of their adjustment on the as built part Recognise the interaction of the process heat source with the feedstock Identify the problems associated with inadequate preparation and setup of the build platform, handling and storage of feedstock and application of the gases used in PBF-LB

5.5.3 Competence Unit 16: Quality Assurance (QA) in PBF-LB

CU 16: Quality Assurance (QA) in PBF-LB	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
General QA principles	2,5
AM Machine QA	1,5
AM Parts QA	1
Visual Inspection Overview	2
Total	7
WORKLOAD	14

Learning Outcomes – Quality Assurance (QA) in PBF-LB	
KNOWLEDGE	Factual and broad knowledge of: – Quality Assurance in PBF-LB – Visual Inspection
SKILLS	Recognise the broader use of QA within engineering Recognise the scope of the PBF-LB operator qualification within the AM industry Support the qualification and requalification procedures of PBF-LB equipment Identify the main procedures, equipment and their role Prepare test reports based on the requirements specified by the manufacturer Read a manufacturing plan Compare geometry and dimensions specified in the technical drawings with the as built parts Use simple measurement devices and techniques to carry out a basic visual inspection of the as built part Identify problems in the as build parts distinguishing between imperfections and defects Report defects suggesting either their removal with post processing operations, further inspection or part disposal

5.5.4 Competence Unit 17: Health, Safety and Environment (HSE) in PBF-LB

CU17: Health, Safety and Environment (HSE) in PBF-LB	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
Health, Safety and Environment	3,5
Total	3,5
WORKLOAD	7

Learning Outcomes – CU17: Health, Safety and Environment (HSE) in PBF-LB	
KNOWLEDGE	Factual and broad of: – Health, Safety and Environment related to PBF-LB
SKILLS	Identify the main hazards and safety measures associated with PBF-LB systems

5.5.5 Competence Unit 18: Hardware, software and build file set-up for PBF-LB

CU 18: Hardware, software and build file set-up for PBF-LB SUBJECT TITLE	RECOMENDED CONTACT HOURS
PBF-LB machine set-up requirements	4
Pre-build check list	3
Consumables, feedstock & substrate	3
Build files	1
Work documentation	2
Practical implementation of HSE procedures (while fit and set up the machine)	1
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Hardware, software and build file set-up for PBF-LB	4 Independent	Hardware, software and build file set-up for PBF-LB	Verifying the PBF-LB system set-up according to the procedure determined by the machine manufacturer and required operational conditions	14	28
			Preparing and verifying the build substrate and feedstock conditions		
			Performing: build file loading, process preparation, process starts, in process observation and mal function detection and mitigation		
			Build observation		
			Following HSE procedures during machine and build file set-up		

Learning Outcomes – CU 18: Hardware, software and build file set-up for PBF-LB	
KNOWLEDGE	Factual and broad knowledge of: Variables of PBF-LB and related operational conditions parameters PBF-LB equipment requirements Materials used for PBF-LB Type of files and work documentation HSE procedures under PBF-LB
SKILLS	Prepare the machine for operation, according to the AM procedure specification Prepare the feedstock, build platform and the machine in accordance to the material being used Verify if the PBF-LB machine complies with the machine manufacturer and/or internal specifications Load files to PBF-LB machines Verify if the PBF-LB machines are working in accordance with the job specification, in terms of process parameters Comply with HSE procedures associated to PBF-LB machines Interpret technical information related to the PBF-LB process and machines

5.5.6 Competence Unit 19: Monitoring and managing the manufacturing of PBF-LB parts

CU 19: Monitoring and managing the manufacturing of the PBF-LB parts	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Machine functionalities and monitoring systems	2
HSE Procedures	0,5
Documentation	1
Total	3,5
WORKLOAD	7

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Monitoring and managing the manufacturing of PBF-LB parts	4 Independent	Monitoring and managing the manufacturing of PBF-LB parts	Following HSE procedures when printing AM parts Following and completing work documentation according to quality/parts requirements Reporting issues and implementing corrective or preventive actions based on parts' requirements feedback from the Engineer	3,5	7

Learning Outcomes – CU 19: Monitoring and managing the manufacturing of the PBF-LB parts	
KNOWLEDGE	Factual and broad of: – Manufacturing of PBF-LB parts – Machine functionalities and monitoring systems
SKILLS	Load powder following mandatory safety procedures Apply HSE procedures when manufacturing parts Interpret technical documentation related to the requirements of the as built parts Identify the main reasons for failure during the manufacturing process Prepare reports on the manufacturing process, including identified issues

5.5.7 Competence Unit 20: Post processing of PBF-LB parts

CU 20: Post processing of PBF-LB parts SUBJECT TITLE	RECOMENDED CONTACT HOURS
Post-build cycle operations	3
Manual tools and methods for post-processing operations	4
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Post processing of PBF-LB parts	4 Independent	Prepare PBF-LB parts for post processing	Providing information from monitoring data about critical areas for extended testing Applying simple manual operations to parts (cleaning, subtractive & post processing) Handing parts for post processing operations Following applicable HSE procedures	7	14

Learning Outcomes – CU 20: Post processing of PBF-LB parts	
KNOWLEDGE	Factual and broad of: – Powder removal processes – Manual Tools and Methods for subtractive operations – Procedures for different post-processing methods and materials
SKILLS	Remove the as build parts and base plates from the machine applying the necessary HSE procedures Carry out simple manual preparation of the as built part for different post-processing methods Remove powder from the powder bed and parts following mandatory safety procedures Separate the as built parts from base plates distinguishing the base plate from the part based on the technical drawing and specifications using simple manual processes

5.5.8 Competence Unit 21: Maintenance of PBF-LB systems

CU 21: Maintenance of PBF-LB systems SUBJECT TITLE	RECOMENDED CONTACT HOURS
General maintenance aspects	2
Optical elements	0,5
Parts maintenance	1,5
Gas supply system	0,5
Auxiliary elements maintenance	1,5
Application driven material change	1
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Maintenance of PBF-LB systems	4 Independent	Maintain and repair the PBF-LB system	Implementing equipment manufacturer's maintenance routines	7	14
			Cleaning and replacing materials components (e.g. powder bed, cleaning agent, filters, cover glass)		
			Reporting problems to the Engineer		
			Following applicable HSE procedures		

Learning Outcomes – CU21: Maintenance of PBF-LB systems	
KNOWLEDGE	Factual and broad of: – Maintenance aspects associated with PBF-LB systems

Learning Outcomes – CU21: Maintenance of PBF-LB systems	
SKILLS	Change protective lens and clean the nozzle Assess the need to perform maintenance operations in PBF-LB system Perform maintenance operations in PBF-LB system Identify the consumables for the different machine parts Report the need to execute specific maintenance Support other technicians during system maintenance Verify the cleanliness of the optic system Verify if the optical system is working correctly Monitoring and calibration status Verify the level of wear of a mechanical component Verify the system gas flow Adequate maintenance routines to the material type Verify the condition and make use of the personal protective equipment

5.5.9 Competence Unit 48: Powder Handling

CU 48: Powder Handling SUBJECT TITLE	RECOMENDED CONTACT HOURS
Overview of Powder Manufacturing Processes	3
Chemical Composition and Physical Properties	4
Particle Size Distribution	2
Powder storage, handling, ageing and documentation	3
Powder reusability	1
HSE procedures	1
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Power Handling	4 Independent	Manage powders for Metal AM	Implementing procedures for powder delivery and storage	14	28
			Preparing and analysing powder according to technical documentation		
			Performing powder reconditioning (e.g. sieving) after build cycle		
			Following HSE procedures		

Learning Outcomes – CU 48: Powder Handling	
KNOWLEDGE	Factual and broad of: – Powder handling, storage and reconditioning
SKILLS	Complete technical documentation related to powders for metal AM Characterise powders according to instructions from the engineer Ensure powder conditioning according to the AM Procedure Specification Control the reusability of powders Handle powders according to HSE procedures

5.5.10 Competence Unit 49: Laser Beam Characterisation

CU 49: Laser Beam and Characterisation SUBJECT TITLE	RECOMENDED CONTACT HOURS
Laser Beam parameters and conditions	2
Measurement Equipment	5
Total	7
WORKLOAD	1

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Laser Beam Characterisation	4 Independent	Verify Laser Beam	Checking of the Laser beam characteristics and properties	7	14

Learning Outcomes – CU 48: Laser Beam Characterisation	
KNOWLEDGE	Factual and broad of: – Laser Beam characteristics and properties – Measurement equipment
SKILLS	Safely carry out power measurements including power stability Safely carry out beam profiling in different areas of the build platform Use other measurement equipment to determine other Laser beam properties Carry out measurement in accordance with existing standards and/or internal specifications

6. Guideline for Metal AM Operator PBF - EB

6.1 Introduction to Metal AM Operator PBF - EB

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	EO-PBF-EB	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 22: PBF-EB Process	14	28
CU 23: Quality Assurance (QA) in PBF-EB	7	14
CU 24: Health, Safety and Environment (HSE) in PBF-EB	3,5	7
CU 50: Hardware, software and build file set-up for PBF-EB	14	28
CU 51: Monitoring and managing the manufacturing of PBF-EB parts	3,5	7
CU 52: Post-processing of PBF-EB parts	7	14
CU 53: Maintenance of PBF-EB systems	7	14
Subtotal (without optional CUs)	63	126
CU 48: Powder Handling	14	28
Total	77	144

* Recommended Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Expected Workload is calculated in hours, corresponding to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Although the hours indicated in the above table are merely recommended, it is mandatory that in total the qualification has a minimum of 40 contact hours.

Within CLLAIM project's qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Sectoral Systems Framework levels (see Appendix I). On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills. Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical workshop training (C), etc., as shown in the following example:

Qualification: Example 1	
RECCOMMENDED CONTACT HOURS	X = SUM (A:C)
Subject Contents	A + B + C

6.2 Occupational Standard

EO PBF-EB is the professional with the specific knowledge, skills, autonomy and responsibility to operate metal AM machines using PBF-EB Process. His/her main tasks are to:

- Operate electron beam powder bed fusion machines for AM, including fitting and setting up, maintenance and repair.

He/She will be able to:

- Remove parts and prepare them for post-processing steps;
- Self-manage the handling of powder (approval, storage, contamination, traceability);
- Develop solutions on basic and specific problems related with electron beam powder-bed fusion machines

6.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to European Operator Qualification admission are the following:

- National compulsory school diploma

6.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
EO PBF-EB	INDEPENDENT	Factual and broad concepts in the field of PBF-EB metal additive manufacturing process.	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific of PBF-EB manufacturing problems	Self-manage of professional activities and simple standard applications of PBF-EB manufacturing in predictable contexts but subject to change.

6.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Operator DED-Arc is listed below.

6.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	14

Learning Outcomes – CU 00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – Directed ernergy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

6.5.2 Competence Unit 22: PBF-EB Process

CU 22: PBF-EB Process SUBJECT TITLE	RECCOMMENDED CONTACT HOURS
Introduction to Additive Manufacturing (AM)	1,5
Applications	1
Process Principles	1
System – Hardware and Software	3
Parameters	3
System – Software	0,5
Feedstock	2
Consumables	1
Post Processing	1
Total	14
WORKLOAD	28

Learning Outcomes – CU22: PBF-EB Process	
KNOWLEDGE	Factual and broad knowledge of: – EB systems – EB characteristics – Build platform – Wire /Powder – Vacuum pressure – Advantages and limitations of the process – Processable materials with EB
SKILLS	Describe the EB systems, including the components and their functions Outline the main advantages and limitations of EB over conventional and other AM processes, namely based on Electron beam Recognise the characteristics of the EB build platform, feedstock and other consumables Recognise the EB parameters and the influence of their adjustment on the as built part Recognise the interaction of the process heat source with the feedstock Identify the problems associated with inadequate preparation and setup of the build platform, handling and storage of feedstock used in EB

6.5.3 Competence Unit 23: Quality Assurance (QA) in PBF-EB

CU 23: Quality Assurance (QA) in PBF-EB	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
General QA principles	2,5
AM Machine QA	1,5
AM Parts QA	1
Visual Inspection Overview	2
Total	7
WORKLOAD	14

Learning Outcomes – CU23: Quality Assurance (QA) in PBF-EB	
KNOWLEDGE	Factual and broad knowledge of: – Quality Assurance in PBF-EB – Visual Inspection
SKILLS	Recognise the broader use of QA within engineering Recognise the scope of the PBF-EB operator qualification within the AM industry Support the qualification and requalification procedures of PBF-EB equipment Identify the main procedures, equipment and their role Prepare test reports based on the requirements specified by the manufacturer Read a manufacturing plan Compare geometry and dimensions specified in the technical drawings with the as built parts Use simple measurement devices and techniques to carry out a basic visual inspection of the as built part Identify problems in the as build parts distinguishing between imperfections and defects Report defects suggesting either their removal with post processing operations, further inspection or part disposal

6.5.4 Competence Unit 24: Health, Safety and Environment (HSE) in PBF-EB

CU24: Health, Safety and Environment (HSE) in PBF-EB	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Health, Safety and Environment	3,5
Total	3,5
WORKLOAD	7

Learning Outcomes – CU24: Health, Safety and Environment (HSE) in PBF-EB	
KNOWLEDGE	Factual and broad of: – Health, Safety and Environment related to PBF-EB
SKILLS	Identify the main hazards and safety measures associated with PBF-EB systems

6.5.5 Competence Unit 50: Hardware, software and build file set-up for PBF-EB

CU 50: Hardware, software and build file set-up for PBF-EB SUBJECT TITLE	RECOMENDED CONTACT HOURS
PBF-EB machine set-up requirements	4
Pre-build check list	3
Consumables, feedstock & substrate	3
Build files	1
Work documentation	2
Practical implementation of HSE procedures (while fit and set up the machine)	1
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Hardware, software and build file set-up for PBF-EB	4 Independent	Hardware, software and build file set-up for PBF-EB	Verifying the PBF-EB system set-up according to the procedure determined by the machine manufacturer and required operational conditions	14	28
			Preparing and verifying the build substrate and feedstock conditions		
			Performing: build file loading, process preparation, process starts, in process observation and mal function detection and mitigation		
			Build observation		
			Following HSE procedures during machine and build file set-up		

Learning Outcomes – CU 50: Hardware, software and build file set-up for PBF-EB	
KNOWLEDGE	Factual and broad knowledge of: – Variables of PBF-EB and related operational conditions parameters – PBF-EB equipment requirements – Materials used for PBF-EB – Type of files and work documentation – HSE procedures under PBF-EB
SKILLS	Prepare the machine for operation, according to the AM procedure specification Prepare the feedstock, build platform and the machine in accordance to the material being used Verify if the PBF-EB machine complies with the machine manufacturer and/or internal specifications Load files to PBF-EB machines Verify if the PBF-EB machines are working in accordance with the job specification, in terms of process parameters Comply with HSE procedures associated to PBF-EB machines Interpret technical information related to the PBF-EB process and machines

6.5.6 Competence Unit 51: Monitoring and managing the manufacturing of PBF-EB parts

CU 51: Monitoring and managing the manufacturing of the PBF-EB parts	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Machine functionalities and monitoring systems	2
HSE Procedures	0,5
Documentation	1
Total	3,5
WORKLOAD	7

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Monitoring and managing the manufacturing of PBF-EB parts	4 Independent	Monitoring and managing the manufacturing of PBF-EB parts	Following HSE procedures when printing AM parts Following and completing work documentation according to quality/parts requirements Reporting issues and implementing corrective or preventive actions based on parts' requirements feedback from the Engineer	3,5	7

Learning Outcomes – CU 51: Monitoring and managing the manufacturing of the PBF-EB parts	
KNOWLEDGE	Factual and broad of: – Manufacturing of PBF-EB parts – Machine functionalities and monitoring systems
SKILLS	Load powder following mandatory safety procedures Apply HSE procedures when manufacturing parts Interpret technical documentation related to the requirements of the as built parts Identify the main reasons for failure during the manufacturing process Prepare reports on the manufacturing process, including identified issues

6.5.7 Competence Unit 52: Post processing of PBF-EB parts

CU 52: Post processing of PBF-EB parts SUBJECT TITLE	RECOMENDED CONTACT HOURS
Powder and parts removal processes	4
Manual tools and methods for post-processing operations	3
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Post processing of PBF-EB parts	4 Independent	Prepare PBF-EB parts for post processing	Providing information from monitoring data about critical areas for extended testing	7	14
			Applying simple manual operations to parts (cleaning, subtractive & post processing)		
			Handing parts for post processing operations		
			Following applicable HSE procedures		

Learning Outcomes – CU 52: Post processing of PBF-EB parts	
KNOWLEDGE	Factual and broad of: — Powder removal processes — Manual Tools and Methods for subtractive operations – Procedures for different post-processing methods and materials
SKILLS	Remove the as build parts and base plates from the machine applying the necessary HSE procedures Carry out simple manual preparation of the as built part for different post-processing methods Remove powder from the powder bed and parts following mandatory safety procedures Separate the as built parts from base plates distinguishing the base plate from the part based on the technical drawing and specifications using simple manual processes

6.5.8 Competence Unit 53: Maintenance of PBF-EB systems

CU 53: Maintenance of PBF-EB systems SUBJECT TITLE	RECOMENDED CONTACT HOURS
General maintenance aspects	2
Optical elements	0,5
Parts maintenance	1,5
Auxiliary elements maintenance	0,5
Application driven material change	1,5
HSE procedures	1
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Maintenance of PBF-EB systems	4 Independent	Maintain and repair the PBF-EB system	Implementing equipment manufacturer's maintenance routines Cleaning and replacing materials components (e.g. powder bed, cleaning agent, filters) Reporting problems to the Engineer Following applicable HSE procedures	7	14

Learning Outcomes – CU21: Maintenance of PBF-EB systems	
KNOWLEDGE	Factual and broad of: – Maintenance aspects associated with PBF-EB systems

Learning Outcomes – CU21: Maintenance of PBF-EB systems	
SKILLS	Clean the nozzle Assess the need to perform maintenance operations in PBF-EB system Perform maintenance operations in PBF-EB system Identify the consumables for the different machine parts Report the need to execute specific maintenance Support other technicians during system maintenance Verify the cleanliness of the system Monitoring and calibration status Verify the level of wear of a mechanical component Verify the system gas flow Adequate maintenance routines to the material type Verify the condition and make use of the personal protective equipment

6.5.9 Competence Unit 48: Powder Handling

CU 48: Powder Handling SUBJECT TITLE	RECOMENDED CONTACT HOURS
Overview of Powder Manufacturing Processes	3
Chemical Composition and Physical Properties	4
Particle Size Distribution	2
Powder storage, handling, ageing and documentation	3
Powder reusability	1
HSE procedures	1
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Power Handling	4 Independent	Manage powders for Metal AM	Implementing procedures for powder delivery and storage	14	28
			Preparing and analysing powder according to technical documentation		
			Performing powder reconditioning (e.g. sieving) after build cycle		
			Following HSE procedures		

Learning Outcomes – CU 48: Powder Handling	
KNOWLEDGE	Factual and broad of: – Powder handling, storage and reconditioning
SKILLS	Complete technical documentation related to powders for metal AM Characterise powders according to instructions from the engineer Ensure powder conditioning according to the AM Procedure Specification Control the reusability of powders Handle powders according to HSE procedures

7. Guideline for Metal AM Designer for DED Processes

7.1 Introduction to Metal AM Designer for DED Processes

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	ED DED	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 25: Post Processing	14	28
CU 57: Relevant principles of DED Processes for Design	21	42
CU 58: Design Metal AM parts for DED Processes	35	70
CU 61: Simulation Analysis	21	42
Subtotal (without optional CUs)		
CU 62: Simulation Execution	21	42
Total	**119**	**238**

* Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Workload is calculated in hours, corresponds to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Within CLLAIM´s project qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Systems Framework levels (see Appendix I).

On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills.

Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical work-shop training(C), as showed in the following example:

Qualification: Example 1	
RECCOMMENDED CONTACT HOURS	X = SUM (A:C)
Subject Contents	A + B + C

7.2 Occupational Standard

Metal AM Designers for DED Processes are the professionals with the specific knowledge, skills, autonomy and responsibility to design metal AM solutions for DED Processes. His/her's main tasks are to:

- Design Metal AM solutions for DED Processes ensuring and validating that parts can be made cost-effective and efficiently.
- Close DED Processes design projects by verifying requirements for production with engineer as well as process requirements, ensuring liaison with other technical areas to sign of drawings.
- Contribute to projects in a teaming environment cooperation with AM Team.

7.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to Metal AM Designer for DED Processes admission are the following:

- Engineering degree in Mechanical, Materials, Aeronautic or similar.

7.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
ED DED	ADVANCED	Advanced knowledge and critical understanding of the theory, principles and applicability of metal additive manufacturing design for DED processes.	Advanced problem-solving skills including critical evaluation and design thinking, allowing to choose the proper technical and economical solutions, when designing parts to be manufactured by DED metal additive manufacturing processes.	Manage complex DED processes design projects, taking responsibility for decision-making in DED processes design applications.

7.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Designer for DED Processes is listed below.

7.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	**14**

Learning Outcomes – CU00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – Directed energy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

7.5.2 Competence Unit 25: Post Processing

CU 25: Post Processing SUBJECT TITLE	CONTACT HOURS
General considerations	2
Thermal treatment	4
Plastic deformation methods	2
Subtractive manufacturing	2
Finishing operations	2
Practical application	2
Total	14
WORKLOAD	**28**

Learning Outcomes – CU 25: Post Processing	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Post processing methods (heat treatment, cold work methods, subtractive manufacturing, finishing operations)
SKILLS	Discuss methods to reduce distortion, using different post processes, for a variety of part geometries and AM processes. Explain the applicable post processing methods to several AM processes as built parts Describe the effect of different heat treatments on microstructure, mechanical properties, residual stress and defects Explain the requirements that the as built part needs to have/comply according to each post process

7.5.3 Competence Unit 57: Relevant principles of DED Processes for Design

CU57: Relevant principles of DED Processes for Design SUBJECT TITLE	RECOMENDED CONTACT HOURS
DED process capabilities	7
DED process limitations	7
Design considerations	7
Total	21
WORKLOAD	**42**

Learning Outcomes – CU 57: Relevant principles of DED Processes for Design	
KNOWLEDGE	Specialised, factual and theoretical of theory, principles and applicability of metal DED processes and related technologies: – Capabilities and limitations of DED processes influence in design – Design considerations required for DED parts design – Post processing influences in design
SKILLS	Associate the degrees of freedom of a DED system to the possibilities in terms of design Relate the capabilities and limitations of DED to design considerations Determine dimensional constraints and geometric tolerances required for DED parts design Provide solution-based approaches to redefine design problems (Design thinking) within DED processes and parts

7.5.4 Competence Unit 58: Design Metal AM parts for DED Processes

CU 58: Design Metal AM parts for DED Processes	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
Parts requirements	3
CAD Software & Software	12
Part optimisation	4
Designing parts	4
Design to cost	2
Data preparation for production	3
Case studies for “Design Thinking & Development	7
Total	35
WORKLOAD	**70**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Design Metal AM parts for DED Processes	6	Design Metal AM parts	Interpreting parts requirements Redesigning parts Assessing Costs in Design Closing design project	35	70

Learning Outcomes – CU 58: Design Metal AM parts for DED Processes	
KNOWLEDGE	Advanced knowledge and critical understanding of: – Influence of parts requirements in design; – Design optimisation.

Learning Outcomes – CU 58: Design Metal AM parts for DED Processes	
SKILLS	Verify and analyse requirements for production providing initial propositions and constraints Analyse relevant costs considering the requirements, materials, machine hour rate and manual preparations to ensure the most efficient design Test additively manufactured parts to assess the need for redesign (for example, when the part design is completed, and its performance needs to be tested. If it fails, some redesign may be needed.) Carry out reengineering design using metal AM to design parts previously produced by conventional processes/methods Ensure liaison with other technical areas (process, production, etc.) Sign off (ESO) drawings (STL/AMF files included)

7.5.5 Competence Unit 61: Simulation Analysis

CU 61: Simulation Analysis	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
Evaluation of Topology Optimization (TO)	4
Mechanical Analysis	5
Fatigue	4
Chemical	3
Thermal Analysis	5
Build Evaluation	2
Documentation	1
Case studies	4
Total	28
WORKLOAD	**56**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Simulation Analysis	6	Analyse simulation results	Evaluating Topology Optimization (TO) Interpreting finite element (FE) simulation results Documenting technical conclusions deriving from simulation results	21	42

Learning Outcomes – CU 61: Analysis Simulation	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Topology Optimization – Stress and Strain Analysis – Phase transformations

Learning Outcomes – CU 61: Analysis Simulation	
SKILLS	Verify compliance between part requirements and simulation results Run topology optimization considering part requirements interpretation in terms of in-service conditions Define part design improvements based on simulation results Elaborate simulation analysis reports proposing production strategies

7.5.6 Competence Unit 62: Simulation Execution

CU 62: Simulation Execution	RECOMMENDED CONTACT HOURS
SUBJECT TITLE	
Pre-Processing	7
Processing	7
Validation	7
Total	21
WORKLOAD	**42**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Simulation Execution	6	Simulate and predict impressions	Execute/perform Topology Optimization Creating finite simulation models (FEM) Debugging modelling optimization	21	42

Learning Outcomes – CU 62: Simulation Execution	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Validation and Calibration strategies – Application of the relevant Material properties, Boundary conditions and mesh characteristics
SKILLS	Choose appropriate CAD file extension to export geometry to the FEA software workspace Judge the type of Simulation Analysis (e.g. Structural, CFD, etc.) according to the problem characteristics Assign physical properties (e.g. material, Boundary conditions, etc) to the geometry to reproduce the in- service solicitations Select proper element type, size, solver and time step to generate a computationally time effective mesh Appraise the quality of the model by comparing physical aspects between the simulation and reality Perform an analysis to assess the converging characteristics of the model Elaborate simulation reports specifying part geometry, boundary conditions, mesh characteristics, material model

8. Guideline for Metal AM Designer for PBF Processes

8.1 Introduction to Metal AM Designer for PBF Processes

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	ED PBF	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 25: Post Processing	14	28
CU 59: Relevant principles of PBF Processes for Design	21	42
CU 60: Design Metal AM parts for PBF Processes	28	56
CU 61: Simulation Analysis	21	42
Subtotal (without optional CUs)		
CU 62: Simulation Execution	21	42
Total	**112**	**224**

* Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Workload is calculated in hours, corresponds to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Within CLLAIM´s projects qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Systems Framework levels (see Appendix I).

On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills.

Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical work-shop training(C), as showed in the following example:

Qualification: Example 1	
RECCOMMENDED CONTACT HOURS	X = SUM (A:C)
Subject Contents	A + B + C

8.2 Occupational Standard

Metal AM Designers for PBF Processes are the professionals with the specific knowledge, skills, autonomy and responsibility to design metal AM solutions for PBF Processes. His/her's main tasks are to:

- Design Metal AM solutions for PBF Processes ensuring and validating that parts can be made cost-effective and efficiently.
- Close PBF Processes design projects by verifying requirements for production with engineer as well as process requirements, ensuring liaison with other technical areas to sign of drawings.
- Contribute to projects in a teaming environment cooperation with AM Team.

8.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to Metal AM Designer for PBF Processes admission are the following:

- Engineering degree in Mechanical, Materials, Aeronautic or similar.

8.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
ED PBF	ADVANCED	Advanced knowledge and critical understanding of the theory, principles and applicability of metal additive manufacturing design for DED processes.	Advanced problem-solving skills including critical evaluation and design thinking, allowing to choose the proper technical and economical solutions, when designing for DED metal additive manufacturing processes, in complex and unpredictable conditions.	Manage complex DED processes design projects, taking responsibility for decision-making in unpredictable DED processes design applications.

8.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Designer for PBF Processes is listed below.

8.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	**14**

Learning Outcomes – CU00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – Directed energy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

8.5.2 Competence Unit 25: Post Processing

CU 25: Post Processing SUBJECT TITLE	CONTACT HOURS
General considerations	2
Thermal treatment	4
Plastic deformation methods	2
Subtractive manufacturing	2
Finishing operations	2
Practical application	2
Total	14
WORKLOAD	**28**

Learning Outcomes – CU 25: Post Processing	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Post processing methods (heat treatment, cold work methods, subtractive manufacturing, finishing operations)
SKILLS	Discuss methods to reduce distortion, using different post processes, for a variety of part geometries and AM processes. Explain the applicable post processing methods to several AM processes as built parts Describe the effect of different heat treatments on microstructure, mechanical properties, residual stress and defects Explain the requirements that the as built part needs to have/comply according to each post process

8.5.3 Competence Unit 59: Relevant principles of PBF Processes for Design

CU59: Relevant principles of PBF Processes for Design SUBJECT TITLE	RECOMENDED CONTACT HOURS
PBF process capabilities	7
PBF process limitations	7
Design considerations	7
Total	21
WORKLOAD	**42**

Learning Outcomes – CU 59: Relevant principles of PBF Processes for Design	
KNOWLEDGE	Specialised, factual and theoretical of theory, principles and applicability of metal DED processes and related technologies: – Capabilities and limitations of PBF processes influence in design – Design considerations required for PBF parts design – Post processing influences in design
SKILLS	Associate the degrees of freedom of a PBF machine to the possibilities in terms of design Relate the capabilities and limitations of PBF to design considerations Determine dimensional constraints and geometric tolerances required for PBF parts design Provide solution-based approaches to redefine design problems (Design thinking) within PBF processes and parts

8.5.4 Competence Unit 60: Design Metal AM parts for PBF Processes

CU 60: Design Metal AM parts for PBF Processes	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
Parts requirements	3
CAD Models & Software	12
Part optimisation	4
Designing parts	4
Design to cost	2
Data preparation for production	3
Total	28
WORKLOAD	**56**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Design Metal AM parts for PBF Processes	6	Design Metal AM parts	Interpreting parts requirements Specifying lattice structures Determining parts orientation (consider powder spreading and curl effect) Redesigning parts Assessing Costs in Design Closing design project	28	56

Learning Outcomes – CU 60: Design Metal AM parts for PBF Processes	
KNOWLEDGE	Advanced knowledge and critical understanding of: – Influence of Parts requirements in design; – Orientation and positioning of parts in the build chamber; – Design optimisation. .

Learning Outcomes – CU 60: Design Metal AM parts for PBF Processes	
SKILLS	Verify and analyse requirements for production providing initial propositions and constraints Analyse relevant costs considering the requirements, materials, machine hour rate and manual preparations to ensure the most efficient design Test additively manufactured parts to assess the need for redesign (for example, when the part design is completed, and its performance needs to be tested. If it fails, some redesign may be needed.) Carry out reengineering design using metal AM to design parts previously produced by conventional processes/methods Ensure liaison with other technical areas (process, production, etc.) Sign off (ESO) drawings (STL/AMF files included)

8.5.5 Competence Unit 61: Simulation Analysis

CU 61: Simulation Analysis SUBJECT TITLE	RECOMMENDED CONTACT HOURS
Evaluation of Topology Optimization (TO)	3
Mechanical Analysis	3
Fatigue	2
Chemical	3
Thermal Analysis	2
Build Evaluation	2
Documentation	2
Case studies	4
Total	21
WORKLOAD	**42**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Simulation Analysis	6	Analyse simulation results	Evaluating Topology Optimization (TO) Interpreting finite element (FE) simulation results Documenting technical conclusions deriving from simulation results	21	42

Learning Outcomes – CU 61: Simulation Analysis	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Topology Optimization – Stress and Strain Analysis – Phase transformations

Learning Outcomes – CU 61: Simulation Analysis	
SKILLS	Verify compliance between part requirements and simulation results Run topology optimization considering part requirements interpretation in terms of in-service conditions Define part design improvements based on simulation results Elaborate simulation analysis reports proposing production strategies

8.5.6 Competence Unit 62: Simulation Execution

CU 62: Simulation Execution	RECOMMENDED CONTACT HOURS
SUBJECT TITLE	
Pre-Processing	7
Processing	7
Validation	7
Total	21
WORKLOAD	**42**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	RECOMMENDED CONTACT HOURS	WORKLOAD
Simulation Execution	6	Simulate and predict impressions	Execute/perform Topology Optimization Creating finite simulation models (FEM) Debugging modelling optimization	21	42

Learning Outcomes – CU 62: Simulation Analysis	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Validation and Calibration strategies – Application of the relevant Material properties, Boundary conditions and mesh characteristics
SKILLS	Choose appropriate CAD file extension to export geometry to the FEA software workspace Judge the type of Simulation Analysis (e.g. Structural, CFD, etc.) according to the problem characteristics Assign physical properties (e.g. material, Boundary conditions, etc) to the geometry to reproduce the in- service solicitations Select proper element type, size, solver and time step to generate a computationally time effective mesh Appraise the quality of the model by comparing physical aspects between the simulation and reality Perform an analysis to assess the converging characteristics of the model Elaborate simulation reports specifying part geometry, boundary conditions, mesh characteristics, material model

9. Guideline for Metal AM Supervisor

9.1 Introduction to Metal AM Supervisor

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	E S	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 01: DED-Arc Process	14	28
CU 08: DED-LB Process	14	28
CU 15: PBF-LB Process	14	28
CU 46: Quality Assurance for Metal AM Processes	14	28
CU 47: HSE for Metal AM Processes	14	28
CU 48: Powder Handling	14	28
Total	**91**	**182**

* Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Workload is calculated in hours, corresponds to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Within CLLAIM´s projects qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Systems Framework levels (see Appendix I).

On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills.

Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical work-shop training(C), as showed in the following example:

Qualification: Example 1	
RECCOMMENDED CONTACT HOURS	X = SUM (A:C)
Subject Contents	A + B + C

9.2 Occupational Standard

Metal AM Supervisors are the professionals with the specific knowledge, skills, autonomy and responsibility to Supervise AM production on shop floor, being its main tasks to:

- Ensure quality Procedures
- Ensure Health & Safety Environment procedures

9.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to Metal AM Designer for PBF Processes admission are the following:

- National compulsory school Diploma
- Basic knowledge and skills related with Quality Assurance and HSE
- At least 1 year of experience in Quality and Safety supervision is recommended.

9.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
E MAM S	INDEPENDENT	Factual and broad concepts in the field of Metal additive manufacturing processes.	Fundamental cognitive and practical skills on simple and specific of Metal additive manufacturing problems required to: • develop proper solutions • application of procedures and tools	Self-manage of professional activities and simple standard applications of Metal AM manufacturing in predictable contexts but subject to change. Take responsibility for supervising routine metal AM production and related personnel.

9.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Supervisor is listed below.

9.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	**14**

Learning Outcomes – CU00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – Directed energy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

9.5.2 Competence Unit 01: DED-Arc Process

CU01: DED-Arc Process SUBJECT TITLE	CONTACT HOURS
DED-Arc System (Hardware & Software)	5
DED-Arc Physical Principles, Processes and Parameters	5
DED-Arc Build platform, feedstock and other consumables	3
Post processing operations	1
Total	14
WORKLOAD	28

Learning Outcomes – CU01: DED-Arc Process	
KNOWLEDGE	Factual and broad of: – DED-Arc systems – Arc physics – Processable materials with DED-Arc – Processing atmosphere requirements with DED-Arc – Sensors and process controls with DED-Arc
SKILLS	Describe the DED–Arc systems, including the components and their functions Distinguish different types of feedstock Associate the interaction of the process heat source with the feedstock Recognise the DED–Arc parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED–Arc build platform, feedstock and other consumables Identify the problems associated with inadequate preparation and set-up of the build platform, handling and storage of feedstock and application of the gases used in DED–Arc

9.5.3 Competence Unit 08: DED-LB Process

CU 08: DED-LB Process	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
DED-LB System (Hardware & Software)	5
DED-LB Physical Principles	2
DED-LB Parameters	3
Build platform, feedstock and other consumables	3
Post processing operations	1
Total	14
WORKLOAD	28

Learning Outcomes – CU08: DED-LB Process	
KNOWLEDGE	Factual and broad of: – DED-LB systems – Laser Characteristics – Build platform – Powder/wire – Gases – Processable materials with DED-LB
SKILLS	Describe the DED-LB systems, including the components and their functions Distinguish different types of feedstock Associate the interaction of the process heat source with the feedstock Recognise the DED-LB parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED-LB build platform, feedstock and other consumables Identify the problems associated with inadequate preparation and set-up of the build platform, handling and storage of feedstock and application of the gases used in DED-LB Recognise the basic principles of 3D CAD systems and machine control software

9.5.4 Competence Unit 15: PBF-LB Process

CU 15: PBF-LB Process	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
PBF-LB Process Principles	2
PBF-LB System – Hardware and Software	4
PBF-LB Parameters	3
PBF-LB Feedstock	2
PBF-LB Consumables	2
Post Processing	1
Total	14
WORKLOAD	28

Learning Outcomes – CU15: PBF-LB Process	
KNOWLEDGE	Factual and broad knowledge of: – PBF-LB systems – Laser characteristics – Build platform – Powder – Gases – Processable materials with PBF-LB
SKILLS	Describe the PBF-LB systems, including the components and their functions Recognise the characteristics of the PBF-LB build platform, feedstock and other consumables Recognise the PBF-LB parameters and the influence of their adjustment on the as built part Recognise the interaction of the process heat source with the feedstock Identify the problems associated with inadequate preparation and setup of the build platform, handling and storage of feedstock and application of the gases used in PBF-LB

9.5.5 Competence Unit 46: Quality Assurance for Metal AM Processes

CU 46: Quality Assurance for Metal AM Processes	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Quality Assurance and Quality Control	5.5
QA for different energy Source Machine	3.5
Wire vs Powder Parts QA	3.5
Communication workflows	1.5
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTION	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Quality Assurance for Metal AM Processes)	4	Supervise Quality Assurance on Shop Floor	Ensuring the implementation of QA/QC procedures and instructions (e.g. feedstock storage and handling;	14	28
			Monitoring the compliance of the AM production process and the AM parts with the relevant documents (e.g. standards, product specifications, legislation);		
			Monitoring/ Implementing corrective actions for eliminating defects;		
			Providing guidance to AM operators in the day-to-day activities;		

			Assigning tasks to Operators based on job requirements.		

Learning Outcomes – CU 46 - Quality Assurance for Metal AM Processes	
KNOWLEDGE	Factual and broad knowledge of theory and applicability of: - Quality Assurance (QA) principles - Metal AM Systems QA - Quality Control in manufacturing chain
SKILLS	Prepare daily work and tasks distribution based on production plans ensuring manufacturing on shop floor. Compare DED-Arc, DED-LB and PBF-LB processes QA/QC procedures identifying each process' QA/QC specific requirements. Name the most common standards used for Metal AM production, Metal AM operator's qualification, Metal AM procedures approval and Metal AM systems qualification. Provide technical inputs to improve QA/QC procedures and instructions related with the handling and storage of feedstock, AM systems and part production. Verify if parts' production (e.g. feedstock storage, in process monitoring) on the shop floor complies with Quality Control procedures and APS.

9.5.6 Competence Unit 47: HSE for Metal AM Processes

CU 47: HSE for Metal AM Processes	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
HSE in facilities	5
HSE for different energy sources	4.5
HSE for different types of feedstock	4.5
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTION	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
HSE for Metal AM Processes	4	Supervise HSE on Shop Floor	Ensuring compliance with HSE requirements and instructions featuring Metal AM processes and systems; Providing support to management and operational teams in all aspects of safety, health, and environmental issues; Monitoring/ Implementing corrective actions to avoid Hazard risks.	14	28

Learning Outcomes – CU 47 HSE for Metal AM Processes	
KNOWLEDGE	Factual and broad knowledge of theory and applicability of: – HSE requirements and instructions featuring Metal AM processes manufacturing – Infrastructures/Facility Requirements featuring Metal AM processes manufacturing

Learning Outcomes – CU 47 HSE for Metal AM Processes	
SKILLS	Identify HSE training requirements for personnel operating at shop floor Describe the HSE hazards occurring on shop floor naming the different specifications applicable to the main metal AM systems Describe HSE procedures for handling and storage of metal AM feedstock naming the differences between wire and powder materials Describe metal AM HSE applicable legislation and standards ensuring personnel follows all the applicable HSE regulations at shop floor Verify if safety metal AM work procedures are properly followed monitoring personnel operations at shop floor Interpret Risk Assessment plans applying appropriate prevention and protection measures for reducing incidents at shop floor Produce incident/accident reports describing all the relevant factors related with the event.

9.5.7 Competence Unit 48: Powder Handling

CU 48: Powder Handling SUBJECT TITLE	RECOMENDED CONTACT HOURS
Overview of Powder Manufacturing Processes	3
Chemical Composition and Physical Properties	4
Particle Size Distribution	2
Powder storage, handling, ageing and documentation	3
Powder reusability	1
HSE procedures	1
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Power Handling	4 Independent	Manage powders for Metal AM	Implementing procedures for powder delivery and storage	14	28
			Preparing and analysing powder according to technical documentation		
			Performing powder reconditioning (e.g. sieving) after build cycle		
			Following HSE procedures		

Learning Outcomes – CU 48: Powder Handling	
KNOWLEDGE	Factual and broad of: – Powder handling, storage and reconditioning
SKILLS	Complete technical documentation related to powders for metal AM Characterise powders according to instructions from the engineer Ensure powder conditioning according to the AM Procedure Specification Control the reusability of powders Handle powders according to HSE procedures

10. Guideline for Metal AM Inspector

10.1 Introduction to Metal AM Inspector

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	E I	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 01: DED-Arc Process	14	28
CU 08: DED-LB Process	14	28
CU 15: PBF-LB Process	14	28
CU 22: PBF-EB Process	14	28
CU 63: Quality Assurance for Inspection	28	56
CU 64: Inspection-Examination and Testing	38.5	77
Total	129.5	259

* Recommended Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Expected Workload is calculated in hours, corresponding to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Although the hours indicated in the above table are merely recommended, it is mandatory that in total the qualification has a minimum of 40 contact hours.

Within EWF´s qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF´s Systems Framework levels (see Appendix I). On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills. Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical workshop training (C), etc., as shown in the following example:

Qualification: Example 1	
RECCOMMENDED CONTACT HOURS	X = SUM (A:C)
Subject Contents	A + B + C

10.2 Occupational Standard

European Metal AM Inspectors are the professionals with the specific knowledge, skills, autonomy and responsibility to conduct inspections to Metal Additive Manufacturing parts production. Their main tasks are:

- Carry out quality assessments of the AM process at various critical stages;
- Perform inspection of all equipment ensuring adequate and controlled use;
- Conduct visual inspection to identify and evaluate imperfections in Metal AM parts and assess against agreed acceptance criteria;
- Verify all Metal AM related activities in production, including (but not limited to) the following points:
    i. Verify data and adequacy of material certificates (base and filler materials);
    ii. Verify identification and traceability of the materials used during the manufacturing process;
    iii. Verify the compliance of feedstock against applicable regulations, standards, codes and/or specifications
- Compile and verify completeness of the final inspection document package.

10.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to European Operator Qualification admission are the following:

- National compulsory school diploma;
- Basic knowledge and skills related with quality assurance and HSE
- Visual acuity test.

10.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
E MAM I	INDEPENDENT	Factual and broad concepts in the field of Metal AM inspection and related applications	Fundamental cognitive and practical skills on simple and specific Metal AM inspections required to: • implement proper solutions • application of Metal AM inspection procedures and tools	Self-manage of professional activities and simple standard applications of Metal AM inspection activities in predictable contexts.

10.5 Mandatory Competence Units Learning Outcomes

10.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED CONTACT HOURS
SUBJECT TITLE	
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	**14**

Learning Outcomes – CU00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – Directed energy deposition – Powder bed fusion – Vat photopolymerization – Material jetting – Binder jetting – Material extrusion – Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

10.5.2 Competence Unit 01: DED-Arc Process

CU01: DED-Arc Process SUBJECT TITLE	CONTACT HOURS
DED-Arc Process principles	2
DED-Arc System (hardware & software)	5
DED-Arc Parameters	3
DED-Arc Build platform, feedstock and other consumables	3
Post processing operations	1
Total	14
WORKLOAD	28

Learning Outcomes – CU01: DED-Arc Process	
KNOWLEDGE	Factual and broad knowledge of: – DED-Arc systems – Arc physics – Processable materials with DED-Arc – Processing atmosphere requirements with DED-Arc – Sensors and process controls with DED-Arc
SKILLS	Describe the DED–Arc systems, including the components and their functions Distinguish different types of feedstock Associate the interaction of the process heat source with the feedstock Recognise the DED–Arc parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED–Arc build platform, feedstock and other consumables Identify the problems associated with inadequate preparation and set-up of the AM equipment, build platform, handling and storage of feedstock and application of the gases used in DED–Arc

10.5.3 Competence Unit 08: DED-LB Process

CU 08: DED-LB Process	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
DED-LB Process principles	2
DED-LB System (hardware & software)	4
DED-LB parameters	3
Build platform, feedstock and other consumables	4
Post processing operations	1
Total	14
WORKLOAD	28

Learning Outcomes – CU08: DED-LB Process	
KNOWLEDGE	Factual and broad of: – DED-LB systems – Laser Characteristics – Build platform – Powder/wire – Gases – Processable materials with DED-LB
SKILLS	Describe the DED-LB systems, including the components and their functions Distinguish different types of feedstock Associate the interaction of the process heat source with the feedstock Recognise the DED-LB parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED-LB build platform, feedstock and other consumables Identify the problems associated with inadequate preparation and set-up of the build platform, handling and storage of feedstock and application of the gases used in DED-LB Recognise the basic principles of 3D CAD systems and machine control software

10.5.4 Competence Unit 15: PBF-LB Process

CU 15: PBF-LB Process SUBJECT TITLE	RECCOMMENDED CONTACT HOURS
PBF-LB Process principles	2
PBF-LB System – Hardware and Software	4
PBF-LB Parameters	3
PBF-LB Build platform, feedstock and other consumables	4
Post Processing	1
Total	14
WORKLOAD	28

Learning Outcomes – CU15: PBF-LB Process	
KNOWLEDGE	Factual and broad knowledge of: – PBF-LB systems – Laser characteristics – Build platform – Powder – Gases – Processable materials with PBF-LB
SKILLS	Describe the PBF-LB systems, including the components and their functions Recognise the characteristics of the PBF-LB build platform, feedstock and other consumables Recognise the PBF-LB parameters and the influence of their adjustment on the as built part Recognise the interaction of the process heat source with the feedstock Identify the problems associated with inadequate preparation and setup of the build platform, handling and storage of feedstock and application of the gases used in PBF-LB

10.5.5 Competence Unit 22: PBF-EB Process

CU 22: PBF-EB Process SUBJECT TITLE	RECCOMMENDED CONTACT HOURS
PBF-EB Process principles	2
PBF-EB System – Hardware and Software	4
PBF-EB Parameters	3
PBF-EB Build platform, feedstock and other consumables	4
Parameters	3
Post Processing	1
Total	14
WORKLOAD	28

Learning Outcomes – CU22: PBF-EB Process	
KNOWLEDGE	Factual and broad knowledge of: – EB systems – EB characteristics – Build platform – Wire /Powder – Vacuum pressure – Advantages and limitations of the process – Processable materials with EB
SKILLS	Describe the EB systems, including the components and their functions Outline the main advantages and limitations of EB over conventional and other AM processes, namely based on Electron beam Recognise the characteristics of the EB build platform, feedstock and other consumables Recognise the EB parameters and the influence of their adjustment on the as built part Recognise the interaction of the process heat source with the feedstock Identify the problems associated with inadequate preparation and setup of the build platform, handling and storage of feedstock used in EB

10.5.6 Competence Unit 63: Quality Assurance for Inspection

CU63: Quality Assurance for Inspection SUBJECT TITLE	RECCOMMENDED CONTACT HOURS
Quality Assurance and Quality Control in AM	7
AM Standards	3.5
Equipment Qualification	7
Parts Qualification	6
General Requirements of training of personnel involved in AM production	2
Measurement, inspection and control	2.5
Total	28
WORKLOAD	**56**

CU	EQF/ EWF LEVEL	JOB FUNCTION	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Quality Assurance for Metal AM Processes)	4	Apply Quality Assurance /Quality Control checks.	Verifying if plant facilities and equipment are adequate to parts production Verifying if parts production is in compliance with applicable standards/codes Identifying non-conformities related with all AM production value chain Verifying the adequacy of qualification records of staff engaged in the AM process.	14	28

Learning Outcomes – CU63: Quality Assurance and Quality Control for Inspection	
KNOWLEDGE	Factual and broad of knowledge: – Quality Assurance and Quality Control principles in Metal AM production – Machine Qualification – Parts Qualification – Standards applied to AM production – Metal AM personnel role and activities – Measurement, inspection and control during Metal AM production
SKILLS	Outline the role, responsibilities, attitude and code of ethics of Metal AM inspectors in construction codes and quality standards. Review Metal AM personnel's approval/qualification for acceptance with applicable standards and specification. Review Metal AM Systems approval/qualification for acceptance with applicable standards and specification. Check an AMPS for acceptance with applicable standards and specification. Recognise methods of measurement used in the control of Metal AM. Recognise working procedures for the measurement of Metal AM parameters. Recognise the need for calibration of equipment, and the methods to validate calibration. Interpret inspection and quality non-conformities identifying the applicable corrective measures.

10.5.7 Competence Unit 64: Inspection-Examination and Testing

CU64: Inspection-Examination and Testing	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
Imperfections in AM outputs	7
Thermal treatment processes	7
Microscopy and associated techniques used in metallurgical assessments	3,5
Destructive Testing	7
Non-Destructive Examination	7
Metrology	3,5
Final Inspection (proof testing, documentation review)	3,5
Total	38,5
WORKLOAD	**77**

CU	EQF/ EWF LEVEL	JOB FUNCTION	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Inspection-Examination and Testing	4	Perform Metal AM production inspections	Verifying the requirements of inspection equipment and its suitability for the testing requirements of the AM part (i.e. calibration and certification for metallurgical and mechanical testing).	50.5	110
			Verifying records of equipment and test procedures used for metallurgical and mechanical testing in the AM process.		
			Selecting appropriate test procedures for the		

			inspection activities carried out during an after the AM process, when necessary.		
			Carrying out audits of AM build materials supply and storage to be used for the AM part manufacture		
			Verifying if the manufacturing process is in compliance with the applicable standards		
			Signing off the final Inspection document package per AM part/s		

Learning Outcomes – CU64: Inspection-Examination and Testing	
KNOWLEDGE	Factual and broad of: – Inspection and testing plans; – Characterization and evaluation of Metal AM manufacturing imperfections; – Destructive Testing (DT) and Non- destructive testing (NDT) tests characteristics, application and type of delivered information; – Typical quality control and quality assurance documentation used in Metal AM inspection

Learning Outcomes – CU64: Inspection-Examination and Testing	
SKILLS	Identify, on the test reports, the relevant information and content. Identify the causes of Metal AM parts imperfections, with reference to the different Metal AM processes and Metal AM materials. Recognise the different types of Metal AM imperfections identifying the different levels of imperfection significance including comparison between imperfection families. Apply standards criteria for imperfections acceptance/rejection. Select the appropriate test that is requested by the standard regarding a specific activity, identifying the range and application of the most common NDT test methods. Identify the purpose of visual inspection at all stages of Metal AM manufacturing naming the objective and limitations of tools used to aid visual inspection. Perform visual inspection and report in detail the defects identified during an inspection. Review interpreting DT and NDT test results reports to verify its compliance with the requirements of the Metal AM manufacturing. Outline the roles of the respective levels of personnel in Metal AM manufacturing (preparing procedures, conducting tests, evaluating and reporting the results of tests) Describe the typical structure of Inspection Testing Plan (ITP) Review and validate the main inspections records and reports identifying on the test reports the relevant information and content.

11. Appendix I: EWF Sectoral Systems Framework

AM PROFILE	EQF LEVEL	CLLAIM LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY	QUALIFICATION SYSTEM
	7	EXPERT	Highly specialised and forefront knowledge including original thinking, research and critical assessment of theory, principles and applicability of metal additive manufacturing processes.	Highly specialised problem- solving skills including critical and original evaluation, allowing to define or develop the best technical and economical solutions, when applying metal additive manufacturing processes, in complex and unpredictable conditions	Manage and transform the metal additive manufacturing processes in a highly complex context. Fully responsible for the definition and revision of personnel's tasks.	
DESIGNERS	6	ADVANCED	Advanced knowledge and critical understanding of the theory, principles and applicability of metal additive manufacturing processes.	Advanced problem-solving skills including critical evaluation, allowing to choose the proper technical and economical solutions, when applying metal	Manage the applications of metal additive manufacturing processes in a highly complex context.	AM

						additive manufacturing processes, in complex and unpredictable conditions	Act autonomously in decision making and definition in the definition of the metal additive manufacturing personnel's tasks.	
OPERATORS INSPECTORS SUPERVISORS			5	SPECIALIZED	Specialised, factual and theoretical of theory, principles and applicability of metal additive manufacturing processes	Specialised range of cognitive and practical skills, allowing to develop solutions or choose the appropriate methods, when applying metal additive manufacturing processes in common/regular problems.	Manage and supervise common or standard metal additive manufacturing processes, in an unpredictable context. Take responsibility in standard work and supervise the metal additive manufacturing personnel's tasks.	
			4	INDEPENDENT	Factual and broad concepts in the field of metal additive manufacturing processes.	Fundamental cognitive and practical skills required to develop proper solutions and	Self-manage of professional activities and simple standard applications of	

						application of procedures and tools on simple and specific metal additive manufacturing problems.	metal additive manufacturing processes in predictable contexts but subject to change. Supervise routine tasks and similar function workers, as well as take responsibility for decision making in basic work.	

12. Appendix II: List of Competence Units

CODE	Designation
CU 00	Additive manufacturing Process Overview
CU 01	DED-Arc Process
CU 02	Quality Assurance (QA) in DED-Arc
CU 03	Health, Safety and Environment (HSE) in DED-Arc
CU 04	Fit and set-up of DED-Arc systems
CU 05	Manufacturing of DED-Arc parts
CU 06	Post processing of DED-Arc parts
CU 07	Maintenance of DED-Arc systems
CU 08	DED-LB Process
CU 09	Quality Assurance (QA) in DED-LB
CU 10	Health, Safety and Environment (HSE) in DED-LB
CU 11	Fit and set-up of DED-LB systems
CU 12	Manufacturing of DED-LB parts
CU 13	Post processing of DED-LB parts
CU 14	Maintenance of DED-LB systems
CU 15	PBF-LB Process
CU 16	Quality Assurance (QA) in PBF-LB
CU 17	Health, Safety and Environment (HSE) in PBF-LB
CU 18	Hardware, software and build file set-up for PBF-LB
CU 19	Monitoring and managing the manufacturing of PBF-LB parts
CU 20	Post-processing of PBF-LB parts
CU 21	Maintenance of PBF-LB systems
CU 22	PBF-EB Process
CU 23	Quality Assurance (QA) in PBF-EB
CU 24	Health, Safety and Environment (HSE) in PBF-EB
CU 25	Post Processing
CU 46	Quality Assurance for Metal AM Processes
CU 47	HSE for Metal AM Processes
CU 48	Powder Handling
CU 49	Laser Beam Characterisation
CU 50	Hardware, software and build file set-up for PBF-EB
CU 51	Monitoring and managing the manufacturing of PBF-EB parts
CU 52	Post-processing of PBF-EB parts
CU 53	Maintenance of PBF-EB systems
CU 57	Relevant principles of DED Processes for Design
CU 58	Design Metal AM parts for DED Processes
CU 59	Relevant principles of PBF Processes for Design
CU 60	Design Metal AM parts for PBF Processes
CU 61	Simulation Analysis
CU 62	Simulation Execution
CU 63	Quality Assurance for Inspection
CU 64	Inspection-Examination and Testing