

CURRICULUM AND GUIDELINES ON TRAINING FOR SOLAR ENERGY SOLUTIONS

Solar Energy component of Deliverable D3.1

PRISTINE VET - Erasmus+ Capacity Building in Vocational Education and Training
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1.0	August 2026	Final for submission	Final Solar Energy curriculum and training guidelines with detailed course outlines integrated for S1-01 to S2-07.

Document Status

This document is the Solar Energy component of Deliverable D3.1 and provides the master curriculum and implementation guide for the PRISTINE VET Solar Energy training programme. Detailed teaching and learning materials are maintained separately within the Solar training package under D3.3.

Programme structure

The Solar Energy programme comprises 12 modules - 5 Basic and 7 Advanced. The listed module durations total 17.0 hours at Basic level and 23.5 hours at Advanced level, giving a calculated programme total of 40.5 hours. The module sequence and durations in Section 3.3 form the controlling schedule for this curriculum.

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Acronyms and Abbreviations

Acronym	Meaning
AC	Alternating Current
CAPEX	Capital Expenditure
DC	Direct Current
DHI	Diffuse Horizontal Irradiance
DNI	Direct Normal Irradiance
EACEA	European Education and Culture Executive Agency
EIA	Environmental Impact Assessment
GHI	Global Horizontal Irradiance
GPOA	Plane-of-Array Irradiance
I-V	Current-Voltage characteristic
LCOE	Levelized Cost of Energy
LOTO	Lockout/Tagout
LVRT	Low-Voltage Ride-Through
MPPT	Maximum Power Point Tracking
O&M	Operation and Maintenance
OPEX	Operational Expenditure
PPE	Personal Protective Equipment
PR	Performance Ratio
PV	Photovoltaic

Acronym	Meaning
P-V	Power-Voltage characteristic
SCADA	Supervisory Control and Data Acquisition
SPD	Surge Protective Device
STC	Standard Test Conditions
WBL	Work-Based Learning

Executive Summary

PRISTINE VET is a 24-month Erasmus+ Capacity Building in VET project designed to modernise renewable-energy vocational training in West Africa. Within WP3 - Training Content Development and Learning - the project develops industry-aligned curricula, training materials, digital resources and assessment approaches for solar, wind, biomass and hydrogen energy solutions, with NWC leading the work package.

This Solar Energy Curriculum and Training Guidelines document provides the master structure for the Solar Energy training programme. It converts the available Basic and Advanced Solar course materials into a coherent competency-based VET curriculum and defines programme outcomes, sequencing, delivery, practical learning, assessment, safety, trainer and learner expectations, quality assurance and implementation arrangements.

The curriculum comprises 12 modules: five Basic modules and seven Advanced modules. The Basic level establishes solar-PV system context, solar-resource and conversion fundamentals, mechanical support, electrical structure and foundational power electronics. The Advanced level develops integrated PV-system understanding, advanced array electrical design, control and SCADA, advanced power electronics, plant planning, fault diagnosis, and operation and maintenance.

The listed module durations provide 17.0 hours of Basic learning and 23.5 hours of Advanced learning, for a calculated total of 40.5 hours. Delivery follows a hybrid VET model combining e-learning and instructor-led teaching with calculations, diagrams, simulation, data interpretation, case studies, practical assignments, demonstrations and work-based learning or field exposure where feasible and safe.

Curriculum principle

The curriculum defines what is to be learned, the competencies to be developed, how learning is organised and delivered, and how achievement is evidenced. The detailed D3.3 Solar educational materials provide the teaching content for implementing this curriculum.

1. Project and Curriculum Context

1.1 PRISTINE VET Context

PRISTINE VET addresses green-energy skills development in West Africa through curriculum modernisation, practical technical training, digital learning and stronger links between VET providers, industry and public stakeholders. The project builds on existing photovoltaic content while expanding and updating training across solar, wind, biomass and hydrogen technologies.

WP3 - Training Content Development and Learning - is led by NOWOCERT LIMITED (NWC) for Months 1-12. The work package requires updated, industry-aligned curricula with at least 10 e-learning courses per specialty, alignment with PANER and local/regional/national priorities, stakeholder-informed module and competency design, digital resources and assessment tools, accessible language versions, and course testing with trainers and partner VET providers.

1.2 Deliverable Positioning

WP3 output	Purpose	Solar Energy relationship
D3.1	Curriculum and guidelines on training for Solar, Wind and Biomass Energy Solutions	This document is the Solar Energy component: programme architecture, competencies, detailed course outlines, delivery and implementation guidelines.
D3.3	Educational material on training for Solar Energy Solutions, in English and French	Detailed Solar course content and educational materials used by trainers and learners to implement this curriculum.
D3.4	Report on organisation of courses on training (trainers) for Solar Energy Solutions	Evidence on trainer-course organisation, testing, feedback and refinement following curriculum/material development.

1.3 Project Requirements Addressed by the Curriculum

Project requirement	Curriculum response
Competency-based, industry-aligned curriculum	Programme outcomes, competency domains, detailed module specifications and workplace-oriented evidence.
At least 10 e-learning courses per specialty	12 Solar modules are structured and sequenced across Basic and Advanced levels.
Stakeholder-informed curriculum design	Local contextualisation and structured review by VET institutions, companies and relevant authorities are built into implementation and QA.
Practical technical training	Calculations, PV system diagrams, array and layout tasks, SCADA/data analysis, fault diagnosis, commissioning, O&M and safety activities are embedded.
Digital learning	Hybrid delivery, digital course files, interactive diagrams, simulation, quizzes, monitoring data and SCADA-oriented learning are supported.
English/French and local accessibility	The curriculum supports delivery and adaptation in project languages and local languages where needed without reducing technical competence.
Course testing and feedback	Pilot delivery, trainer/partner feedback, learner feedback and controlled curriculum revision are included in the QA cycle.
Certification alignment	Assessment evidence is designed for later alignment with the WP4 competency-based certification framework and applicable national VET requirements.

2. Purpose, Scope and Design Principles

2.1 Purpose

The purpose of this document is to provide a single, coherent curriculum and implementation framework for Solar Energy training under PRISTINE VET. It is intended for VET providers, trainers, technical experts, curriculum developers and project partners responsible for organising, delivering, assessing and improving the Solar Energy programme.

2.2 Scope

The curriculum covers the complete learning pathway from solar-energy context and PV fundamentals through solar radiation, PV conversion, mechanical mounting, electrical structure, power electronics, advanced array design, control and SCADA, plant planning, fault diagnosis, commissioning, operation and maintenance. It also integrates safety, environmental responsibility, digital learning, assessment, quality assurance and professional practice.

This document does not replace the detailed educational materials. Trainers should use the corresponding S1/S2 course materials for the full technical explanations, figures, equations, worked examples and extended topic treatment. The curriculum controls the learning sequence, outcomes, competency expectations, delivery logic and evidence of learning.

Curriculum principle

The curriculum defines what is to be learned, the competencies to be developed, how learning is organised and delivered, and how achievement is evidenced. The detailed Solar educational materials provide the subject matter used to implement that curriculum.

2.3 Curriculum Design Principles

Principle	Application
Competency-based	Learning outcomes describe demonstrable knowledge, interpretation, calculation, analysis and practical capability rather than topic exposure alone.

Principle	Application
Progressive	Basic modules establish foundations; Advanced modules require system integration, design reasoning, data interpretation, diagnosis, planning and lifecycle thinking.
Industry-aligned	Content is organised around real PV plants, modules and arrays, mounting structures, electrical systems, inverters, controls, grid connection, diagnostics and O&M.
Practice-oriented	Theory is connected to calculations, system diagrams, design worksheets, SCADA/monitoring data, fault scenarios, inspection and maintenance cases.
Hybrid and digitally enabled	E-learning and digital resources are combined with instructor-led explanation, simulation, case work and supervised practical learning.
Context-responsive	Examples, cases, site conditions and implementation arrangements should be adapted to West African energy systems and partner-country priorities.
Inclusive	Training should support equal opportunity, gender mainstreaming, accessible participation and respectful learning environments.
Safety-led	Electrical, mechanical, roof/height, installation and maintenance hazards are integrated into teaching and practical activity design.
Quality-controlled	Curriculum and materials are subject to review, course testing, feedback, revision and version control.

2.4 Local Contextualisation and Standards

The technical core of the curriculum should remain consistent across partner institutions, while examples, datasets, system scales, delivery methods and practical arrangements should be contextualised to local solar resources, grid conditions, building and land-use contexts, available equipment and labour-market needs. Applicable national and local requirements for electrical safety, structures, grid connection, environmental protection, occupational safety and VET delivery should be applied during localisation and stakeholder validation.

3. Programme Profile and Structure

3.1 Programme Profile

Programme title	PRISTINE VET Certificate Courses on Solar Energy Solutions - Curriculum and Training Guidelines
Programme structure	12 course modules: 5 Basic + 7 Advanced
Total recommended learning time	40.5 hours calculated from the listed module durations (17.0 Basic + 23.5 Advanced)
Delivery mode	Hybrid VET: e-learning/classroom theory + practical activities, calculations, demonstrations, simulations, case studies and WBL/field exposure where feasible
Target audience	VET college students in West Africa; renewable-energy technicians; energy-sector trainees and technical assistants; engineers seeking structured Solar PV knowledge; professionals interested in clean-energy technologies
Recommended prerequisites	Basic mathematics; basic physics; basic electrical/electronic and mechanical concepts; familiarity with renewable-energy technologies. These are recommended rather than mandatory.
Trainer profile	Renewable-energy engineers, Solar PV specialists and experienced technical trainers. Advanced modules should involve subject specialists in PV electrical design, power electronics, control/SCADA, plant planning, diagnostics and O&M as appropriate.
Programme levels	Basic (S1) and Advanced (S2). These are programme-internal levels; formal qualification/accreditation positioning is to be aligned with WP4 and applicable national frameworks.
Language/accessibility	Master curriculum in English; supporting materials to be available/adapted in English and French and, where needed, local languages in accordance with WP3 arrangements.

Assessment basis

Learning-outcome aligned quizzes, technical exercises, calculation/design tasks, case analysis, data interpretation, system-evaluation tasks, practical assignments and troubleshooting scenarios.

3.2 Programme Aims

- Provide learners with a structured understanding of Solar PV energy from solar-resource fundamentals to complete plant operation and lifecycle management.
- Develop practical and analytical competence in PV conversion, mechanical mounting, electrical configuration, power electronics, control, SCADA and grid integration.
- Build the ability to interpret PV performance data, recognise abnormal behaviour, diagnose common faults and support safe troubleshooting and maintenance.
- Develop competence in solar-resource assessment, site selection, PV plant layout, shading analysis, grid connection and preliminary economic/environmental planning.
- Connect theory with technical practice through calculations, simulations, system diagrams, case studies, practical assignments and work-based learning opportunities.
- Support industry-relevant green skills and employment pathways within West African renewable-energy systems.
- Provide a consistent curriculum basis for trainer development, course testing, certification alignment and future curriculum updating.

3.3 Programme Structure and Recommended Sequence

Code	Course / Module	Level	Duration
S1-01	History of and Introduction to Solar Energy	Basic	3.0 h
S1-02	Basic Solar Radiation Rules in PV Energy Conversion and Plant Design	Basic	4.0 h
S1-03	Mechanical Structure and Mechanisms in Solar PV Systems - Part I	Basic	4.0 h
S1-04	Electrical Structure in Solar PV Systems - Part I	Basic	3.5 h
S1-05	Power Electronics in Solar Energy Generation	Basic	2.5 h
S2-01	Introduction to Advanced Mechanisms within Solar PV Systems	Advanced	2.5 h
S2-02	Electrical Structure in Solar PV Systems - Part II	Advanced	4.0 h
S2-03	Control, Monitoring, and SCADA Systems in Solar PV Plants	Advanced	3.0 h
S2-04	Power Electronics Technologies in Solar PV Systems	Advanced	3.5 h
S2-05	Solar Energy Generation Plants Planning and Allocation	Advanced	4.5 h
S2-06	Fault Identification and Diagnostics in Solar PV Systems	Advanced	3.0 h
S2-07	Solar PV Plant Operation and Maintenance Schedule	Advanced	3.0 h

Basic level total: 17.0 hours. Advanced level total: 23.5 hours. Calculated programme total: 40.5 hours.

3.4 Basic-to-Advanced Progression

Domain	Basic expectation	Advanced expectation
Solar resource and PV context	Recognise solar-energy technologies, system configurations, applications, resource variability and energy-transition role.	Interpret resource, project, performance and lifecycle implications across complete PV plants.
PV conversion and performance	Explain irradiance/irradiation, solar geometry, PV conversion and first-order environmental effects.	Use performance indicators, system losses and operating data to support control, planning, diagnostics and O&M decisions.
Mechanical systems	Identify modules, frames, rails, clamps, fixed/ground/rooftop structures, foundations and basic load paths.	Integrate mechanical considerations into plant design, installation, commissioning, inspection, reliability and lifecycle decisions.

Domain	Basic expectation	Advanced expectation
Electrical systems	Explain PV cell/module/string/array behaviour, DC components, protection and basic inverter matching.	Design and analyse string limits, parallel arrays, segmentation, losses, protection, grid architecture and electrical reliability.
Power electronics	Understand inverters, DC/DC conversion, DC-link functions, basic MPPT and grid/stand-alone operation.	Analyse inverter topologies, multi-MPPT/module-level electronics, grid synchronization, power quality, grid support, thermal management and smart inverters.
Control / SCADA	Recognise monitoring and inverter-control functions within the basic PV energy pathway.	Analyse hierarchical control, MPPT/inverter control, plant controllers, sensors, SCADA, alarms, hybrid operation and grid support.
Planning / diagnostics / O&M	Introduction through system components, project lifecycle and safety context.	Plan sites and layouts; evaluate grid/economic constraints; diagnose faults; support commissioning, performance monitoring, maintenance and lifecycle management.

4. Programme Learning Outcomes and Competency Framework

4.1 Programme Learning Outcomes

Code	Programme learning outcome
PLO1	Explain the development, applications and energy-system role of solar energy and describe the main configurations and lifecycle stages of Solar PV systems.
PLO2	Apply foundational solar-radiation, solar-geometry and PV-conversion concepts to explain PV performance, environmental effects and preliminary plant-design choices.
PLO3	Identify and explain PV mechanical structures, mounting systems, load paths, foundations, materials, installation requirements and basic structural safety.
PLO4	Explain PV electrical generation, cells/modules/strings/arrays, DC infrastructure, protection, I-V/P-V behaviour, basic array sizing and inverter matching.
PLO5	Explain Solar PV power-electronic conversion, inverter operation, DC/DC conversion, MPPT, DC-link functions and foundational load/grid interfacing.
PLO6	Analyse advanced PV array electrical design, electrical losses, mismatch, grounding/protection, grid-connected architecture and reliability issues.
PLO7	Analyse PV plant control, inverter coordination, SCADA/data acquisition, performance monitoring, alarms, hybrid operation and grid-support functions.
PLO8	Evaluate advanced inverter topologies, converter/MPPT technologies, power quality, synchronization, reactive-power control, grid support, thermal management and emerging power-electronic technologies.
PLO9	Interpret solar-resource, site, shading, layout, grid, economic, environmental and project-lifecycle information for PV plant planning and allocation.
PLO10	Identify and diagnose common module, string, wiring, inverter and protection faults using appropriate electrical measurements, I-V curves, thermography and monitoring/SCADA information.
PLO11	Support safe PV installation, commissioning, operation, performance monitoring, preventive/corrective/predictive maintenance, troubleshooting and lifecycle management.
PLO12	Apply appropriate health, safety, environmental and professional-practice principles and use technical diagrams, calculations, datasets and digital tools to communicate and solve structured Solar PV problems.

4.2 Competency Domains

Code	Competency domain	Scope
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Code	Competency domain	Scope
C1	Solar resource, PV fundamentals and sector context	Solar-energy development, resource variability, PV applications, system configurations, energy pathway and lifecycle context.
C2	Solar radiation, PV conversion and performance	Irradiance/irradiation, solar geometry, plane-of-array resource, photovoltaic effect, environmental losses, energy yield and performance reasoning.
C3	Mechanical structures and installation	Modules, frames, rails, clamps, rooftop/ground structures, fixed/tracking concepts, foundations, load paths, materials, installation and mechanical safety.
C4	Electrical systems, protection and array design	Cells/modules/strings/arrays, DC components, I-V/P-V behaviour, string sizing, cable/mismatch losses, grounding, protection, transformers, switchgear and grid architecture.
C5	Power electronics, control, SCADA and grid integration	Inverters, DC/DC converters, MPPT, DC-link, plant/inverter control, sensors, SCADA, synchronization, power quality, reactive power and grid support.
C6	PV plant planning, grid connection and project feasibility	Solar-resource/site assessment, shading, layout, system sizing, grid constraints, permitting, economics, environmental/social considerations and project lifecycle.
C7	Fault diagnostics, commissioning, O&M and performance	Fault classification, diagnostic tools, troubleshooting, commissioning, PR/yield/availability, inspection, preventive/corrective/predictive maintenance and lifecycle reliability.
C8	Safety, sustainability and professional practice	DC/AC electrical safety, LOTO, work at height, installation hazards, PPE, environmental responsibility, inclusion, teamwork and professional conduct.

4.3 Module-to-Competency Mapping

Module	Primary competency domains	Emphasis
S1-01	C1, C8	Solar-energy context, PV system overview, applications and lifecycle foundation
S1-02	C1, C2	Solar radiation, PV conversion, environmental effects and preliminary plant design
S1-03	C3, C8	Mechanical structure, mounting, load paths, durability and safe installation
S1-04	C2, C4, C8	PV electrical generation, array structure, protection, I-V/P-V behaviour and inverter matching
S1-05	C4, C5	Foundational power electronics, inverter operation, MPPT and grid/load interface
S2-01	C1-C7	Integrated systems thinking across PV plant design, control, diagnostics and lifecycle
S2-02	C4, C7, C8	Advanced array electrical design, losses, protection, grid architecture and reliability
S2-03	C5, C7	Control, SCADA, performance monitoring, alarms and hybrid/grid-support operation
S2-04	C5, C7	Advanced inverter/converter topologies, MPPT, power quality, grid support and reliability
S2-05	C1, C2, C3, C4, C6, C8	Site/resource assessment, layout, grid, economics, environmental planning and project feasibility
S2-06	C4, C5, C7, C8	PV fault classification, diagnostics, root cause analysis and corrective response
S2-07	C3, C4, C5, C7, C8	Installation/commissioning, operations, performance, maintenance, safety and lifecycle management

5. Detailed Course Outlines and Module Specifications

The following 12 course outlines define the learning outcomes, teaching sequence, applied activities, assessment approach and progression for each Solar Energy module. They provide a curriculum-level roadmap derived from the Basic and Advanced Solar materials. The outlines intentionally summarise rather than reproduce the full technical teaching content, which remains in the detailed Solar educational materials.

5.1 S1-01 - History of and Introduction to Solar Energy

Course code	S1-01
Level	Basic
Recommended duration	3.0 hours
Course description	Establish a common foundation in the development, applications, system architecture and strategic role of solar energy, while introducing the complete Solar PV energy pathway and project lifecycle.

Learning Outcomes

- Describe the development of solar-energy technologies and recognise major milestones in photovoltaic deployment.
- Explain solar energy as a variable renewable resource and identify the main factors that influence solar availability.
- Distinguish photovoltaic, solar-thermal and concentrated-solar-power concepts at introductory level.
- Trace the Solar PV energy pathway from solar radiation through modules, arrays, electrical collection, power conversion and final energy use.
- Compare rooftop, ground-mounted, fixed/tracking, stand-alone and grid-connected PV configurations and common application scales.
- Explain the role of solar energy in decarbonisation and describe the main stages from site assessment to operation and maintenance.

Detailed Course Outline

Topic	Main topics and subtopics
1. Development of solar-energy technologies	Early solar applications; evolution of photovoltaic and solar-thermal systems; key milestones in modern Solar PV deployment.
2. Solar energy as a renewable resource	Nature and variability of solar radiation; daily and seasonal availability; effects of location, weather, shading, dust, temperature and receiving-surface orientation.
3. Solar-energy technologies and PV energy pathway	PV, solar thermal and concentrated solar power overview; sunlight-to-DC conversion; modules, strings and arrays; electrical collection, conversion and delivery to loads or grid.
4. Main PV subsystems	Solar resource and PV array; mechanical mounting/support; electrical collection/protection; inverters/power electronics; monitoring and control.
5. PV system configurations and applications	Rooftop/building-mounted and ground-mounted systems; fixed-tilt and tracking concepts; stand-alone and grid-connected systems; residential, commercial, industrial, rural and utility-scale applications.
6. Project lifecycle and energy-transition role	Site assessment, preliminary planning, installation, inspection, commissioning, monitoring and maintenance; decarbonisation role, benefits, limitations and global/regional trends.

Recommended Practical / Simulation Activities

- Create a system block diagram tracing energy from sunlight to a local load or the utility grid.
- Identify and label the main subsystems in a rooftop or ground-mounted PV installation.
- Compare two Solar PV applications, such as a decentralized/rural system and a utility-scale plant, using a structured worksheet.
- Map the main stages of a PV project lifecycle and identify where mechanical, electrical, safety and operational decisions enter.

Assessment Approach

Knowledge quiz plus a PV-system mapping exercise and a short application/lifecycle comparison task.

Progression and Linkage

Provides the system vocabulary and context required for solar-resource and conversion study in S1-02 and for the mechanical, electrical and power-electronic modules that follow.

5.2 S1-02 - Basic Solar Radiation Rules in PV Energy Conversion and Plant Design

Course code	S1-02
Level	Basic
Recommended duration	4.0 hours
Course description	Develop the solar-resource and PV-conversion understanding needed to explain why irradiance, solar geometry, temperature, shading and losses determine PV output and preliminary plant design.

Learning Outcomes

- Distinguish irradiance from irradiation and explain direct, diffuse, reflected, GHI, DNI, DHI and plane-of-array radiation concepts.
- Describe the apparent motion of the sun using basic solar angles and explain why orientation and tilt affect received energy.
- Explain the photovoltaic conversion process and interpret principal electrical quantities of a PV cell, module, string and array.
- Quantify or interpret first-order effects of irradiance, cell temperature, shading, soiling and weather on PV power and energy production.
- Apply basic orientation, tilt, row-spacing, loss-budget, performance-ratio and energy-yield relationships in preliminary PV plant design.
- Identify trade-offs between energy capture, losses, land/layout constraints and practical plant design.

Detailed Course Outline

Topic	Main topics and subtopics
1. Solar-radiation fundamentals	Irradiance versus irradiation; direct, diffuse and reflected radiation; GHI, DNI, DHI, plane-of-array irradiance and ground reflectance.
2. Sun path and solar geometry	Latitude, declination, hour angle, zenith, altitude, azimuth and incidence angle; relation of solar position to array orientation and tilt.
3. PV energy-conversion principles	Photovoltaic effect; cell, module, string and array concepts; DC power generation; operating point and introductory I-V/P-V behaviour.
4. Environmental effects on PV output	Irradiance and temperature effects; partial shading and mismatch; soiling/dust; weather-related resource and thermal effects.
5. Basic PV plant design rules	Orientation and tilt; row spacing and inter-row shading; basic layout logic; preliminary energy-yield estimation.
6. Performance and design trade-offs	Efficiency and loss budget; performance ratio; energy yield; land use and layout; balancing resource capture, losses and practical constraints.

Recommended Practical / Simulation Activities

- Interpret a simple GHI/DNI/plane-of-array dataset and explain its implications for expected PV production.
- Use a sun-path or solar-angle exercise to compare candidate module orientations/tilts.
- Complete a simplified row-spacing/shading exercise for a fixed-tilt array.
- Estimate energy yield or performance ratio from a structured dataset and identify the main loss categories.

Assessment Approach

Quiz plus solar-resource interpretation and one or more calculation/design exercises covering radiation, energy yield, performance ratio or row spacing.

Progression and Linkage

Provides the resource and performance foundation for S1-03 mechanical layout, S1-04 electrical behaviour, and later planning, control, diagnostics and O&M modules.

5.3 S1-03 - Mechanical Structure and Mechanisms in Solar PV Systems - Part I

Course code	S1-03
Level	Basic
Recommended duration	4.0 hours
Course description	Introduce the mechanical subsystem of a Solar PV installation and explain how modules, mounting structures, connections and foundations maintain orientation and transfer environmental and operational loads safely to the supporting roof or soil.

Learning Outcomes

- Identify the principal mechanical components of a PV system and describe the structural roles of modules, frames, rails, clamps, fasteners, posts, brackets and foundations.
- Distinguish rooftop, ground-mounted, fixed-tilt and basic tracking configurations according to their mechanical arrangement and load-transfer path.
- Explain how gravity, wind, thermal movement and other actions are transferred from modules to the supporting roof, structure, foundation or soil.
- Apply fundamental concepts of equilibrium, stress, wind pressure, foundation stability, thermal expansion and connection preload at introductory level.
- Describe requirements for strength, serviceability, durability, corrosion resistance, alignment and maintenance access.
- Apply safe module handling, fastening, inspection and basic mechanical installation practices.

Detailed Course Outline

Topic	Main topics and subtopics
1. Mechanical function and complete load path	PV modules as both energy-conversion and structural components; support, orientation and load transfer; equilibrium and the need for continuity across every connection.
2. Modules, frames, rails, clamps and fasteners	Module construction and handling sensitivity; rails, brackets, posts and braces; mid/end clamps; fastener grade, preload and connection quality.
3. Mounting-system types	Rooftop mounting, roof attachments and ballast concepts; ground-mounted structures; fixed-tilt systems; introductory tracker arrangement and movement.
4. Structural support and foundations	Load transfer through supports; concrete, pile/ground-screw and other foundation concepts; soil capacity and roof-support considerations.
5. Basic mechanical design conditions	Gravity and wind actions; uplift; thermal expansion; alignment, deflection and serviceability; site-specific environmental actions.
6. Materials and durability	Corrosion, material compatibility and weather exposure; structural durability; inspection of looseness, deformation or deterioration.
7. Installation and safety	Module handling, approved clamping, alignment, fastening/preload, installation sequence, access and basic safe-work practices.

Recommended Practical / Simulation Activities

- Label a PV mounting-system diagram and trace the load path from module surface to roof or soil.
- Compare rooftop, ground-mounted and fixed/tracking arrangements against site and installation constraints.
- Complete a basic equilibrium, wind-pressure or thermal-expansion exercise using course examples.
- Use an installation/inspection checklist to identify alignment, fastening, corrosion and handling concerns.

Assessment Approach

Component-identification quiz plus a load-path/design exercise and a structured installation/inspection task.

Progression and Linkage

Provides the mechanical foundation for integrated system thinking in S2-01, site/layout decisions in S2-05 and installation/commissioning/O&M in S2-07.

5.4 S1-04 - Electrical Structure in Solar PV Systems - Part I

Course code	S1-04
Level	Basic
Recommended duration	3.5 hours
Course description	Build foundational competence in PV electrical generation, module/string/array configuration, DC components, protection, electrical characteristics and safe matching of the PV array with inverter operating limits.

Learning Outcomes

- Explain the fundamental electrical principles governing PV generation and describe PV cell, module, string and array behaviour under changing operating conditions.
- Analyse how series and parallel connections affect PV voltage, current and power.
- Identify DC cables, connectors, combiner boxes, disconnect switches and protective devices and explain their functions.
- Apply basic grounding, overcurrent protection, polarity-verification and insulation-safety principles.
- Interpret module electrical characteristics using I-V and P-V curves and explain the influence of irradiance and temperature.
- Perform basic array sizing and configure PV strings within inverter operating requirements.
- Match PV array electrical characteristics with inverter specifications for safe and efficient operation.

Detailed Course Outline

Topic	Main topics and subtopics
1. PV electrical-generation fundamentals	Photovoltaic effect; PV cell electrical behaviour and equivalent-circuit concept; DC voltage/current generation; influence of irradiance, temperature and load.
2. Modules, strings and arrays	Module electrical ratings; series, parallel and series-parallel connections; string configuration; array sizing and segmentation at basic level.
3. Main DC electrical components	PV cables and connectors; combiner boxes; disconnect switches; fuses and basic circuit protection; monitoring points.
4. Basic protection and electrical safety	Grounding concepts; overcurrent protection on DC/AC sides; polarity verification; insulation integrity; safe isolation and handling principles.
5. Electrical output characteristics	Open-circuit voltage, short-circuit current and maximum-power-point quantities; I-V and P-V curves; series/shunt resistance and environmental effects.
6. Basic array sizing and inverter matching	String voltage/current checks; inverter input range and power compatibility; configuration choices that support safe, efficient and reliable operation.

Recommended Practical / Simulation Activities

- Calculate voltage/current changes for simple series and parallel module arrangements.
- Interpret I-V and P-V curves under different irradiance or temperature conditions.
- Complete a basic string-sizing and inverter-matching exercise.
- Annotate a PV DC single-line/block diagram with cables, combiner, disconnect and protection functions.

Assessment Approach

Quiz plus series/parallel and I-V/P-V interpretation exercises, with a basic string-sizing or protection/matching task.

Progression and Linkage

Provides the electrical foundation for S1-05 power electronics, advanced array design in S2-02, control in S2-03, diagnostics in S2-06 and O&M in S2-07.

5.5 S1-05 - Power Electronics in Solar Energy Generation

Course code	S1-05
Level	Basic
Recommended duration	2.5 hours
Course description	Introduce the power-electronic devices and control functions that condition variable PV DC power, track the available maximum power and deliver usable electricity to stand-alone loads or the utility grid.

Learning Outcomes

- Explain the role of power electronics in PV energy conversion, power conditioning and grid integration.
- Identify diodes, semiconductor switching devices, DC/DC converters, inverters and DC-link components and explain their basic functions.
- Describe stand-alone and grid-connected inverter operation and basic output voltage/frequency control.
- Explain the PV power curve and the purpose and basic operation of maximum power point tracking.
- Recognise the influence of conversion losses, thermal effects, reliability and protection on PV power-electronic performance.
- Distinguish at introductory level between single-stage and two-stage PV conversion pathways.

Detailed Course Outline

Topic	Main topics and subtopics
1. Role of power electronics in PV systems	PV array-to-load/grid energy pathway; need for conversion, control and conditioning; interface between variable DC generation and useful electrical power.
2. Main power-electronic components	Diodes and switching devices; DC/DC converters; inverters; DC-link capacitors/inductors and output filtering functions.
3. Basic inverter operation	Stand-alone and grid-connected inverter concepts; DC-to-AC conversion; synchronization context; basic voltage and frequency regulation.
4. Maximum Power Point Tracking	PV power-curve concept; changing maximum-power point with environmental conditions; purpose and basic logic of MPPT.
5. Practical performance and reliability	Conversion losses and efficiency; thermal effects and cooling; basic protection, reliability and operating-limit considerations; single-stage versus two-stage configurations.

Recommended Practical / Simulation Activities

- Build or annotate a PV array - converter - DC-link - inverter - grid/load block diagram.
- Match power-electronic components to their functions and typical efficiency/thermal concerns.
- Interpret a simple P-V curve and identify why MPPT is required under changing irradiance or temperature.
- Compare stand-alone and grid-connected inverter functions using a structured worksheet.

Assessment Approach

Knowledge quiz plus block-diagram/component-function exercises and a short MPPT or inverter-operation task.

Progression and Linkage

Prepares learners for advanced array/inverter interaction, control/SCADA and advanced power electronics in S2-02 to S2-04.

5.6 S2-01 - Introduction to Advanced Mechanisms within Solar PV Systems

Course code	S2-01
Level	Advanced
Recommended duration	2.5 hours
Course description	Transition learners from component-level knowledge to an integrated view of the complete Solar PV plant, linking planning, array/electrical design, power conversion, control, monitoring, diagnostics, commissioning and lifecycle O&M.

Learning Outcomes

- Explain why a Solar PV plant must be understood as an integrated energy-conversion system rather than a collection of independent components.
- Trace energy flow from solar radiation through modules, strings, arrays, power converters, inverters, transformers and switchgear.
- Explain how control, SCADA, protection, diagnostics and maintenance support safe and reliable plant operation.
- Connect site/resource planning, electrical design, power electronics, control, fault diagnosis and O&M across the project lifecycle.
- Recognise how losses or faults in one subsystem can affect plant performance and availability.
- Explain the purpose and progression of the specialist Advanced modules S2-02 to S2-07.

Detailed Course Outline

Topic	Main topics and subtopics
1. Advanced PV system architecture	Utility-scale and distributed PV plant structure; modules/arrays, DC collection, inverters, transformers, switchgear and grid interface; hybrid/storage context.
2. Mechanical and electrical integration	Module-to-array integration; mounting/layout interface; DC collection; inverter/transformer placement; system-level energy path.
3. Power electronics, control and monitoring integration	Inverters and DC/DC converters; MPPT; plant controllers; sensors/meters; communication networks and SCADA supervision.
4. Advanced operating modes	Normal operation, low irradiance and partial shading; curtailment and grid-support operation; plant response to changing environmental/grid conditions.
5. Protection, performance and diagnostics overview	Protection functions, alarms, performance indicators and monitoring; distinguishing environmental variation from abnormal operation or fault.
6. Project and asset lifecycle roadmap	Planning and site assessment; design; installation/commissioning; operation; fault diagnosis; maintenance; end-of-life management and cross-system dependencies.

Recommended Practical / Simulation Activities

- Create an integrated PV plant system map linking resource, mechanical, electrical, conversion, control, grid and O&M subsystems.
- Analyse a short cross-system case in which shading, an electrical issue or inverter limitation affects plant output.
- Develop a roadmap showing how S2-02 to S2-07 connect across the plant lifecycle.

Assessment Approach

Short systems-integration quiz plus a complete-system mapping or cross-system case-analysis task.

Progression and Linkage

Acts as the bridge into S2-02 to S2-07 and should be completed before the specialist Advanced modules.

5.7 S2-02 - Electrical Structure in Solar PV Systems - Part II

Course code	S2-02
Level	Advanced
Recommended duration	4.0 hours
Course description	Develop advanced competence in PV array electrical configuration, string-voltage design, mismatch/loss analysis, DC protection, grid-connected plant architecture and long-term electrical reliability.

Learning Outcomes

- Design PV array electrical configurations by determining appropriate string voltage limits, parallel-string arrangements and array segmentation.
- Analyse cable losses, module mismatch and partial-shading effects and evaluate their impact on energy production.
- Explain advanced DC protection coordination, surge/lightning protection and ground-fault protection.
- Describe grid-connected PV electrical architecture including inverter stations, transformers, switchgear and medium-voltage collection networks.
- Assess insulation degradation, connector heating and potential-induced degradation and recommend appropriate mitigation or maintenance responses.
- Relate array electrical design choices to inverter compatibility, protection, reliability and lifecycle performance.

Detailed Course Outline

Topic	Main topics and subtopics
1. Advanced PV array electrical design	String voltage limits under hot/cold conditions; inverter MPPT and maximum-DC limits; parallel-string balancing; array segmentation and operating reliability.
2. Electrical losses and mismatch	Cable voltage/power losses; module mismatch; partial shading; bypass-diode behaviour; effects on string/array output and energy yield.
3. Protection and grounding systems	DC protection coordination; overcurrent/isolation concepts; surge and lightning protection; grounding and ground-fault protection.
4. Grid-connected electrical architecture	Inverter stations; transformers and switchgear; AC collection; medium-voltage collection networks; interfaces between array, conversion equipment and grid.
5. Advanced electrical reliability	Insulation degradation, leakage/ground faults, connector heating/high resistance and potential-induced degradation; detection, prevention and maintenance implications.

Recommended Practical / Simulation Activities

- Complete a hot/cold string-voltage design check against inverter operating limits.
- Estimate or compare cable/mismatch losses for alternative array arrangements.
- Develop a simplified DC protection and grounding diagram for a PV array section.
- Interpret an electrical-reliability case involving connector heating, insulation degradation or partial shading.

Assessment Approach

Technical design/calculation exercise plus an electrical-loss/protection or reliability case and targeted quiz.

Progression and Linkage

Provides the electrical design and reliability basis for control/SCADA in S2-03, power electronics in S2-04, fault diagnosis in S2-06 and O&M in S2-07.

5.8 S2-03 - Control, Monitoring, and SCADA Systems in Solar PV Plants

Course code	S2-03
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Level	Advanced
Recommended duration	3.0 hours
Course description	Develop system-level understanding of PV inverter and plant control, MPPT, supervisory control, sensors/communications, SCADA data, alarm management and coordinated operation of grid-connected, microgrid and hybrid PV systems.

Learning Outcomes

- Explain PV plant control objectives, closed-loop control and coordination between individual inverters and the plant controller.
- Analyse MPPT and inverter-control strategies under varying irradiance and grid conditions, including DC-link, active-power and reactive-power control.
- Describe SCADA architecture and the roles of field sensors, meters, communication networks, data acquisition, data logging and visualization.
- Analyse operational data, performance indicators, alarms and event logs to evaluate plant behaviour and support fault diagnosis.
- Explain control strategies for PV-storage and hybrid systems, including load-following operation and voltage/frequency support.
- Relate control and monitoring functions to reliable, safe and grid-compliant PV plant operation.

Detailed Course Outline

Topic	Main topics and subtopics
1. PV plant control fundamentals	Control objectives for islanded and grid-connected systems; closed-loop control; hierarchical converter/plant control; coordination between inverters and plant power controller.
2. MPPT and inverter control	MPPT under variable irradiance; single/two-stage control context; DC-link voltage regulation; inverter current control; active and reactive power control.
3. SCADA architecture and data acquisition	Irradiance, temperature and electrical sensors; meters; communication networks; data acquisition, logging, visualization and centralized supervision.
4. Operational monitoring, KPIs and alarms	Performance ratio and other operational indicators; alarm categories; event logs/status codes; interpreting trends and deviations for performance and diagnostic purposes.
5. Control in microgrids and hybrid systems	PV-storage coordination; load-following operation; power balancing; voltage/frequency support and coordinated control across distributed resources.

Recommended Practical / Simulation Activities

- Draw and explain a closed-loop PV inverter/plant-control pathway.
- Interpret a sample SCADA dashboard, event log or alarm sequence and identify the next checks.
- Calculate or interpret a basic performance-ratio/KPI example using monitoring data.
- Analyse a simple PV-storage or microgrid operating scenario and identify control objectives.

Assessment Approach

Control-system diagram exercise, SCADA/data/alarm case and knowledge quiz, with a short performance-monitoring or hybrid-control task where feasible.

Progression and Linkage

Integrates advanced electrical knowledge from S2-02 with inverter/grid functions in S2-04 and provides monitoring foundations for S2-06 diagnostics and S2-07 O&M.

5.9 S2-04 - Power Electronics Technologies in Solar PV Systems

Course code	S2-04
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Level	Advanced
Recommended duration	3.5 hours
Course description	Advance learner competence in modern PV inverter architectures, DC/DC conversion, distributed MPPT, grid synchronization, power quality, grid-support functions, thermal/reliability management and emerging smart-inverter technologies.

Learning Outcomes

- Differentiate central, string and micro-inverter architectures and evaluate their applications and trade-offs.
- Explain advanced DC/DC converter technologies used for voltage regulation and maximum power extraction.
- Analyse multi-MPPT systems, power optimizers and module-level power electronics for non-uniform operating conditions.
- Describe grid synchronization and evaluate harmonic mitigation, filtering, power-factor control and reactive-power regulation.
- Explain LVRT, volt-var regulation, frequency support and active-power curtailment as grid-support functions.
- Assess thermal management, switching-device reliability, wide-bandgap semiconductors and smart/hybrid inverter developments.

Detailed Course Outline

Topic	Main topics and subtopics
1. Advanced Solar inverter topologies	Central, string and micro-inverter/module-level architectures; selection according to system scale, shading, maintainability, reliability, efficiency and cost.
2. DC/DC converter technologies	Buck, boost and buck-boost concepts; voltage adaptation; conversion pathway and use with single-stage/two-stage PV architectures.
3. Multi-MPPT and module-level power electronics	Multiple MPPT channels; power optimizers; module-level control; mismatch/shading performance and distributed monitoring.
4. Grid interface and power quality	Grid synchronization; harmonic generation and mitigation; filtering; power factor; reactive-power regulation and current quality.
5. Grid-support functions	Low-voltage ride-through; volt-var control; frequency support; active-power curtailment and smart-inverter participation in grid stability.
6. Reliability and emerging technologies	Switching/conduction losses, thermal management and cooling; semiconductor stress and protection; SiC/GaN wide-bandgap devices; smart and hybrid inverter technologies.

Recommended Practical / Simulation Activities

- Compare central, string and micro-inverter architectures for two contrasting PV applications.
- Build a block diagram of a multi-MPPT/two-stage PV conversion system and trace its control objectives.
- Analyse a simplified power-quality/grid-support case involving reactive power, harmonics or LVRT.
- Review a thermal/reliability scenario and identify the design or operational factors that affect converter lifetime.

Assessment Approach

Converter-topology comparison plus a grid-interface/control case and technical quiz; include a reliability/thermal or MPPT application task where appropriate.

Progression and Linkage

Supports plant electrical architecture and grid decisions in S2-05, fault diagnosis in S2-06 and inverter maintenance/performance management in S2-07.

5.10 S2-05 - Solar Energy Generation Plants Planning and Allocation

Course code	S2-05
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Level	Advanced
Recommended duration	4.5 hours
Course description	Expand learning from PV component technology to complete plant development, combining solar-resource assessment, site selection, system sizing, layout/shading, grid connection, project feasibility, environmental considerations and implementation decisions.

Learning Outcomes

- Describe the main stages of Solar PV project development from site identification and feasibility through permitting, construction, commissioning and operation.
- Identify and evaluate key factors for solar plant site selection, including irradiance, land/topography, access, grid proximity and environmental/regulatory constraints.
- Assess solar-resource data and apply preliminary system sizing and energy-yield reasoning.
- Apply basic PV layout, orientation/tilt, shading analysis and inter-row spacing concepts.
- Evaluate grid-connection considerations including interconnection requirements, capacity, congestion, curtailment and grid-code constraints.
- Perform a preliminary economic assessment using CAPEX, OPEX and LCOE concepts and relate technical choices to project viability.
- Recognise environmental, land-use, permitting and stakeholder considerations that influence project allocation and development.

Detailed Course Outline

Topic	Main topics and subtopics
1. Solar project development process	Site identification and screening; feasibility; design and permitting; procurement/construction; commissioning; operation and project-lifecycle decision points.
2. Solar-resource and site assessment	Historical irradiance and meteorological data; GHI/DNI context; shading; terrain/topography; land availability; geotechnical/support context; access and infrastructure.
3. System sizing and energy-yield estimation	DC nameplate capacity, performance ratio and resource assumptions; expected annual energy yield; relationship between demand, land, technology, inverter efficiency and system losses.
4. PV plant layout and allocation	Orientation and tilt; row spacing; inter-row shading; access and maintenance corridors; array segmentation; inverter/transformer placement and layout optimization.
5. Grid connection and constraints	Point of interconnection; collection/substation context; local grid capacity; voltage/frequency/stability considerations; congestion, curtailment and grid-code requirements.
6. Economic evaluation and feasibility	CAPEX, OPEX and LCOE concepts; preliminary cost/energy comparison; effect of resource, losses, grid connection and design choices on project viability.
7. Environmental, regulatory and stakeholder considerations	Environmental screening/EIA context, zoning/permitting, land use, ecological/social constraints and early stakeholder coordination.

Recommended Practical / Simulation Activities

- Complete a structured site-screening exercise using solar-resource, terrain, access, land and grid criteria.
- Estimate preliminary system size and annual energy yield from a simplified resource/performance dataset.
- Develop a basic layout and row-spacing/shading rationale for a hypothetical site.
- Identify a plausible grid interconnection approach and key grid constraints for the case.
- Prepare a preliminary CAPEX/OPEX/LCOE or feasibility comparison using provided assumptions.

Assessment Approach

Resource/site interpretation, layout/sizing exercise and integrated Solar PV planning case with a short technical/economic assessment.

Progression and Linkage

Connects earlier resource, mechanical, electrical and inverter knowledge to real project development and provides the project baseline for diagnostics, commissioning and lifecycle O&M in S2-06 and S2-07.

5.11 S2-06 - Fault Identification and Diagnostics in Solar PV Systems

Course code	S2-06
Level	Advanced
Recommended duration	3.0 hours
Course description	Develop a systematic approach to identifying, localising and diagnosing PV faults by combining electrical behaviour, thermal evidence, performance normalization, I-V analysis, monitoring/SCADA data and structured root-cause reasoning.

Learning Outcomes

- Classify common Solar PV faults by location, physical mechanism, operating effect and severity.
- Explain how module defects, wiring problems, shading, degradation, inverter failures and protection faults alter PV electrical and thermal behaviour.
- Interpret fault signatures in voltage, current, power, insulation resistance, I-V curves, infrared images and SCADA records.
- Compare measured performance with expected/healthy behaviour while accounting for irradiance, temperature and operating state.
- Apply a systematic troubleshooting process including detection, localization, root-cause analysis, corrective action, verification and documentation.
- Relate fault severity to safety, energy loss, availability, maintenance priority and escalation needs.

Detailed Course Outline

Topic	Main topics and subtopics
1. Fault concepts and classification	Fault versus symptom; sudden, gradual, intermittent and condition-dependent faults; array-configuration effects; expected-versus-measured performance and normalized residual thinking.
2. PV module faults	Hotspots; cell cracks and interconnection defects; delamination/moisture deterioration; soiling and partial shading; long-term module degradation and bypass-diode issues.
3. String, wiring and electrical faults	Open-circuit and short-circuit faults; ground/insulation faults; arc faults; connector and high-resistance faults; consequences for current, voltage, heating and protection.
4. Inverter and protection faults	Inverter abnormal states and shutdowns; protection-device operation; alarms, trips and interaction with array/grid conditions.
5. Diagnostic tools and techniques	I-V curve tracing; infrared thermography; voltage/current/insulation measurements; SCADA data and alarm analysis; combining multiple methods to improve confidence.
6. Root cause, corrective action and verification	Structured troubleshooting workflow; energy-loss/criticality assessment; repair or replacement; post-repair verification and technical documentation.

Recommended Practical / Simulation Activities

- Classify a set of PV fault symptoms by subsystem, likely cause and severity.
- Interpret simplified I-V curves showing mismatch, open-circuit, shading or resistance-related abnormalities.
- Analyse an infrared/thermography example or annotated thermal image for hotspot or connection concerns.
- Use SCADA/monitoring and electrical measurements to build a fault-localization decision sequence.
- Complete a root-cause and corrective-action worksheet including post-repair verification.

Assessment Approach

Case-based diagnostic assessment using electrical/SCADA/I-V or thermal evidence, supported by a fault-classification quiz and troubleshooting workflow task.

Progression and Linkage

Consolidates electrical, control and power-electronic learning and prepares learners for safe fault-based, corrective and predictive maintenance in S2-07.

5.12 S2-07 - Solar PV Plant Operation and Maintenance Schedule

Course code	S2-07
Level	Advanced
Recommended duration	3.0 hours
Course description	Integrate installation, commissioning, operation, performance monitoring, preventive/corrective/predictive maintenance, troubleshooting, safety and lifecycle management into a practical Solar PV O&M framework.

Learning Outcomes

- Describe key mechanical and electrical installation/commissioning checks and controlled energization requirements.
- Interpret daily operational indicators, energy yield, availability and performance ratio in relation to irradiance and operating conditions.
- Develop preventive maintenance arrangements covering cleaning, visual inspection and electrical/mechanical inspection intervals.
- Distinguish corrective and predictive maintenance and relate condition-monitoring information to maintenance planning.
- Apply systematic troubleshooting and escalation using plant records, monitoring data and diagnostic evidence.
- Apply DC electrical safety, LOTO, PPE, work-at-height/site rules and controlled re-energization principles during O&M activities.
- Explain spare-parts, documentation, handover and end-of-life considerations within lifecycle asset management.

Detailed Course Outline

Topic	Main topics and subtopics
1. PV plant installation and commissioning	Mechanical installation checks; module/mounting integrity; DC/AC cabling, polarity, grounding and insulation checks; inverter/combiner functional tests; controlled energization; grid connection and anti-islanding/protection verification; performance baseline and handover.
2. Operation and performance monitoring	Daily operating status; inverter/string/AC behaviour; monitoring-system availability; energy yield; plant availability; performance-ratio tracking and comparison with expected conditions.
3. Preventive maintenance planning	Cleaning schedules; visual inspections; mechanical fastening/structure checks; electrical connections, cables, protection and inverter inspections; risk/criticality-based intervals.
4. Corrective and predictive maintenance	Fault-based maintenance; safe troubleshooting and repair; condition monitoring; trend/data-driven maintenance planning; prioritisation according to safety, energy loss and criticality.
5. O&M safety and work control	DC electrical hazards, insulation and polarity; safe isolation and LOTO; PPE; roof/height and installation risks; emergency procedures and controlled return to service.
6. Lifecycle and asset management	Spare-parts planning; maintenance records and work orders; performance baselines; documentation/handover; component replacement and end-of-life management.

Recommended Practical / Simulation Activities

- Build a commissioning checklist covering mechanical, electrical, functional and performance-verification steps.
- Interpret a short monitoring dataset and distinguish resource-driven variation from operational underperformance.
- Develop a preventive maintenance schedule for modules, structures, DC systems, inverters and monitoring equipment.
- Complete a classroom job-safety/LOTO sequence before a simulated PV maintenance activity.
- Use a troubleshooting and maintenance-priority case to connect fault evidence, safety, corrective action and documentation.

Assessment Approach

O&M case plus maintenance-schedule task, commissioning/performance interpretation, troubleshooting scenario and safety knowledge check.

Progression and Linkage

Capstone-style module integrating resource, mechanical, electrical, power-electronic, control, planning and diagnostic knowledge into safe lifecycle operation of Solar PV plants.

6. Teaching, Learning and Practical Training Guidelines

6.1 Delivery Model

The programme uses a hybrid VET approach that combines e-learning for theoretical concepts with instructor-led explanation and supervised practical learning. It also supports dual-learning elements through internships and on-the-job training where feasible. Delivery should move learners between concept, demonstration, guided practice, application, feedback and reflection.

Learning mode	Purpose	Examples
E-learning / digital theory	Introduce concepts efficiently and provide flexible access.	Short video lectures, technical illustrations, interactive diagrams, readings, quizzes and recorded demonstrations.
Instructor-led learning	Clarify difficult technical concepts and connect modules.	Worked examples, guided discussion, PV system diagrams, calculations, safety briefings and debriefs.
Simulation / data activity	Practise interpretation and decision-making without unnecessary risk.	Solar-resource datasets, sun-path/shading exercises, I-V/P-V curves, inverter/control diagrams, SCADA/alarm data, fault and maintenance scenarios.
Workshop / practical demonstration	Develop component recognition, safe procedures and practical reasoning.	PV modules/mounting examples, DC components, inverter/control demonstrations, test instruments, inspection and diagnostic exercises.
Case-based learning	Connect engineering with real project and operational decisions.	West African PV applications, site selection, grid constraints, shading, faults, O&M, environmental and economic trade-offs.
WBL / field exposure	Reinforce workplace context and professional practice.	Supervised site visits, internships, on-the-job observation, industry mentoring and project-based assignments where available.

6.2 Recommended Session Pattern

Stage	Guideline
1. Orientation	State learning outcomes, relevance, safety expectations and links to prior modules.
2. Concept input	Use concise lecture/e-learning material, diagrams and worked examples.
3. Guided application	Learners complete calculations, system tracing, interpretation or decision tasks.
4. Practical/case activity	Apply concepts through simulation, component work, dataset, design task, fault scenario or project case.

Stage	Guideline
5. Assessment and feedback	Use aligned knowledge and applied assessment evidence appropriate to the module outcomes and available time.
6. Reflection and transfer	Summarise the competence gained and link it to the next module or workplace task.

6.3 Practical Training Principles

- Practical activity must be directly linked to stated learning outcomes and should produce observable evidence of competence.
- High-risk tasks should first be taught through diagrams, mock-ups, simulation or supervised demonstration before any live equipment exposure.
- Where full-scale PV facilities are unavailable, use PV module/component examples, mounting mock-ups, safe low-voltage training rigs, inverter/control simulations, sample SCADA data, I-V/thermal examples and structured cases.
- Work-based learning should be planned with clear learning objectives, supervision arrangements, safety requirements and learner reflection/evidence.
- Practical activities should be contextualised to available Solar PV technologies and partner-country operating conditions without reducing core competency expectations.

6.4 Train-the-Trainer Guidance

Trainers should be briefed on the complete curriculum architecture, Basic-to-Advanced progression, assessment expectations, safety requirements and the relationship between this curriculum and the detailed D3.3 Solar materials. Trainer development should include opportunities to review current PV modules and array configurations, mounting practices, electrical protection, inverter and MPPT technologies, control/SCADA, diagnostic tools, planning and O&M practice. Cross-specialist team teaching is recommended for advanced electrical, power-electronic, control/SCADA, planning, diagnostics and O&M topics when one instructor cannot credibly cover the full technical breadth.

7. Assessment and Certification Alignment

7.1 Assessment Principles

- Assessment must be aligned to the learning outcomes of each module.
- Both theoretical understanding and practical/analytical competence should be evidenced where relevant.
- Assessment should progress from knowledge, identification and basic calculation at Basic level to design reasoning, analysis, data interpretation, diagnosis, evaluation and planning at Advanced level.
- Learners should receive timely feedback that identifies technical misconceptions and guides further practice.
- Assessment tasks should use realistic Solar PV contexts and avoid testing material that has not been taught or supported by the course materials.
- No live high-risk electrical task should be used as an assessment unless the training environment, equipment, competent supervision and safety procedures make the activity appropriate.

7.2 Assessment Methods

Method	Use in the programme
Multiple-choice / short-answer quizzes	Terminology, concepts, component functions, safety rules and basic technical understanding.
Technical calculations / exercises	Solar radiation, series/parallel electrical relationships, string sizing, loss/yield/PR calculations, row spacing and preliminary system sizing.
Case-study analysis	PV plant planning, grid constraints, shading, environmental issues, faults, O&M decisions and project trade-offs.
System-evaluation mini-tasks	Trace energy/control paths, interpret I-V/P-V curves or SCADA indicators, analyse subsystem interactions and evaluate design/operating choices.

Method	Use in the programme
Practical assignments	Component identification, mounting/load-path inspection, DC-system diagrams, data interpretation, commissioning checklists and maintenance planning.
Troubleshooting scenarios	Identify symptoms, plausible causes, diagnostic steps, safety controls and appropriate corrective/escalation actions using electrical, thermal or monitoring evidence.

7.3 Successful Completion and Certification

WP4 alignment required

No numeric pass mark, attendance threshold or final certification rule is set in this curriculum. Successful-completion thresholds, assessment criteria and certification procedures shall be applied in accordance with the PRISTINE VET competency-based certification framework under WP4 and applicable national VET requirements.

7.4 Assessment Quality Controls

- Use an assessment blueprint linking each item or task to module learning outcomes.
- Review questions and practical tasks for technical correctness, clarity, difficulty, language accessibility and realistic PV context.
- Use consistent marking guidance or rubrics for calculations, practical, data-analysis and case-based tasks.
- Record results and participant feedback in accordance with project record-keeping and data-protection requirements.
- Review assessment performance during course testing and revise weak or ambiguous items through controlled versioning.

8. Training Resources, Health and Safety, Environment and Inclusion

8.1 Recommended Training Resources

Resource area	Recommended provision
Digital learning	LMS/shared learning platform, internet-enabled devices, projector/display, short videos, interactive diagrams, quizzes and digital course files.
Solar resource and plant design	Sample irradiance datasets, sun-path information, GHI/DNI/DHI/plane-of-array examples, shading/layout worksheets, maps/site data and appropriate design/simulation tools where available.
Mechanical learning	PV module samples or mock-ups, frames, rails, clamps, fasteners, roof/ground-mount examples, foundation/load-path diagrams and safe installation tools/demonstrations.
Electrical learning	PV module/string examples, DC cables/connectors, combiner/protection examples, electrical schematics, safe low-voltage rigs, multimeters and insulation/polarity demonstrations.
Power electronics / control / SCADA	Inverter and DC/DC converter diagrams or safe training equipment, MPPT/control simulations, sensors/meters, SCADA screenshots or datasets, alarm/event examples and grid-interface diagrams.
Diagnostics / O&M / safety	I-V curve examples or tracer access where available, thermal images/thermography examples, maintenance/commissioning checklists, PPE, LOTO demonstration devices and job-safety/risk-assessment templates.

8.2 Health and Safety Requirements

Safety is a cross-cutting competency and must be integrated into every module that involves PV modules, electrical circuits, mounting structures, rooftops, installation, commissioning, diagnostics or maintenance. Training providers should apply local legal requirements and site procedures and must not permit unsupervised high-risk activity.

Hazard area	Training guideline
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Hazard area	Training guideline
PV DC electrical hazards	Treat PV DC circuits as potentially energized when exposed to light. Use isolation, verification, polarity/insulation checks, appropriate tools and competent supervision; avoid unsafe live-work exercises.
AC / grid / MV hazards	Use isolation, verification, grounding and competent-person rules. Live grid/MV training is not appropriate for unsupervised learner practice.
LOTO and re-energization	Teach controlled isolation, lockout/tagout where applicable, verification of safe state, communication and controlled return to service before maintenance scenarios.
Arc, connector and thermal hazards	Teach correct connection, inspection and fault recognition; avoid disturbing damaged or suspect connectors/circuits without safe isolation and competent supervision.
Roof / work-at-height hazards	Use appropriate access, fall-protection, exclusion zones, rescue awareness and competent supervision for any real height exposure.
Mechanical installation and lifting	Address module handling, sharp edges, manual handling, lifting zones, mounting stability, tool use, fastening and weather conditions.
PPE and emergency response	Select PPE for task hazards; brief emergency isolation, first response, incident reporting and evacuation arrangements.
Weather and site conditions	Consider heat, lightning, rain, dust, wind and other site conditions during outdoor installation, inspection or O&M activities.

8.3 Environmental and Sustainability Considerations

- Position Solar PV within climate mitigation, energy access and sustainable-energy objectives while recognising lifecycle environmental impacts.
- Address land use, shading/terrain constraints, environmental and social screening, permitting and community/stakeholder considerations in plant planning.
- Connect soiling, cleaning, component condition and maintenance quality with energy yield and resource-efficient operation.
- Introduce lifecycle thinking for module/inverter/component replacement, spare parts, waste and end-of-life management where relevant to O&M.
- Use cases that help learners balance energy yield, reliability, cost, environmental responsibility, safety and social acceptability.

8.4 Inclusion, Gender and Accessibility

Training delivery must support equal opportunity and non-discrimination. PRISTINE VET places explicit emphasis on increasing women's participation in green-energy VET and on inclusive access for underrepresented groups. Recruitment, examples, group work, practical assignments, mentoring and training environments should therefore be designed to avoid exclusion and to support equitable participation.

- Use gender-sensitive and inclusive communication and imagery.
- Plan practical activities so every learner has meaningful hands-on or analytical participation.
- Provide reasonable accessibility adaptations where feasible and avoid unnecessary barriers in digital learning.
- Monitor participation and learner feedback in accordance with project requirements and privacy rules.
- Use English/French and local-language support where needed to improve understanding without changing the technical competence expected.

8.5 Data Protection and Learner Records

Where training activities collect personal data, assessment results, participation records, feedback or images, providers should follow applicable data-protection requirements and project procedures, including lawful and transparent processing, data minimisation, secure storage, restricted access and appropriate participant information/consent.

9. Trainer and Learner Guidelines

9.1 Trainer Guidelines

- Use the curriculum outcomes and module specifications as the controlling teaching plan; use the S1/S2 educational materials as the detailed content source.
- Check prerequisite knowledge at the start of each level and provide bridging explanation where necessary.
- Explicitly connect Basic solar-resource, mechanical, electrical and inverter concepts to Advanced design, control, planning, diagnostic and O&M applications rather than repeating content without progression.
- Use diagrams, calculations, worked examples, PV datasets, I-V/P-V curves, SCADA data, cases and practical activities to make engineering concepts observable and relevant.
- Adapt examples and datasets to local solar resources, grid conditions, available PV technologies, building/land contexts and labour-market needs after stakeholder validation.
- Conduct a safety briefing before practical or field activity and stop any activity that cannot be performed safely with available supervision and equipment.
- Use assessment results and learner feedback to identify topics that require reteaching or curriculum/material revision.
- Keep course records, assessment evidence and versioned materials organised in the project/shared institutional repository.

9.2 Learner Guidelines

- Complete modules in the recommended sequence unless the trainer confirms equivalent prior competence.
- Participate in theoretical, digital, practical and case-based learning activities and ask for clarification when technical or safety concepts are unclear.
- Follow all laboratory, workshop, rooftop/field and electrical/mechanical safety instructions and use required PPE.
- Keep technical notes, calculations, diagrams, design worksheets and assessment evidence organised as part of a learning portfolio where used by the provider.
- Use SCADA/data/simulation exercises responsibly and distinguish between training simulations and authorised real-system operation.
- Apply professional conduct, teamwork, respectful communication and environmental responsibility during training and workplace exposure.

9.3 Suggested Learning Portfolio Evidence

Level	Example portfolio evidence
Basic level	Solar-energy/PV system map, solar-resource/energy-yield task, mounting/load-path exercise, PV electrical diagram/string-sizing exercise, inverter/MPPT block diagram and module quizzes.
Advanced level	Integrated PV plant map, advanced string/protection case, control/SCADA analysis, inverter-topology/grid-support exercise, plant-planning case, fault-diagnostic evidence, commissioning/O&M schedule and safety task.

10. Quality Assurance, Monitoring and Curriculum Review

10.1 Quality Assurance Objectives

Quality assurance should ensure that the curriculum remains technically accurate, pedagogically coherent, industry-relevant, inclusive, assessable and consistent with project requirements. Quality checks should cover both the curriculum and the detailed Solar educational materials used to deliver it.

10.2 Curriculum QA Cycle

Stage	Required action
1. Pre-delivery review	Confirm module codes/titles, durations, outcomes, learning materials, activities, assessment tasks, safety requirements and trainer readiness.

Stage	Required action
2. Stakeholder validation	Collect structured input from VET institutions, companies/industry experts and relevant authorities on workforce needs, technology relevance and local constraints.
3. Course testing	Pilot modules with trainers/partner VET providers; record implementation issues, learner questions, timing and resource gaps.
4. Feedback analysis	Review learner/trainer feedback, assessment performance, practical feasibility and inclusion/access issues.
5. Technical/pedagogical revision	Correct inaccuracies, reduce duplication, improve progression and update activities/assessment while preserving approved outcomes and document control.
6. Version control and approval	Issue a new controlled version, archive superseded versions and retain evidence of review/approval.

10.3 Monitoring Indicators for Training Delivery

- Completion of planned modules and assessments within the agreed delivery schedule.
- Learner participation and completion, including monitoring of gender participation and inclusive access.
- Assessment performance by learning outcome and identification of recurring knowledge or skill gaps.
- Learner and trainer feedback on clarity, relevance, practical value and digital accessibility.
- Availability and adequacy of Solar PV components, instruments, digital resources and safe practical-learning opportunities.
- Number and quality of industry/VET stakeholder contributions to curriculum review and WBL opportunities.
- Correct use of project visibility, document control, data-protection and record-keeping procedures.

10.4 Curriculum Review Triggers

- New Solar PV module, inverter, storage, monitoring, diagnostic or mounting technologies that materially change industry practice.
- Changes in grid requirements, national policy, electrical/structural safety rules or certification frameworks.
- Repeated learner/trainer feedback showing unclear sequencing, duplication or insufficient practical application.
- Assessment evidence indicating learning outcomes are not being reliably achieved.
- Changes in available VET infrastructure, digital tools or industry partnership opportunities.
- Formal feedback from WP3 course testing, WP4 certification development or project quality-assurance review.

11. Implementation, Document Control and Relationship to Educational Materials

11.1 Recommended Implementation Sequence

Phase	Implementation guidance
Phase 1 - Prepare	Confirm trainers, learner cohort, facilities, digital access, safety controls, language needs and current Solar course-file versions.
Phase 2 - Deliver Basic level	Complete S1-01 to S1-05, using formative assessment to confirm readiness for Advanced work.
Phase 3 - Deliver Advanced level	Complete S2-01 to S2-07 in sequence, increasing emphasis on integrated design, data interpretation, planning, diagnostics, commissioning and lifecycle O&M.
Phase 4 - Practical/WBL consolidation	Where feasible, use workshops, supervised field exposure, industry mentoring or applied projects to consolidate competencies.
Phase 5 - Assessment and feedback	Complete module evidence, collect learner/trainer feedback and identify gaps or revisions.
Phase 6 - Certification alignment / reporting	Apply the approved WP4 certification procedures when available and retain required evidence for project reporting and QA.

11.2 Relationship between Curriculum and Detailed Course Materials

Curriculum / Guidelines (this document)	Detailed Solar Educational Materials (D3.3)
Defines programme purpose, levels, module sequence, hours and learning outcomes.	Provides full technical explanations, figures, equations, examples and detailed teaching content.
Defines competency domains and expected evidence.	Provides the subject matter used to build learner understanding and practice.
Defines delivery, practical training, assessment, safety and QA principles.	Provides module-specific content that trainers adapt into lessons, digital resources and activities.
Controls coherence and Basic-to-Advanced progression.	Supports implementation but should not independently change approved curriculum outcomes or module structure.

11.3 Document Management and Version Control

- Store the approved DOCX master and PDF submission copy in the PRISTINE VET shared project repository using clear versioned filenames.
- Use the PDF version as the fixed-layout submission/distribution copy and retain the DOCX as the controlled editable master.
- Archive superseded versions so that only the current approved files remain active for delivery and reporting.
- Maintain the required EU visibility elements, funding acknowledgement and disclaimer on official/public versions.
- Retain curriculum, delivery, assessment, feedback and approval records in accordance with project record-keeping requirements.

CURRICULUM AND GUIDELINES ON TRAINING FOR WIND ENERGY SOLUTIONS

Wind Energy component of Deliverable D3.1

PRISTINE VET - Erasmus+ Capacity Building in Vocational Education and Training
Work Package 3: Training Content Development and Learning

Lead beneficiary **NOWOCERT LIMITED (NWC)**

Project acronym PRISTINE VET

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Revision History

Version	Date	Status	Description
1.0	August 2026	Final for submission	Final Wind Energy curriculum and training guidelines with detailed course outlines integrated for W1-01 to W2-07.

Document Status

This document is the Wind Energy component of Deliverable D3.1 and provides the master curriculum and implementation guide for the PRISTINE VET Wind Energy training programme. Detailed teaching and learning materials are maintained separately within the Wind training package.

Programme structure

The Wind Energy programme comprises 12 modules - 5 Basic and 7 Advanced - with a total recommended learning time of 43.5 hours. The module sequence and durations in Section 3.3 form the controlling schedule for this curriculum.

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Acronyms and Abbreviations

Acronym	Meaning
AEP	Annual Energy Production
CAPEX	Capital Expenditure
CFD	Computational Fluid Dynamics
DFIG	Doubly-Fed Induction Generator
EACEA	European Education and Culture Executive Agency
FRT	Fault Ride-Through
HMI	Human-Machine Interface
HV	High Voltage
LCOE	Levelized Cost of Energy
LOTO	Lockout/Tagout
LVRT	Low-Voltage Ride-Through
NWC	NOWOCERT LIMITED
O&M	Operation and Maintenance

Acronym	Meaning
PANER	Strategic National Plan for Renewable Energies
PE	Power Electronics
PMSG	Permanent Magnet Synchronous Generator
PPE	Personal Protective Equipment
PWM	Pulse Width Modulation
SCADA	Supervisory Control and Data Acquisition
VET	Vocational Education and Training
WBL	Work-Based Learning
WP	Work Package
WRA	Wind Resource Assessment

Executive Summary

PRISTINE VET is a 24-month Erasmus+ Capacity Building in VET initiative that seeks to modernise renewable-energy vocational training in West Africa through industry-aligned curricula, practical technical training, digital learning, certification development, stronger industry-academia cooperation and inclusive participation. WP3 is led by NOWOCERT LIMITED and covers the design and development of updated training content for solar, wind, biomass and hydrogen energy solutions.

This Wind Energy Curriculum and Training Guidelines document provides the master structure for the Wind Energy training programme. It translates the available Basic and Advanced Wind course materials into a coherent competency-based VET curriculum and defines programme objectives, learning outcomes, module sequencing, delivery methodology, practical training guidance, assessment approaches, trainer and learner expectations, resource requirements, safety provisions, quality assurance and curriculum review mechanisms.

The curriculum comprises 12 modules: five Basic modules and seven Advanced modules. The Basic level establishes core understanding of wind-energy development, resource characteristics, aerodynamics, mechanical systems, electrical systems and power electronics. The Advanced level integrates these foundations into system-level analysis, drivetrain and actuator mechanisms, advanced electrical performance, control and SCADA, converter technologies, wind-farm planning, grid integration, installation, commissioning, O&M, troubleshooting, safety and lifecycle performance.

The total recommended learning time is 43.5 hours. Delivery follows a hybrid VET model combining e-learning and classroom instruction with technical exercises, simulations, case studies, practical assignments, demonstrations and, where partner capacity allows, work-based learning or supervised field exposure. Assessment is aligned to module learning outcomes and uses quizzes, technical exercises, case-study analysis, system-evaluation tasks and practical troubleshooting scenarios. Final certification thresholds and formal qualification rules are to be aligned with the competency-based certification framework developed under WP4.

Curriculum principle

The curriculum defines what is to be learned, the competencies to be developed, how the learning is organised and delivered, and how achievement is evidenced. The detailed D3.5 educational materials provide the teaching content for implementing this curriculum.

1. Project and Curriculum Context

1.1 PRISTINE VET Context

The PRISTINE VET project addresses the green-energy skills gap in West Africa by strengthening collaboration between VET institutions, industry and public stakeholders, modernising curricula and expanding access to practical and digital learning. The project gives particular attention to green skills, employability, private-sector relevance, gender inclusion and the participation of underrepresented groups.

WP3 - Training Content Development and Learning - aims to modernise renewable-energy VET curricula through updated, industry-aligned content for solar, wind, biomass and hydrogen. The project handbook specifies curriculum design through stakeholder consultations to define modules, competencies and guidelines, followed by development of training materials, digital resources, assessment tools, language adaptation and course testing with trainers and West African VET partners.

1.2 Deliverable Positioning

WP3 output	Purpose	Wind Energy relationship
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WP3 output	Purpose	Wind Energy relationship
D3.1	Curriculum and guidelines on training for Solar, Wind and Biomass Energy Solutions	This document is the Wind Energy component: programme architecture, competencies, delivery and implementation guidelines.
D3.5	Educational material on training for Wind Energy Solutions, in English and French	Detailed course content and educational materials used by trainers and learners to implement this curriculum.
D3.6	Report on organisation of courses on training (trainers) for Wind Energy Solutions	Evidence on trainer-course organisation, testing, feedback and refinement following curriculum/material development.

1.3 Project Requirements Addressed by the Curriculum

Project requirement	Curriculum response
Competency-based, industry-aligned curriculum	Programme outcomes, competency domains, module specifications and workplace-oriented evidence.
At least 10 e-learning courses per specialty	12 Wind modules are structured and sequenced; 43.5 total hours.
Stakeholder-informed curriculum design	Local contextualisation and structured review by VET institutions, companies and authorities are built into implementation and QA.
Practical technical training	Practical tasks, simulations, troubleshooting, O&M, installation/commissioning cases and WBL guidance are embedded.
Digital learning	Hybrid delivery, short digital lectures, diagrams, simulations, quizzes, digital datasets and SCADA-oriented learning are included.
English/French and local accessibility	The curriculum supports adaptation of learning materials into project languages and local languages where needed.
Course testing and feedback	Pilot delivery, trainer/partner feedback, learner feedback and controlled curriculum revision are included in the QA cycle.
Inclusion and gender mainstreaming	Equal-opportunity participation, non-discrimination and gender-sensitive training delivery are specified.
EU visibility and project compliance	Document control, visibility statement, record keeping, data protection and versioning guidance are incorporated.

2. Purpose, Scope and Design Principles

2.1 Purpose

The purpose of this document is to provide a single, coherent curriculum and implementation framework for Wind Energy training under PRISTINE VET. It is intended for VET providers, trainers, technical experts, curriculum managers and project partners responsible for planning, delivering, assessing, quality-assuring and updating Wind Energy training.

2.2 Scope

The curriculum covers foundational and advanced wind-energy knowledge and skills: wind resources and energy conversion; turbine aerodynamics; mechanical and electrical systems; power electronics; control and SCADA; grid connection and power quality; wind-farm planning and resource assessment; installation and commissioning; operation and performance monitoring; maintenance and troubleshooting; safety; environmental considerations; and project-development principles.

This document does not replace the detailed educational materials. Trainers should use the corresponding W1/W2 course materials for the full technical explanations, illustrations, equations, examples and topic-specific teaching content.

2.3 Curriculum Design Principles

Principle	Application
Competency-based	Learning outcomes describe demonstrable knowledge, analysis and practical capability rather than topic exposure alone.
Progressive	Basic modules establish foundations; Advanced modules require integration, analysis, diagnosis, planning and lifecycle thinking.
Industry-aligned	Content is organised around real turbine systems, wind-farm development, operation, maintenance, grid integration and reliability.
Practice-oriented	Theory is connected to calculations, diagrams, data interpretation, simulation, fault scenarios, maintenance and project cases.
Hybrid and digitally enabled	E-learning and digital resources are combined with instructor-led and hands-on learning.
Context-responsive	Examples, cases, equipment choices and implementation arrangements should be adapted to West African energy systems and partner-country priorities.
Inclusive	Training should support equal opportunity, gender mainstreaming and accessible participation.
Safe and responsible	Health, safety, environmental responsibility, data protection and professional conduct are integrated throughout.
Quality-assured	Delivery, assessment and materials are reviewed using participant feedback, trainer review, stakeholder input and controlled version management.

2.4 Local Contextualisation and Standards

The technical core of the curriculum should remain consistent across partner institutions, while implementation should be contextualised to relevant PANER priorities, local/regional/national energy policies, partner-country grid requirements, available turbine technologies, safety rules, VET infrastructure and labour-market needs. Specific national standards or grid-code references should be inserted or updated by the responsible partner/VET provider during local adaptation and stakeholder review rather than assumed centrally.

3. Programme Profile and Structure

3.1 Programme Profile

Programme title	PRISTINE VET Certificate Courses on Wind Energy Solutions - Curriculum and Training Guidelines
Programme structure	12 course modules: 5 Basic + 7 Advanced
Total recommended learning time	43.5 hours
Delivery mode	Hybrid VET: e-learning/classroom theory + practical activities, demonstrations, simulations, case studies and WBL/field exposure where feasible
Target audience	VET college students in West Africa; renewable-energy technicians; energy-sector trainees and technical assistants; engineers seeking wind-energy knowledge; professionals interested in clean-energy technologies

Recommended prerequisites	Basic mathematics; basic electrical/electronic and mechanical concepts; basic physics; familiarity with renewable-energy technologies. These are recommended rather than mandatory.
Trainer profile	Renewable-energy engineers, wind-energy specialists and experienced technical trainers. Advanced modules should involve subject specialists in mechanical systems, electrical/power systems, power electronics, control/SCADA, wind-farm planning and O&M as appropriate.
Programme levels	Basic (W1) and Advanced (W2). These are programme-internal levels; formal qualification/accreditation positioning is to be aligned with WP4 and applicable national frameworks.
Language/accessibility	Master curriculum in English; supporting materials to be available/adapted in English and French and, where needed, local languages in accordance with WP3 arrangements.
Assessment basis	Learning-outcome aligned quizzes, technical exercises, case analyses, system-evaluation mini-tasks, practical assignments and troubleshooting scenarios; 5-10 assessment items per course/module.

3.2 Programme Aims

- Provide learners with a structured understanding of wind energy from resource fundamentals to turbine and wind-farm operation.
- Develop practical and analytical competence in wind-turbine aerodynamic, mechanical, electrical, power-electronic and control systems.
- Prepare learners to interpret operational data, identify faults, support troubleshooting and contribute to safe maintenance activities.
- Develop competence in wind-farm planning, wind-resource assessment, grid connection, environmental considerations and project lifecycle thinking.
- Connect theory with real technical practice through simulations, case studies, practical assignments and work-based learning opportunities.
- Support industry-relevant green skills and employment pathways within West African renewable-energy systems.
- Provide a consistent curriculum basis for trainer development, course testing, certification alignment and future curriculum updating.

3.3 Programme Structure and Recommended Sequence

Code	Course / Module	Level	Duration
W1-01	History of and Introduction to Wind Energy	Basic	3.0 h
W1-02	Basic Aerodynamic Rules in Wind Energy Conversion and Plant Design	Basic	4.0 h
W1-03	Mechanical Structure and Mechanisms in Wind Turbines - Part I	Basic	4.0 h
W1-04	Electrical Structure in Wind Turbines - Part I	Basic	3.5 h
W1-05	Power Electronics in Wind Energy Generation	Basic	2.5 h
W2-01	Introduction to Advanced Mechanisms within Wind Turbines	Advanced	3.0 h
W2-02	Mechanical Structure and Mechanisms in Wind Turbines - Part II	Advanced	3.0 h
W2-03	Electrical Structure in Wind Turbines - Part II	Advanced	4.0 h
W2-04	Controlling Mechanisms and Their Rules in Wind Turbines	Advanced	3.0 h
W2-05	Power Electronics Technologies in Wind Turbines - Advanced	Advanced	3.5 h
W2-06	Wind Energy Generation Plants Planning and Allocation	Advanced	5.0 h
W2-07	Plants and Turbines Maintenance Schedule	Advanced	5.0 h

Basic level total: 17.0 hours. **Advanced level total:** 26.5 hours. **Programme total:** 43.5 hours.

3.4 Basic-to-Advanced Progression

Domain	Basic expectation	Advanced expectation
Wind resource and context	Recognise wind properties, applications and energy-transition role.	Interpret resource, site, project and lifecycle implications.
Aerodynamics	Explain wind power, lift/drag, turbine types and blade performance.	Apply aerodynamic understanding to operating regions, control, planning and system performance.
Mechanical systems	Identify turbine structures, drivetrain components and load paths.	Analyse torque/speed transfer, gearboxes, couplings, actuators, faults and maintenance.
Electrical systems	Explain generation, generator types, transformers, cables and protection.	Analyse faults, power quality, protection, FRT/LVRT, diagnostics and reliability.
Power electronics	Understand conversion, components and basic control.	Analyse converter topologies, modulation, active/reactive power, losses, thermal management and grid support.
Control / SCADA	Understand basic system interaction and control context.	Analyse closed-loop control, pitch/yaw/torque control, SCADA, alarms, coordinated control and fail-safe operation.
Projects / O&M	Introduction through component and energy-system context.	Plan sites and wind farms; understand installation/commissioning; interpret KPIs; plan maintenance and troubleshooting.

4. Programme Learning Outcomes and Competency Framework

4.1 Programme Learning Outcomes

Code	Programme learning outcome
PLO1	Explain the historical, environmental and energy-system role of wind power and describe key wind-resource characteristics.
PLO2	Apply foundational aerodynamic concepts and wind-power relationships to explain turbine performance, operating limits and design trade-offs.
PLO3	Identify and explain wind-turbine mechanical structures, drivetrain components, load paths, braking, yaw and actuator mechanisms.
PLO4	Explain electrical energy conversion, generator configurations, electrical infrastructure, protection and power-electronic interfaces.
PLO5	Analyse wind-turbine control, sensing, SCADA, power-electronic control, grid connection and power-quality requirements.
PLO6	Recognise and analyse common mechanical, electrical, control and converter faults and select appropriate monitoring or troubleshooting approaches.
PLO7	Interpret basic wind-resource, site, layout, grid, environmental and economic information for wind-farm planning and feasibility.
PLO8	Describe and support key installation, commissioning, operating and performance-monitoring activities in wind energy systems.

Code	Programme learning outcome
PLO9	Differentiate preventive, corrective and predictive maintenance approaches and contribute to maintenance planning and lifecycle reliability.
PLO10	Apply appropriate health, safety, environmental and risk-control principles to training and wind-energy technical activities.
PLO11	Use technical diagrams, simulations, datasets, monitoring information and digital learning tools to solve structured wind-energy problems.
PLO12	Communicate technical findings, work collaboratively and demonstrate professional responsibility in VET and industry-oriented learning contexts.

4.2 Competency Domains

Code	Competency domain	Scope
C1	Wind resource, energy fundamentals and sector context	Wind formation and characteristics, wind-energy role, resource interpretation, onshore/offshore context.
C2	Aerodynamics and turbine performance	Energy conversion, lift/drag, power coefficient, turbine types, operating regions, blade and wake effects.
C3	Mechanical systems and drivetrain	Rotor, nacelle, tower, shafts, bearings, gearboxes, couplings, braking, yaw/pitch mechanisms and structural loads.
C4	Electrical systems and power electronics	Generators, conversion, transformers, cables, switchgear, protection, converter components and topologies.
C5	Control, SCADA, grid integration and power quality	Sensors, controllers, actuators, pitch/yaw/torque control, SCADA, synchronization, power quality and grid support.
C6	Wind-farm planning, installation and commissioning	WRA, site selection, microsites, grid connection, permitting, project lifecycle, installation and commissioning.
C7	Operation, maintenance, diagnostics and performance	Operating modes, KPIs, condition monitoring, maintenance strategies, faults, troubleshooting and lifecycle reliability.
C8	Safety, sustainability and professional practice	PPE, LOTO, work at height, electrical/rotating equipment safety, environmental/social considerations, inclusion and professional conduct.

4.3 Module-to-Competency Mapping

Module	Primary competency domains	Emphasis
W1-01	C1, C8	Foundational sector/resource understanding and sustainability context
W1-02	C1, C2	Aerodynamic fundamentals, performance and design
W1-03	C2, C3, C8	Mechanical structure, load paths and safe design
W1-04	C4, C5, C8	Electrical conversion, protection and grid-aware design
W1-05	C4, C5	Power conversion and basic control/interface concepts
W2-01	C2-C7	Integrated systems thinking across turbine and wind-farm lifecycle
W2-02	C3, C7, C8	Advanced drivetrain, actuators, reliability and maintenance
W2-03	C4, C5, C7, C8	Electrical faults, power quality, grid compliance and diagnostics
W2-04	C5, C7, C8	Control, SCADA, coordinated operation and fail-safe response

Module	Primary competency domains	Emphasis
W2-05	C4, C5, C7	Advanced converters, control, grid support, losses and reliability
W2-06	C1, C6, C8	Resource/site assessment, project planning, grid and environmental integration
W2-07	C3-C8	Installation, commissioning, operation, maintenance, troubleshooting, safety and performance

5. Detailed Course Outlines and Module Specifications

The following 12 course outlines define the learning outcomes, teaching sequence, applied activities, assessment approach and progression for each Wind Energy module. The outlines provide the curriculum-level roadmap for delivery; the detailed course materials provide the full technical teaching content.

5.1 W1-01 - History of and Introduction to Wind Energy

Course code	W1-01
Level	Basic
Recommended duration	3.0 hours
Course description	Establish a common foundation in the evolution, resource characteristics, applications and strategic role of wind energy before learners progress to turbine engineering topics.

Learning Outcomes

- Describe the historical development of wind energy from traditional windmills to modern utility-scale turbines.
- Explain how atmospheric motion creates wind as a usable energy resource.
- Identify wind speed, direction, variability and air density and explain their effect on energy production.
- Distinguish onshore and offshore wind applications and their roles in electricity systems.
- Analyse major wind-energy trends and recognise current technical, environmental and economic challenges.
- Evaluate the contribution of wind energy to decarbonisation, energy security and sustainable power systems.

Detailed Course Outline

Topic	Main topics and subtopics
1. Historical development of wind energy	Traditional uses of wind; transition from mechanical windmills to electricity-generating turbines; major technology milestones and growth of modern wind power.
2. Wind as an energy resource	Atmospheric motion and kinetic energy; wind speed, direction, variability and air density; implications for energy production and siting.
3. Wind energy in modern power systems	Electricity-generation role; centralised and decentralised applications; onshore and offshore wind systems.
4. Wind energy and the clean-energy transition	Decarbonisation, energy security, renewable electricity access, benefits and limitations of wind power.
5. Challenges and future opportunities	Intermittency, site selection, grid integration, environmental and economic considerations; technology innovation, digital monitoring and future development opportunities.

Recommended Practical / Simulation Activities

- Interpret a simple wind-property dataset and discuss implications for energy production.
- Compare an onshore and an offshore wind application using a short case-study template.
- Map technical, environmental and economic opportunities/challenges for a West African wind application.

Assessment Approach

Knowledge quiz plus a short case-study or structured comparison task.

Progression and Linkage

Provides context and resource concepts required for W1-02 and later wind-farm planning in W2-06.

5.2 W1-02 - Basic Aerodynamic Rules in Wind Energy Conversion and Plant Design

Course code	W1-02
Level	Basic
Recommended duration	4.0 hours
Course description	Develop the aerodynamic understanding needed to explain how wind turbines capture energy, how blades and operating conditions affect performance, and why turbine and wind-farm design must manage aerodynamic trade-offs.

Learning Outcomes

- Explain the aerodynamic principles behind wind-energy conversion.
- Apply the fundamental wind-power relationship and interpret the influence of air density, swept area and wind speed.
- Explain lift, drag, airfoil behaviour, angle of attack, stall, tip-speed ratio and power coefficient.
- Analyse how aerodynamics influences blade, rotor and turbine design and operating limits.
- Compare major turbine types and recognise wake, terrain and spacing effects.
- Identify trade-offs between aerodynamic efficiency, structural loading, durability and safe operation.

Detailed Course Outline

Topic	Main topics and subtopics
1. Introduction to wind aerodynamics	Role of aerodynamics in the wind-energy conversion chain; wind-to-rotor-to-generator pathway; horizontal-axis, vertical-axis and small-wind turbine concepts.
2. Wind-energy conversion principles	Kinetic energy in wind; fundamental wind-power relationship; air density, swept area and wind speed; power coefficient; Betz limit; turbine power curve and operating regions.
3. Fundamental aerodynamic forces	Lift and drag; airfoil shape and pressure distribution; angle of attack; stall behaviour and relevance to turbine operation.
4. Rotor aerodynamics	Blade design and geometry; tip-speed ratio; rotor swept area; relationship between TSR, energy capture and turbine efficiency.
5. Aerodynamic control mechanisms	Pitch control; stall and active-stall concepts; yaw control and wind alignment; influence on safe and efficient operation.
6. Aerodynamics and structural design interaction	Aerodynamic loading on blades and tower; fatigue and extreme loads; trade-offs between efficiency, structural integrity, durability and safety.
7. Wind-farm aerodynamics	Wake effects and energy losses; turbine spacing; terrain and atmospheric influences on plant performance.
8. Design optimisation and efficiency	Maximising energy capture; reducing aerodynamic and mechanical losses; introductory simulation and CFD concepts for design evaluation.

Recommended Practical / Simulation Activities

- Calculate and compare available wind power at different wind speeds using the course equations.
- Interpret a turbine power curve and identify cut-in, rated and cut-out operating regions.
- Use a simplified layout exercise to discuss wake and spacing effects.

Assessment Approach

Quiz plus a technical calculation/interpretation exercise and short design trade-off task.

Progression and Linkage

Supports mechanical understanding in W1-03 and advanced control, planning and performance analysis in W2 modules.

5.3 W1-03 - Mechanical Structure and Mechanisms in Wind Turbines - Part I

Course code	W1-03
Level	Basic
Recommended duration	4.0 hours
Course description	Introduce the physical structure of a wind turbine and explain how mechanical components support energy capture, torque transfer, load management, safe operation and long-term reliability.

Learning Outcomes

- Identify the rotor, nacelle, drivetrain, tower, hub, shaft, bearings, gearbox, braking system and yaw system.
- Explain the function of major mechanical subsystems and their interaction with aerodynamic and electrical systems.
- Describe the mechanical layout of a horizontal-axis wind turbine from rotor to generator interface.
- Trace mechanical and structural loads from blades and hub through drivetrain, nacelle, tower and foundation.
- Recognise design considerations including strength, fatigue, vibration, corrosion protection, safety, reliability and maintenance access.

Detailed Course Outline

Topic	Main topics and subtopics
1. Introduction to turbine mechanical systems	Overall wind-turbine structure; interaction between aerodynamic, mechanical and electrical systems; importance of mechanical design to performance and reliability.
2. Main structural sections	Rotor, nacelle, tower and foundation interface; structural support functions and system arrangement.
3. Rotor components	Blades, hub and nose cone/spinner; mechanical roles, blade connection and load-transfer functions.
4. Drivetrain components	Main shaft, bearings, gearbox and couplings; transmission of rotor torque, speed conversion, friction reduction and mechanical connection.
5. Braking and safety-related mechanisms	Mechanical brake, rotor-locking systems and emergency stopping concepts.
6. Yaw and orientation mechanisms	Yaw-system purpose; yaw bearing, drives and motors; turbine alignment with wind direction.
7. Nacelle and support structure	Nacelle frame/bedplate; mounting of drivetrain components; load distribution and structural rigidity.
8. Tower as a mechanical structure	Tower purpose and types; support of nacelle/rotor assembly; principal mechanical loads on the tower.
9. Mechanical load path	Load transfer from blades to hub, shaft and bearings; nacelle-to-tower and tower-to-foundation pathways.
10. Mechanical design considerations	Static and dynamic loads; fatigue, vibration and corrosion; reliability, maintenance access, safety and operational durability.

Recommended Practical / Simulation Activities

- Label a turbine cutaway/component diagram and explain the function of each part.
- Trace an aerodynamic load path from blade to foundation.
- Review a simple mechanical-fault scenario and identify affected components and inspection points.

Assessment Approach

Component-identification quiz plus a load-path/system explanation task and practical diagram exercise.

Progression and Linkage

Provides the foundation for advanced drivetrain, gearbox, coupling and actuator analysis in W2-02.

5.4 W1-04 - Electrical Structure in Wind Turbines - Part I

Course code	W1-04
Level	Basic
Recommended duration	3.5 hours
Course description	Build foundational competence in electrical energy conversion, generator configurations and the electrical infrastructure that connects a wind turbine to a grid or local load.

Learning Outcomes

- Identify generators, converters, transformers, cables, switchgear, protection systems and control units.
- Explain electromagnetic induction and the conversion of mechanical rotation into electrical energy.
- Distinguish synchronous, induction/asynchronous, DFIG and permanent-magnet generator configurations.
- Trace electrical energy flow from generator to grid-compatible output.
- Explain the importance of voltage, current, frequency, power electronics, protection, insulation, cooling and reliability.

Detailed Course Outline

Topic	Main topics and subtopics
1. Introduction to wind-turbine electrical systems	Electrical subsystem architecture; interaction with mechanical and control systems; role of electrical design in energy production.
2. Fundamentals of electricity generation	Electromagnetism, magnetic flux and Faraday induction; conversion of mechanical rotation into electrical energy.
3. Wind-turbine generators	Induction/asynchronous and synchronous generators; speed, torque and efficiency characteristics.
4. Common generator configurations	DFIG and PMSG systems; geared and direct-drive configurations; advantages and limitations.
5. Electrical power characteristics	Voltage, current and frequency; AC/DC concepts; basic synchronization and grid-compatibility requirements.
6. Power-conversion basics	Need for converters and inverters; role of power electronics in variable-speed turbine operation.
7. Electrical infrastructure and protection	Transformers, cables, switchgear and grounding; overcurrent and fault-protection concepts; generator-to-grid energy pathway.
8. Cooling and insulation	Thermal management of generators and converters; insulation requirements; effect on reliability and service life.
9. Fixed-speed and variable-speed operation	Operational differences; impact on energy capture, electrical output and grid compatibility.

Recommended Practical / Simulation Activities

- Trace the electrical energy pathway on a wind-turbine block diagram.
- Compare generator configurations against a small set of operating criteria.
- Work through a basic protection/overcurrent or grounding scenario.

Assessment Approach

Quiz plus generator-comparison and electrical-path/protection exercises.

Progression and Linkage

Provides the electrical foundation for W1-05 and advanced electrical faults/grid integration in W2-03.

5.5 W1-05 - Power Electronics in Wind Energy Generation

Course code	W1-05
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Level	Basic
Recommended duration	2.5 hours
Course description	Introduce the power-electronic devices and conversion stages that enable controllable, variable-speed wind-energy conversion and grid-compatible electrical output.

Learning Outcomes

- Explain the role of power electronics in energy conversion, power control and grid connection.
- Identify rectifiers, inverters, converters, switching devices and DC-link components and explain their functions.
- Describe AC-DC-AC conversion and the energy-flow interface between generator and grid.
- Explain basic switching/modulation, voltage-control and frequency-control concepts.
- Recognise common wind-turbine architectures that use partial or full power-electronic interfaces.

Detailed Course Outline

Topic	Main topics and subtopics
1. Introduction to power electronics in wind energy	Definition and role of power electronics; why electronic conversion is essential for modern variable-speed turbines and grid connection.
2. Basic electrical energy conversion	AC and DC fundamentals; AC-to-DC rectification; DC-to-AC inversion; generator-to-grid energy flow.
3. Key power-electronic components	Diodes, rectifiers, inverters, switching devices, power converters and DC-link capacitors/inductors.
4. Power-conversion architectures in wind turbines	Generator-grid interface; fixed- versus variable-speed context; introductory DFIG and full-converter systems.
5. Basic control concepts	Switching principles; introductory PWM; conceptual voltage and frequency control.
6. Practical role in turbine operation	Power regulation, grid compatibility, efficiency and performance improvement.
7. Introduction to advanced concepts	Losses and efficiency; cooling and thermal considerations; basic grid-support functions, smart converters and future trends.

Recommended Practical / Simulation Activities

- Build or annotate an AC-DC-AC conversion block diagram.
- Match power-electronic components to their functions and typical failure/thermal concerns.
- Compare basic turbine electrical architectures using a structured worksheet.

Assessment Approach

Knowledge quiz plus block-diagram and component-function exercises.

Progression and Linkage

Prepares learners for converter topologies, advanced modulation, grid support and reliability in W2-05.

5.6 W2-01 - Introduction to Advanced Mechanisms within Wind Turbines

Course code	W2-01
Level	Advanced
Recommended duration	3.0 hours
Course description	Transition learners from component-level knowledge to an integrated system view of the turbine and wind-farm lifecycle, establishing the roadmap for Advanced modules.

Learning Outcomes

- Explain why advanced wind-turbine study requires integration of mechanical, electrical, control and power-electronic systems.
- Describe how performance, safety, reliability, planning and maintenance interact across the turbine lifecycle.
- Connect advanced mechanical, electrical, control, power-electronic, planning and maintenance sessions into a coherent energy and asset-management pathway.
- Recognise how faults or weaknesses in one subsystem can affect overall turbine performance.
- Explain the progression from component mechanisms to system-level performance and wind-farm operation.

Detailed Course Outline

Topic	Main topics and subtopics
1. Introduction to the Advanced Wind programme	Integrated view of modern wind turbines as mechanical, electrical, control and power-electronic systems operating within a wind-farm lifecycle.
2. Why advanced mechanisms matter	Changing wind and load conditions; torque transfer, vibration, alignment, electrical disturbances, grid requirements, protection, safety and reliability.
3. Advanced mechanical pathway	Roadmap to drivetrain, gearbox, couplings, pitch/yaw mechanisms, actuators, lubrication, cooling, vibration and mechanical failures in W2-02.
4. Electrical, control and power-electronic pathway	Roadmap to electrical faults and grid integration in W2-03; control/SCADA in W2-04; advanced converters and grid support in W2-05.
5. Wind-farm planning and lifecycle pathway	Roadmap to site/resource assessment, layout and project development in W2-06; operation, maintenance, diagnostics and lifecycle reliability in W2-07.
6. Connection between sessions and learning approach	Energy-path and lifecycle progression; subsystem interactions; fault propagation; practical engineering reasoning focused on safety, efficiency, reliability and grid-compatible operation.

Recommended Practical / Simulation Activities

- Create a system map linking aerodynamic, mechanical, electrical, control and grid subsystems.
- Analyse a short cross-system fault-propagation case.
- Develop a learner roadmap showing how the Advanced modules connect from turbine internals to wind-farm lifecycle.

Assessment Approach

Short systems-integration quiz plus an integrated-system mapping or case-analysis task.

Progression and Linkage

Acts as the bridge into W2-02 to W2-07 and should be completed before the specialist Advanced modules.

5.7 W2-02 - Mechanical Structure and Mechanisms in Wind Turbines - Part II

Course code	W2-02
Level	Advanced
Recommended duration	3.0 hours
Course description	Deepen mechanical competence through analysis of torque/speed transfer, gearbox systems, couplings, pitch/yaw actuation, reliability, condition monitoring and maintenance.

Learning Outcomes

- Explain advanced drivetrain operation including torque transfer and speed conversion.
- Describe gearbox configurations, gear ratios, lubrication, cooling and common failure mechanisms.
- Explain how couplings support alignment, vibration control and torque transmission.
- Describe electric and hydraulic pitch/yaw actuator mechanisms and their control/safety roles.
- Analyse common faults and maintenance needs in gearboxes, bearings, couplings and actuators.

- Relate condition monitoring and predictive maintenance to drivetrain reliability and lifecycle performance.

Detailed Course Outline

Topic	Main topics and subtopics
1. Advanced drivetrain overview	Recap of drivetrain components; torque and speed transformation; mechanical energy flow through the nacelle and generator interface.
2. Gearbox systems	Purpose of gearboxes; planetary/epicyclic, parallel-shaft and hybrid configurations; gear ratios and speed conversion.
3. Gearbox reliability and support systems	Gear wear, pitting and bearing failures; lubrication and cooling; reliability and alternative drivetrain considerations.
4. Mechanical couplings	Rigid, flexible and torsional couplings; torque transmission, misalignment compensation, vibration damping and selection criteria.
5. Pitch-control mechanisms	Pitch bearings and electric/hydraulic pitch drives; active/passive concepts; power regulation and safety functions.
6. Yaw actuation systems	Yaw motors and drives; yaw brakes and locking; alignment optimisation and load management.
7. Actuator technologies	Hydraulic and electric actuators; working principles, strengths, limitations and roles in turbine control and safety.
8. Mechanical-control system integration	Sensors and feedback; automation and real-time adjustment; interaction between mechanical mechanisms and turbine control.
9. Reliability, maintenance and design trade-offs	Condition monitoring using vibration and oil analysis; preventive/predictive maintenance; efficiency-reliability, weight-strength, cost-performance and maintainability trade-offs.

Recommended Practical / Simulation Activities

- Work through a conceptual gearbox ratio/speed transformation exercise.
- Interpret a drivetrain fault scenario using vibration/lubrication symptoms.
- Compare hydraulic and electric actuator options for pitch/yaw functions.

Assessment Approach

Technical exercise plus fault-diagnosis/maintenance case and targeted quiz.

Progression and Linkage

Supports advanced control in W2-04 and maintenance/troubleshooting in W2-07.

5.8 W2-03 - Electrical Structure in Wind Turbines - Part II

Course code	W2-03
Level	Advanced
Recommended duration	4.0 hours
Course description	Develop competence in real operating electrical problems, power quality, protection, grid compliance, monitoring and reliability of modern wind turbines.

Learning Outcomes

- Analyse common generator, converter, cable, transformer and protection-system faults.
- Evaluate harmonics, flicker, voltage fluctuations, frequency variation and their impact on equipment and grids.
- Explain advanced solutions using converters, reactive-power control, voltage regulation and harmonic filtering.
- Explain synchronization, grid-code requirements, FRT and LVRT concepts.
- Use monitoring, SCADA and diagnostic information to support fault detection and maintenance planning.
- Evaluate protection and reliability strategies for wind-turbine electrical systems.

Detailed Course Outline

Topic	Main topics and subtopics
1. Advanced electrical-system architecture	Recap of electrical architecture; increasing system complexity; role of advanced control and monitoring.
2. Common electrical problems	Generator overheating, insulation degradation and bearing currents; converter component failures; cable and connection faults; thermal and grid-related stress.
3. Power-quality challenges	Voltage fluctuations, flicker, harmonics, frequency variation and impacts on equipment and the grid.
4. Power-electronic and control solutions	Full-scale and back-to-back converter concepts; voltage/frequency regulation; reactive-power compensation; harmonic filtering.
5. Grid integration and compliance	Grid requirements; synchronization; fault ride-through and low-voltage ride-through concepts; support for stable grid interaction.
6. Electrical protection systems	Overcurrent, short-circuit and ground-fault protection; surge/lightning protection; relay coordination and circuit-breaker functions.
7. Monitoring and diagnostics	SCADA, sensors and measurement systems; thermal monitoring; electrical-signal analysis; alarms and condition monitoring.
8. Maintenance and reliability strategies	Preventive and predictive maintenance; electrical troubleshooting; component replacement and lifecycle management.
9. Practical fault cases	Real-world electrical failure scenarios; root-cause analysis; engineering solutions and lessons learned.

Recommended Practical / Simulation Activities

- Interpret an electrical-fault or alarm scenario and identify likely causes and checks.
- Evaluate a power-quality case and select an appropriate mitigation approach.
- Develop a simple protection/monitoring response sequence for an abnormal condition.

Assessment Approach

Case-based electrical diagnosis, power-quality/grid exercise and quiz.

Progression and Linkage

Feeds directly into W2-04 control/SCADA, W2-05 advanced power electronics and W2-07 O&M.

5.9 W2-04 - Controlling Mechanisms and Their Rules in Wind Turbines

Course code	W2-04
Level	Advanced
Recommended duration	3.0 hours
Course description	Develop system-level understanding of turbine control, sensing, actuation, operating regions, SCADA, coordinated wind-farm control, reliability and fail-safe protection.

Learning Outcomes

- Explain open-loop and closed-loop control, feedback mechanisms and control objectives.
- Identify sensors, controllers, actuators and communication networks used in turbine control.
- Analyse pitch, yaw, torque and speed-control strategies and their effect on energy capture and loads.
- Explain turbine control across cut-in, below-rated, rated and cut-out operating regions.
- Explain SCADA architecture, monitoring, alarms, data acquisition and remote operation.
- Evaluate coordinated control in wind farms/microgrids and grid-support functions.
- Assess common sensor, communication, actuator and control failures and appropriate diagnostic/fail-safe responses.

Detailed Course Outline

Topic	Main topics and subtopics
1. Control-system fundamentals	Purpose of turbine control; open-loop and closed-loop architectures; feedback and basic stability concepts.
2. Control-system components	Anemometers, wind vanes and condition sensors; PLCs/embedded controllers; pitch/yaw actuators and communication systems.
3. Turbine operating regions	Cut-in, below-rated, rated and cut-out regions; power-curve interpretation; start-up and shutdown behaviour.
4. Turbine control strategies	Pitch, passive/active stall and yaw control; generator torque and speed control; MPPT context; power regulation and load reduction.
5. SCADA and monitoring	SCADA architecture; data acquisition; alarms and fault reporting; remote operation and diagnostics.
6. Wind-farm and microgrid control	Coordinated turbine control; power smoothing and load balancing; microgrid/hybrid integration; frequency and voltage support.
7. Fault detection and troubleshooting	Sensor and communication faults; actuator/control-system malfunctions; diagnostic approaches and safe fault response.
8. Safety and protection through control	Emergency shutdown, overspeed protection, redundancy and fail-safe operation.
9. Advanced control concepts - overview	Adaptive and predictive control; digital/smart control; introductory role of AI and data analytics in turbine control.

Recommended Practical / Simulation Activities

- Draw and explain a closed-loop turbine control pathway.
- Interpret a simplified SCADA alarm/event sequence.
- Analyse a pitch/yaw/sensor failure case and propose a safe response.

Assessment Approach

Control-system diagram exercise, SCADA/fault case and knowledge quiz.

Progression and Linkage

Integrates with W2-05 grid/converter control and W2-07 operational monitoring and troubleshooting.

5.10 W2-05 - Power Electronics Technologies in Wind Turbines - Advanced

Course code	W2-05
Level	Advanced
Recommended duration	3.5 hours
Course description	Advance learner competence in modern converter devices, topologies, control methods, grid support, losses, thermal management, protection and emerging power-electronic technologies.

Learning Outcomes

- Explain how advanced power electronics enable variable-speed operation, energy conversion and grid integration.
- Identify semiconductor devices, rectifiers, inverters, DC-link and filtering elements and describe their functions.
- Analyse back-to-back converter structures, partial-scale DFIG converters and full-scale converter systems.
- Explain PWM/vector-control concepts and active/reactive power, voltage and frequency regulation.
- Evaluate synchronization, harmonics/flicker, power factor, voltage support and FRT functions.
- Assess switching/conduction losses, thermal stress, cooling and converter-protection requirements.
- Recognise emerging technologies including multilevel converters and wide-bandgap semiconductor devices.

Detailed Course Outline

Topic	Main topics and subtopics
1. Advanced power electronics in wind energy	Role of power electronics in modern turbines; evolution from fixed-speed to variable-speed operation and flexible grid interfacing.
2. Power-electronic fundamentals and devices	AC/DC and DC/AC conversion; switching principles; diodes, IGBTs, MOSFETs, capacitors and inductors.
3. Converter topologies	Rectifiers and inverters; back-to-back converters; generator-side and grid-side stages; full-scale PMSG and partial-scale DFIG configurations.
4. DC-link and energy-conversion chain	DC-link function; energy-flow control; voltage stabilisation and filtering.
5. Converter control techniques	PWM and space-vector/vector-control concepts; active and reactive power control; frequency and voltage regulation.
6. Grid integration and power quality	Grid synchronization; harmonic generation and mitigation; flicker; power factor; voltage support and fault-ride-through/grid-support functions.
7. Losses and thermal management	Conduction and switching losses; efficiency optimisation; air and liquid cooling approaches.
8. Reliability and protection	Common converter failure modes; overvoltage, overcurrent and thermal protection; fault detection and mitigation.
9. Advanced and emerging technologies	Multilevel converters; wide-bandgap devices such as SiC and GaN; smart/digital converters and energy-storage integration.
10. Industry applications and cases	Comparison of turbine converter architectures and technology choices; field-performance lessons and engineering trade-offs.

Recommended Practical / Simulation Activities

- Compare partial-scale DFIG and full-scale PMSG converter pathways.
- Trace control objectives across generator-side and grid-side converter stages.
- Analyse a simplified converter thermal/loss or protection scenario.

Assessment Approach

Converter-topology comparison, control/grid case and technical quiz.

Progression and Linkage

Supports advanced grid integration, electrical troubleshooting and lifecycle performance in W2-06 and W2-07.

5.11 W2-06 - Wind Energy Generation Plants Planning and Allocation

Course code	W2-06
Level	Advanced
Recommended duration	5.0 hours
Course description	Expand learning from turbine technology to wind-farm development, combining resource assessment, site selection, layout, grid connection, environmental/regulatory requirements, economics and project lifecycle decisions.

Learning Outcomes

- Describe the wind-farm development lifecycle from site identification through construction, commissioning and operation.
- Explain wind-resource assessment, exclusionary screening and preliminary site evaluation.
- Analyse technical and economic feasibility using wind data, energy-yield considerations, wake effects, site constraints and project viability.
- Evaluate topography, turbine technology, land use, logistics, grid connection and layout considerations.

- Explain the role of environmental screening, permitting, land rights and regulatory compliance.
- Apply basic project-planning principles involving engineering, financing, risk and stakeholder coordination.
- Identify common technical, environmental, economic and administrative challenges and possible mitigation approaches.

Detailed Course Outline

Topic	Main topics and subtopics
1. Wind-farm development lifecycle	Site identification, preliminary screening, feasibility, design/permitting/financing, procurement, construction, commissioning and operation.
2. Wind-resource assessment	Anemometers and met masts; LiDAR/SoDAR and remote sensing; wind-speed distributions, Weibull concepts, wind roses and long-term assessment.
3. Site-selection criteria	Wind availability and consistency; terrain and topography; land use, access and logistics; environmental and social constraints.
4. Wind-farm layout and micro-siting	Turbine placement; spacing and alignment; wake effects and losses; layout optimisation and software-tool concepts.
5. Electrical infrastructure and grid connection	Collection systems, substations and transformers; transmission lines; grid connection points and interconnection requirements.
6. Grid constraints and system integration	Grid capacity and congestion; voltage/frequency stability; intermittency and variability; curtailment and dispatch limitations.
7. Industrial and decentralised applications	Direct industrial use; PPAs; wind-plus-storage/renewable hybrid systems; off-grid and captive-power applications.
8. Economic considerations	CAPEX, OPEX and LCOE concepts; project viability; financing and policy-support considerations.
9. Environmental and regulatory aspects	Environmental impact screening/assessment; noise, visual and ecological effects; land and permitting/compliance considerations.
10. Planning cases, stakeholders and risk	Wind-farm planning case; stakeholder coordination; project risks, mitigation measures and lessons from practical applications.

Recommended Practical / Simulation Activities

- Complete a structured site-screening and feasibility case.
- Interpret a sample wind rose or simplified Weibull/resource dataset.
- Develop a basic micro-siting/layout rationale considering wakes, access and grid connection.
- Map the project lifecycle and identify approval, stakeholder and risk-control points.

Assessment Approach

Resource/site interpretation exercise plus a wind-farm planning case and short technical quiz.

Progression and Linkage

Prepares learners to connect technical design decisions with implementation, commissioning and lifecycle O&M in W2-07.

5.12 W2-07 - Plants and Turbines Maintenance Schedule

Course code	W2-07
Level	Advanced
Recommended duration	5.0 hours
Course description	Integrate installation, commissioning, operation, performance monitoring, maintenance, troubleshooting, safety and lifecycle reliability into a practical O&M framework.

Learning Outcomes

- Describe key turbine installation and commissioning steps and associated safety controls.
- Explain turbine operating modes and use of SCADA for operational monitoring.
- Interpret core performance indicators including power output, availability and capacity factor.
- Differentiate preventive, corrective and predictive maintenance and develop a basic maintenance schedule.
- Recognise mechanical, electrical and control-system maintenance needs and common fault symptoms.
- Apply a systematic troubleshooting approach using monitoring data and diagnostic tools.
- Apply appropriate work-at-height, electrical, LOTO, emergency and PPE principles.
- Explain how maintenance strategy affects AEP, availability, reliability, downtime and lifecycle cost.

Detailed Course Outline

Topic	Main topics and subtopics
1. Introduction to wind-turbine O&M	Role of O&M in performance, reliability and cost; effect on availability, annual energy production and lifecycle value.
2. Installation and commissioning basics	Site/foundation preparation; tower erection; nacelle and rotor installation; system checks, testing and commissioning.
3. Operation and monitoring	Turbine operating modes; SCADA monitoring and control; key performance indicators including power output, availability and capacity factor.
4. Maintenance strategies	Preventive/scheduled maintenance; corrective repair and component replacement; predictive/condition-based maintenance.
5. Mechanical maintenance	Gearbox inspection and lubrication; bearing monitoring; blade inspection; yaw and pitch system maintenance.
6. Electrical maintenance	Generator inspection/testing; converter and power-electronics checks; cable/connection inspection; transformer and switchgear maintenance.
7. Troubleshooting techniques	Systematic fault diagnosis; mechanical vibration, electrical and control faults; use of diagnostic tools, monitoring data and software.
8. Safety procedures in O&M	Working-at-height safety; electrical safety and lockout/tagout; emergency procedures; PPE and supervised safe work.
9. Reliability and lifecycle management	Failure modes and root-cause analysis; reliability-centred maintenance; spare-parts management and downtime reduction.
10. Practical cases and field applications	Real maintenance scenarios; troubleshooting exercises; safe decision-making and industry best-practice examples.

Recommended Practical / Simulation Activities

- Build a simplified preventive maintenance schedule for a turbine subsystem.
- Interpret a SCADA/KPI snapshot and identify operational concerns.
- Use a troubleshooting decision tree for a mechanical, electrical or control fault.
- Conduct a classroom safety/JSA and LOTO sequence exercise before any practical maintenance activity.

Assessment Approach

O&M case, maintenance-schedule task, troubleshooting scenario and safety knowledge check.

Progression and Linkage

Capstone-style module integrating knowledge from mechanical, electrical, control, power-electronic and planning modules.

6. Teaching, Learning and Practical Training Guidelines

6.1 Delivery Model

The programme uses a hybrid VET approach that combines e-learning for theoretical concepts with instructor-led explanation and supervised practical learning. It also supports dual-learning elements through internships and on-the-job training where feasible. Delivery should move learners between concept, demonstration, guided practice, application, feedback and reflection.

Learning mode	Purpose	Examples
E-learning / digital theory	Introduce concepts efficiently and provide flexible access.	Short video lectures, technical illustrations, interactive diagrams, readings, quizzes and recorded demonstrations.
Instructor-led learning	Clarify difficult technical concepts and connect modules.	Worked examples, guided discussion, system diagrams, calculations, safety briefings and debriefs.
Simulation / data activity	Practise interpretation and decision-making without exposure to unnecessary risk.	Power curves, wind datasets, simple CFD concepts, converter/control diagrams, SCADA/alarm datasets and maintenance scenarios.
Workshop / practical demonstration	Develop component recognition, safe procedures and practical reasoning.	Turbine component models, electrical/mechanical demonstrations, test instruments, diagnostic exercises and maintenance planning.
Case-based learning	Connect engineering with real project and operational decisions.	West African energy-system cases, site selection, grid constraints, faults, O&M, environmental and economic trade-offs.
WBL / field exposure	Reinforce workplace context and professional practice.	Supervised visits, internships, on-the-job observation, industry mentoring and project-based assignments where available.

6.2 Recommended Session Pattern

Stage	Guideline
1. Orientation	State learning outcomes, relevance, safety expectations and links to prior modules.
2. Concept input	Use concise lecture/e-learning material, diagrams and worked examples.
3. Guided application	Learners complete calculations, system tracing, interpretation or decision tasks.
4. Practical/case activity	Apply concepts through simulation, component work, fault scenario, dataset or project case.
5. Assessment and feedback	Use 5-10 aligned assessment items plus practical evidence where appropriate.
6. Reflection and transfer	Summarise the competence gained and link it to the next module or workplace task.

6.3 Practical Training Principles

- Practical activity must be directly linked to stated learning outcomes and should produce observable evidence of competence.
- High-risk tasks should first be taught through diagrams, mock-ups, simulation or supervised demonstration before any live equipment exposure.
- Where full-scale wind-turbine facilities are unavailable, use component models, cutaways, training rigs, digital twins/simulations, sample SCADA datasets and structured case studies.
- Work-based learning should be planned with clear learning objectives, supervision arrangements, safety requirements and learner reflection/evidence.
- Practical activities should be contextualised to available technologies and the operating conditions of partner-country energy systems without reducing core competency expectations.

6.4 Train-the-Trainer Guidance

Trainers should be briefed on the complete curriculum architecture, Basic-to-Advanced progression, assessment expectations, safety requirements and the relationship between this curriculum and the detailed D3.5 materials. Trainer development should include opportunities to review emerging wind technologies, power-system requirements, digital tools, O&M practice and locally relevant case studies. Cross-specialist team teaching is recommended for advanced mechanical, electrical, control, power-electronic and wind-farm planning topics when one instructor cannot credibly cover the full technical breadth.

7. Assessment and Certification Alignment

7.1 Assessment Principles

- Assessment must be aligned to the learning outcomes of each module.
- Both theoretical understanding and practical/analytical competence should be evidenced where relevant.
- Assessment should progress from knowledge and interpretation at Basic level to analysis, diagnosis, evaluation and planning at Advanced level.
- Learners should receive timely feedback that identifies technical misconceptions and guides further practice.
- Assessment tasks should use realistic wind-energy contexts and avoid testing details that are not part of the taught material.

7.2 Assessment Methods

Method	Use in the programme
Multiple-choice / short-answer quizzes	Terminology, concepts, component functions, safety rules and basic technical understanding.
Technical exercises	Wind-power calculations, block diagrams, component selection/comparison, operating-region interpretation and performance reasoning.
Case-study analysis	Wind-farm planning, grid issues, environmental constraints, faults, maintenance decisions and project trade-offs.
System-evaluation mini-tasks	Trace energy/control paths, analyse subsystem interactions and evaluate operating or design choices.
Practical assignments	Component identification, data interpretation, monitoring/SCADA analysis, maintenance planning and safe-procedure exercises.
Troubleshooting scenarios	Identify symptoms, plausible causes, diagnostic steps, safety controls and appropriate corrective/escalation actions.

7.3 Module Assessment Volume

Each course/module should include 5-10 assessment items aligned with its learning outcomes. Trainers may combine short knowledge items with one or more applied tasks so that the complete evidence set covers both understanding and application within the available module time.

7.4 Successful Completion and Certification

WP4 alignment required

No numeric pass mark, attendance threshold or final certification rule is set in this curriculum. Successful-completion thresholds, assessment criteria and certification procedures shall be applied in accordance with the PRISTINE VET competency-based certification framework under WP4 and applicable national VET requirements.

7.5 Assessment Quality Controls

- Use an assessment blueprint linking each item/task to module learning outcomes.
- Review questions and practical tasks for technical correctness, clarity, difficulty and language accessibility.

- Use consistent marking guidance/rubrics for practical and case-based tasks.
- Record results and participant feedback in accordance with project record-keeping and data-protection requirements.
- Review assessment performance during course testing and revise weak or ambiguous items through controlled versioning.

8. Training Resources, Health and Safety, Environment and Inclusion

8.1 Recommended Training Resources

Resource area	Recommended provision
Digital learning	LMS or shared learning platform, internet-enabled devices, projector/display, short videos, interactive diagrams, quizzes and digital course files.
Wind-resource and planning	Sample wind datasets, wind roses, Weibull examples, maps, terrain/site data, layout worksheets and access to suitable simulation/planning tools where available.
Mechanical learning	Turbine component diagrams/cutaways/models; bearings, couplings, gearbox/pitch/yaw examples or training rigs where available; vibration/oil-analysis demonstrations.
Electrical/power-electronic learning	Electrical schematics, generator/converter diagrams, safe low-voltage training rigs, multimeters/test instruments, protection examples and converter/control simulations.
Control/SCADA learning	Sensor/actuator examples, PLC/HMI demonstrations, SCADA screenshots or sample datasets, alarm/fault scenarios and control-loop diagrams.
O&M and safety	Maintenance checklists, inspection forms, diagnostic scenarios, PPE examples, LOTO demonstration devices and job-safety/risk-assessment templates.

8.2 Health and Safety Requirements

Safety is a cross-cutting competency and must be integrated into every module that involves equipment, electrical systems, moving machinery, installation or maintenance. Training providers should apply local legal requirements and site procedures and must not permit unsupervised high-risk activity.

Hazard area	Training guideline
Working at height	Use appropriate fall-protection principles, access control, rescue awareness and competent supervision for any real height exposure.
Electrical / HV hazards	Use isolation, verification, grounding and competent-person rules. Live HV training is not appropriate for unsupervised learner practice.
LOTO	Teach isolation, lockout/tagout, verification of zero-energy state and controlled re-energisation before maintenance scenarios.
Rotating/mechanical systems	Control stored energy, pinch points, rotating parts, braking/locking mechanisms and safe approach distances.
Lifting/installation	Address crane/lifting zones, suspended loads, transport logistics, weather limits and communication responsibilities.
PPE and emergency response	Select PPE for task hazards; brief emergency stop, first response, reporting and evacuation arrangements.
Weather/site conditions	Consider high winds, lightning, heat, remote access and other environmental conditions during field or O&M activity.

8.3 Environmental and Sustainability Considerations

- Integrate wind energy within climate mitigation and sustainable-energy-system objectives while recognising lifecycle environmental impacts.
- Address site selection, biodiversity, bird/bat impacts, noise, visual effects, land use and community acceptance within wind-farm planning.
- Introduce environmental and social screening/EIA concepts and permitting as part of W2-06.
- Encourage lifecycle thinking for materials, component replacement, waste, blade end-of-life and circular-economy opportunities where relevant.
- Use cases that help learners balance energy yield, reliability, cost, environmental responsibility and social acceptability.

8.4 Inclusion, Gender and Accessibility

Training delivery must support equal opportunity and non-discrimination. PRISTINE VET places explicit emphasis on increasing women's participation in green-energy VET and on inclusive access for underrepresented groups. Recruitment, examples, group work, practical assignments, mentoring and training environments should therefore be designed to avoid exclusion and to support equitable participation.

- Use gender-sensitive and inclusive communication and imagery.
- Plan practical activities so every learner has meaningful hands-on or analytical participation.
- Provide reasonable accessibility adaptations where feasible and avoid unnecessary barriers in digital learning.
- Monitor participation data and learner feedback in accordance with project requirements and privacy rules.
- Use English/French and local-language support where needed to improve understanding without changing the technical competence expected.

8.5 Data Protection and Learner Records

Where training activities collect personal data, assessment results, participation records, feedback or images, providers should follow applicable data-protection requirements and project procedures, including lawful and transparent processing, data minimisation, secure storage, restricted access and appropriate participant information/consent.

9. Trainer and Learner Guidelines

9.1 Trainer Guidelines

- Use the curriculum outcomes and module specifications as the controlling teaching plan; use the W1/W2 educational materials as the detailed content source.
- Check prerequisite knowledge at the start of each level and provide bridging explanation where necessary.
- Explicitly connect Basic concepts to Advanced applications rather than repeating content without progression.
- Use diagrams, worked examples, cases and practical activities to make abstract engineering concepts observable and relevant.
- Adapt examples and datasets to local wind resources, grid conditions, available technologies and labour-market context after stakeholder validation.
- Conduct a safety briefing before practical or field activity and stop any activity that cannot be performed safely with available supervision/equipment.
- Use assessment results and learner feedback to identify topics that require reteaching or curriculum-material revision.
- Keep course records, assessment evidence and versioned materials organised in the project/shared institutional repository.

9.2 Learner Guidelines

- Complete modules in the recommended sequence unless the trainer confirms equivalent prior competence.
- Participate in theoretical, digital, practical and case-based learning activities and ask for clarification when technical or safety concepts are unclear.
- Follow all laboratory, workshop, field and electrical/mechanical safety instructions and use required PPE.

- Keep technical notes, calculations, diagrams and assessment evidence organised as part of a learning portfolio where used by the provider.
- Use SCADA/data/simulation exercises responsibly and distinguish between training simulations and authorised real-system operation.
- Apply professional conduct, teamwork, respectful communication and environmental responsibility during training and workplace exposure.

9.3 Suggested Learning Portfolio Evidence

Level	Example portfolio evidence
Basic level	Wind-resource interpretation, aerodynamic calculation/power-curve task, turbine mechanical/electrical diagrams, power-electronic conversion exercise and module quizzes.
Advanced level	Integrated system map, drivetrain fault analysis, electrical/power-quality case, control/SCADA case, converter comparison, wind-farm planning exercise, maintenance schedule/troubleshooting evidence and safety task.

10. Quality Assurance, Monitoring and Curriculum Review

10.1 Quality Assurance Objectives

Quality assurance should ensure that the curriculum remains technically accurate, pedagogically coherent, industry-relevant, inclusive, assessable and consistent with project requirements. Quality checks should cover both the curriculum and the detailed educational materials used to deliver it.

10.2 Curriculum QA Cycle

Stage	Required action
1. Pre-delivery review	Confirm module codes/titles, durations, outcomes, learning materials, activities, assessment items, safety requirements and trainer readiness.
2. Stakeholder validation	Collect structured input from VET institutions, companies/industry experts and relevant authorities on workforce needs, technology relevance and local constraints.
3. Course testing	Pilot modules with trainers/partner VET providers; record implementation issues, learner questions, timing and resource gaps.
4. Feedback analysis	Review learner/trainer feedback, assessment performance, practical feasibility and inclusion/access issues.
5. Technical/pedagogical revision	Correct inaccuracies, reduce duplication, improve progression and update activities/assessment while preserving approved outcomes.
6. Version control and approval	Issue a new controlled version, archive superseded versions and retain evidence of review/approval.

10.3 Monitoring Indicators for Training Delivery

- Completion of planned modules and assessments within the agreed delivery schedule.
- Learner participation and completion, including monitoring of gender participation and inclusive access.
- Assessment performance by learning outcome and identification of recurring knowledge/skill gaps.
- Learner and trainer satisfaction/feedback on clarity, relevance, practical value and digital accessibility.
- Availability and adequacy of equipment, digital resources and safe practical-learning opportunities.
- Number and quality of industry/VET stakeholder contributions to curriculum review and WBL opportunities.
- Correct use of project visibility, document control, data-protection and record-keeping procedures.

10.4 Curriculum Review Triggers

- New wind-turbine technologies or substantial changes in industry practice.
- Changes in grid requirements, national policy, safety rules or certification frameworks.
- Repeated learner/trainer feedback showing unclear sequencing, duplication or insufficient practice.
- Assessment evidence indicating learning outcomes are not being reliably achieved.
- Changes in available VET infrastructure, digital tools or industry partnership opportunities.
- Formal feedback from WP3 course testing, WP4 certification development or project quality-assurance review.

11. Implementation, Document Control and Relationship to Educational Materials

11.1 Recommended Implementation Sequence

Phase	Implementation guidance
Phase 1 - Prepare	Confirm trainers, learner cohort, facilities, digital access, safety controls, language needs and current course-file versions.
Phase 2 - Deliver Basic level	Complete W1-01 to W1-05, using formative assessment to confirm readiness for Advanced work.
Phase 3 - Deliver Advanced level	Complete W2-01 to W2-07 in sequence, increasing emphasis on system integration, cases, diagnostics and planning.
Phase 4 - Practical/WBL consolidation	Where feasible, use workshops, supervised field exposure, industry mentoring or applied projects to consolidate competencies.
Phase 5 - Assessment and feedback	Complete module evidence, collect learner/trainer feedback and identify gaps or revisions.
Phase 6 - Certification alignment / reporting	Apply the approved WP4 certification procedures when available and retain required evidence for project reporting and QA.

11.2 Relationship between Curriculum and Detailed Course Materials

Curriculum / Guidelines (this document)	Detailed Wind Educational Materials (D3.5)
Defines programme purpose, levels, module sequence, hours and learning outcomes.	Provides full technical explanations, figures, equations, examples, readings and detailed teaching content.
Defines competency domains and expected evidence.	Provides the subject matter used to build learner understanding and practice.
Defines delivery, practical training, assessment, safety and QA principles.	Provides module-specific content that trainers adapt into lessons, digital resources and activities.
Controls coherence and Basic-to-Advanced progression.	Supports implementation but should not independently change approved curriculum outcomes or module structure.

11.3 Document Management and Version Control

- Store the approved DOCX master and PDF submission copy in the PRISTINE VET shared project repository using clear versioned filenames.
- Archive superseded versions so that only the current approved files remain active for delivery and reporting.
- Maintain the required EU visibility elements, funding acknowledgement and disclaimer on official/public versions.
- Retain curriculum, delivery, assessment and feedback records in accordance with project record-keeping requirements.

CURRICULUM AND GUIDELINES ON TRAINING FOR BIOMASS ENERGY SOLUTIONS

Biomass Energy component of Deliverable D3.1

PRISTINE VET - Erasmus+ Capacity Building in Vocational Education and Training
Work Package 3: Training Content Development and Learning

Lead beneficiary **NOWOCERT LIMITED (NWC)**

Project acronym PRISTINE VET

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Technology component	Biomass Energy Solutions
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Revision History

Version	Date	Status	Description
1.0	August 2026	Final for submission	Final Biomass Energy curriculum and training guidelines with detailed course outlines integrated for BM-B1 to BM-B5 and BM-A1 to BM-A5.

Document Status

This document is the Biomass Energy component of Deliverable D3.1 and provides the master curriculum and implementation guide for the PRISTINE VET Biomass Energy training programme. Detailed teaching and learning materials are maintained separately within the Biomass training package under D3.7.

Programme structure

The Biomass Energy programme comprises 10 top-level course modules - 5 Basic and 5 Advanced - supported by 50 coded chapter-level learning units (24 Basic and 26 Advanced). The supplied Biomass materials do not prescribe contact hours; delivery time should therefore be set through trainer planning and validated during pilot delivery rather than invented in this curriculum.

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Acronyms and Abbreviations

Acronym	Meaning
AD	Anaerobic Digestion
AFR	Air-Fuel Ratio
BCR	Benefit-Cost Ratio
CBET	Competency-Based Education and Training
CHP	Combined Heat and Power
C/N	Carbon-to-Nitrogen Ratio
CSTR	Continuous Stirred Tank Reactor
EACEA	European Education and Culture Executive Agency
HRT	Hydraulic Retention Time
IRR	Internal Rate of Return
LCOE	Levelized Cost of Energy
LOTO	Lockout/Tagout
NPV	Net Present Value
O&M	Operation and Maintenance
OHSE	Occupational Health, Safety and Environment
OLR	Organic Loading Rate
PANER	Strategic National Plan for Renewable Energies
PPE	Personal Protective Equipment

Acronym	Meaning
RES	Renewable Energy Source
TS	Total Solids
VET	Vocational Education and Training
VS	Volatile Solids
WBL	Work-Based Learning
WP	Work Package

Executive Summary

PRISTINE VET is a 24-month Erasmus+ Capacity Building in VET project designed to modernise renewable-energy vocational training in West Africa. Within WP3 - Training Content Development and Learning - the project develops industry-aligned curricula, training materials, digital resources and assessment approaches for solar, wind, biomass and hydrogen energy solutions, with NOWOCERT LIMITED (NWC) leading the work package.

This Biomass Energy Curriculum and Training Guidelines document converts the supplied Basic and Advanced Biomass course materials into a coherent competency-based VET curriculum. It defines programme outcomes, Basic-to-Advanced progression, detailed course outlines, delivery methodology, practical learning, assessment, safety and environmental expectations, trainer and learner responsibilities, quality assurance and implementation arrangements.

The curriculum comprises 10 top-level modules: five Basic and five Advanced. The Basic level establishes biomass resources and sustainability, feedstock characteristics and management, conversion pathways, biogas fundamentals, gasification and rural biomass-energy applications, and foundational installation/O&M practice. The Advanced level develops engineering competence in biogas design and optimisation, gasification design and syngas quality, biodiesel and bioethanol production and quality management, biomass power/CHP and rural energy-system design, and advanced installation, monitoring, maintenance, troubleshooting and OHSE practice.

Across the 10 modules, the source material contains 50 coded learning units. Delivery should follow a hybrid VET model combining e-learning and instructor-led teaching with calculations, process diagrams, feedstock assessment, laboratory/workshop demonstrations, plant design tasks, case studies, operational data interpretation and supervised field or work-based learning where feasible and safe. Formal contact hours are not specified in the source materials and should be validated through pilot delivery.

Curriculum principle

The curriculum defines what is to be learned, the competencies to be developed, how learning is organised and delivered, and how achievement is evidenced. The detailed D3.7 Biomass educational materials provide the technical teaching content for implementing this curriculum.

1. Project and Curriculum Context

1.1 PRISTINE VET Context

PRISTINE VET addresses green-energy skills development in West Africa through curriculum modernisation, practical technical training, digital learning and stronger links between VET providers, industry and public stakeholders. Biomass is particularly relevant to agricultural, livestock, forestry, food-processing, municipal-waste and rural energy contexts in the partner region.

WP3 - Training Content Development and Learning - is led by NOWOCERT LIMITED (NWC) for Months 1-12. The work package requires updated, industry-aligned curricula with at least 10 e-learning courses per specialty, alignment with PANER and local/regional/national priorities, stakeholder-informed module and competency design, digital resources and assessment tools, accessible language versions, and course testing with trainers and partner VET providers.

1.2 Deliverable Positioning

WP3 output	Purpose	Biomass Energy relationship
D3.1	Curriculum and guidelines on training for Solar, Wind and Biomass Energy Solutions	This document is the Biomass Energy component: programme architecture, competencies, detailed course outlines, delivery and implementation guidelines.

WP3 output	Purpose	Biomass Energy relationship
D3.7	Educational material on training for Biomass Energy Solutions, in English and French	Detailed Biomass course content and educational materials used by trainers and learners to implement this curriculum.
D3.8	Report on organisation of courses on training (trainers) for Biomass Energy Solutions	Evidence on trainer-course organisation, testing, feedback and refinement following curriculum/material development.

1.3 Project Requirements Addressed by the Curriculum

Project requirement	Curriculum response
Competency-based, industry-aligned curriculum	Programme outcomes, competency domains, detailed module specifications, practical evidence and workplace-oriented tasks.
At least 10 e-learning courses per specialty	10 Biomass course modules are structured across Basic and Advanced levels, supported by 50 coded learning units.
Stakeholder-informed curriculum design	Local contextualisation and structured review by VET institutions, biomass-sector companies, agro-industries, waste-management actors and relevant authorities are built into implementation and QA.
Practical technical training	Feedstock assessment, process calculations, system diagrams, design/sizing, monitoring, troubleshooting, maintenance, safety and project-evaluation activities are embedded.
Digital learning	Hybrid delivery, digital course files, process diagrams, calculation exercises, quizzes, operational datasets and simulation/case tasks are supported.
English/French and local accessibility	The curriculum supports delivery and adaptation in project languages and local languages where needed without reducing technical competence.
Course testing and feedback	Pilot delivery, trainer/partner feedback, learner feedback and controlled curriculum revision are included in the QA cycle.
Certification alignment	Assessment evidence is designed for later alignment with the WP4 competency-based certification framework and applicable national VET requirements.

2. Purpose, Scope and Design Principles

2.1 Purpose

The purpose of this document is to provide a single, coherent curriculum and implementation framework for Biomass Energy training under PRISTINE VET. It is intended for VET providers, trainers, technical experts, curriculum developers and project partners responsible for organising, delivering, assessing and improving Biomass Energy training.

2.2 Scope

The curriculum covers biomass resources and sustainability; feedstock properties, collection, storage and preprocessing; conversion pathways; anaerobic digestion and biogas; gasification and syngas; biodiesel and bioethanol; biomass power generation and CHP; decentralized and rural energy systems; resource assessment and sizing; techno-economic and socio-economic evaluation; installation, commissioning, operation, monitoring, maintenance, troubleshooting, safety and environmental practice.

This document does not replace the detailed educational materials. Trainers should use the corresponding BM-B and BM-A course materials for the full technical explanations, figures, equations, worked examples, case studies and chapter-specific practical activities. The curriculum controls the learning sequence, outcomes, competency expectations, delivery logic and evidence of learning.

2.3 Curriculum Design Principles

Principle	Application
Competency-based	Learning outcomes describe demonstrable understanding, calculation, analysis, technology selection, design reasoning and practical capability.
Progressive	Basic modules establish resources, processes and safe operating foundations; Advanced modules require design, optimisation, quality management, diagnostics and project-level decision making.
Industry-aligned	Content is organised around real biomass supply chains, digesters, gasifiers, biofuel processes, boilers/CHP, mini-grids, installation and O&M.
Practice-oriented	Theory is connected to feedstock tests, calculations, process-flow diagrams, design worksheets, operational data, fault cases, maintenance plans and project cases.
Hybrid and digitally enabled	E-learning and digital resources are combined with instructor-led explanation, simulations, case work and supervised practical learning.
Context-responsive	Feedstocks, examples, project scales and implementation arrangements should reflect West African agricultural, industrial, municipal and rural-energy conditions.
Inclusive	Training should support equal opportunity, gender mainstreaming, accessible participation and respectful learning environments.
Safety-led	Biological, chemical, fire, gas, pressure, thermal, dust, mechanical and electrical hazards are integrated into practical activity design.
Quality-controlled	Curriculum and materials are subject to stakeholder review, course testing, feedback, revision and version control.

2.4 Local Contextualisation and Standards

The technical core of the curriculum should remain consistent across partner institutions, while examples, feedstocks, plant scales, datasets, delivery methods and practical arrangements should be contextualised to local resource availability, climate, agricultural and industrial practices, grid and rural-energy conditions, available equipment and labour-market needs. Applicable national and local requirements for waste handling, environmental protection, pressure and gas systems, chemical handling, fire safety, electrical safety, occupational safety, emissions, permitting and VET delivery should be applied during localisation and stakeholder validation.

3. Programme Profile and Structure

3.1 Programme Profile

Programme title	PRISTINE VET Certificate Courses on Biomass Energy Solutions - Curriculum and Training Guidelines
Programme structure	10 top-level course modules: 5 Basic + 5 Advanced
Learning-unit structure	50 coded learning units: 24 Basic + 26 Advanced
Contact hours	Not prescribed in the supplied Biomass course materials; to be set through trainer planning and validated during pilot delivery
Delivery mode	Hybrid VET: e-learning/classroom theory + practical activities, calculations, demonstrations, simulations, case studies and WBL/field exposure where feasible
Target audience	VET students in West Africa; biomass/bioenergy technicians; agro-processing and waste-management trainees; energy-sector technical assistants; engineers; entrepreneurs and professionals seeking biomass-energy skills
Recommended prerequisites	Basic mathematics and science; introductory chemistry/biology; basic mechanical/electrical concepts; familiarity with renewable energy. Recommended rather than mandatory.
Trainer profile	Biomass/bioenergy engineers, renewable-energy specialists and experienced technical trainers. Advanced modules should involve specialists in anaerobic digestion, gasification, biofuels, power/CHP, project evaluation, O&M and OHSE as appropriate.

Programme levels	Basic (BM-B) and Advanced (BM-A). These are programme-internal levels; formal qualification/accreditation positioning is to align with WP4 and applicable national frameworks.
Language/accessibility	Master curriculum in English; supporting materials to be available/adapted in English and French and, where needed, local languages in accordance with WP3 arrangements.
Assessment basis	Learning-outcome aligned quizzes, calculations, feedstock/resource exercises, design and sizing tasks, process diagrams, case analyses, practical assignments, monitoring/diagnostic tasks and maintenance/safety scenarios.

3.2 Programme Aims

- Provide learners with a structured understanding of biomass energy from resource availability and feedstock management to conversion, utilization and lifecycle operation.
- Develop practical and analytical competence in biomass feedstock characterization, anaerobic digestion, gasification, biofuel production, biomass power generation and decentralized energy systems.
- Prepare learners to select appropriate conversion technologies based on feedstock properties, energy demand, scale, safety, environmental and economic considerations.
- Develop competence in system design, sizing, performance monitoring, optimisation, fault diagnosis, maintenance and safe operation.
- Integrate sustainable biomass-resource management, waste-to-energy principles, environmental protection, community participation and socio-economic evaluation.
- Connect theory with practical work through laboratory/workshop activities, calculations, process diagrams, case studies and work-based learning opportunities.
- Support industry-relevant green skills, entrepreneurship and employment pathways within West African biomass and renewable-energy systems.
- Provide a consistent curriculum basis for trainer development, course testing, certification alignment and future curriculum updating.

3.3 Programme Structure and Recommended Sequence

Code	Course / Module	Level	Learning units
BM-B1	Introduction to Biomass Energy and Energy Resources	Basic	5
BM-B2	Biomass Conversion Technologies Fundamentals	Basic	3
BM-B3	Biogas Technology Fundamentals	Basic	5
BM-B4	Biomass Gasification and Biofuels Fundamentals	Basic	6
BM-B5	Biomass System Installation, Operation, Maintenance and Safety	Basic	5
BM-A1	Advanced Biogas System Design, Operation and Optimization	Advanced	5
BM-A2	Biomass Gasification Systems Design and Performance Analysis	Advanced	5
BM-A3	Biofuels Production Technologies and Quality Management	Advanced	5
BM-A4	Biomass Power Generation and Rural Energy Systems Design	Advanced	6
BM-A5	Biomass System Installation, Operation, Maintenance and Safety	Advanced	5

Basic level: 5 modules and 24 coded learning units. Advanced level: 5 modules and 26 coded learning units.
Programme total: 10 modules and 50 coded learning units.

Source coding note

The supplied Basic Biomass file defines BM-Bx-y as the Basic-track convention. In the final Basic O&M course, the opening course and first chapter are labelled BM-A5 / BM-A5-1, after which the file continues BM-B5-2 to BM-B5-5. For coherent curriculum control, this document normalises that Basic course as BM-B5 while retaining the separate Advanced BM-A5 course as supplied.

3.4 Basic-to-Advanced Progression

Domain	Basic expectation	Advanced expectation
Resources and feedstocks	Identify biomass resources; explain moisture, calorific value, bulk density and ash; manage collection, storage and preprocessing.	Characterise feedstocks quantitatively; select and prepare substrates/fuels; evaluate co-digestion, pretreatment, resource availability and supply reliability.
Conversion pathways	Compare thermochemical, biochemical, mechanical and chemical pathways and match them to simple applications.	Design and optimise biogas, gasification, biofuel and power-generation processes using engineering calculations and performance indicators.
Biogas	Explain anaerobic digestion, components, operating factors and end uses.	Design and size digesters; calculate HRT/OLR and gas yield; diagnose process instability; optimise and select utilization/upgrading options.
Gasification and syngas	Explain gasifier types, drying/pyrolysis/oxidation/reduction stages, syngas formation and basic monitoring.	Select reactor designs; control temperature/pressure/AFR; evaluate contaminants and cleaning; perform energy-balance and efficiency analysis.
Biofuels	Recognise basic chemical/mechanical pathways, oil extraction, transesterification and densification concepts.	Apply biodiesel/bioethanol production, purification/upgrading, quality-control, storage, handling and distribution principles.
Power and rural energy systems	Recognise mini-grid, community-energy, resource-mapping, system-sizing and basic feasibility concepts.	Design biomass power/CHP and rural systems; evaluate demand, fuel supply, efficiency, financial and socio-economic viability.
Installation, O&M and safety	Follow basic installation, startup/shutdown, monitoring, maintenance, troubleshooting and safety procedures.	Plan commissioning, performance monitoring, preventive/corrective maintenance, fault diagnosis and OHSE controls at system level.

4. Programme Learning Outcomes and Competency Framework

4.1 Programme Learning Outcomes

Code	Programme learning outcome
PLO1	Explain the role of biomass energy in renewable-energy systems and identify major agricultural, forestry, livestock, municipal and industrial biomass resources relevant to West Africa.
PLO2	Characterise biomass feedstocks using moisture, calorific value, bulk density, ash, solids, C/N and related properties, and apply appropriate collection, storage, preprocessing and sustainability practices.
PLO3	Compare thermochemical, biochemical, mechanical and chemical biomass-conversion pathways and select suitable technologies for defined feedstocks and energy needs.
PLO4	Explain, design and evaluate anaerobic digestion and biogas systems, including feedstock selection, digester configuration, sizing, HRT/OLR, process control, optimisation and utilization.
PLO5	Explain and analyse biomass gasification systems, including reactor types, process stages, operating parameters, syngas composition/cleaning, performance and applications.
PLO6	Explain and apply biodiesel and bioethanol production, processing, upgrading, quality-control, storage and handling principles.
PLO7	Explain and analyse biomass combustion, steam/power generation, CHP, decentralized systems, mini-grids and productive-use applications.
PLO8	Conduct structured biomass-resource, demand, system-sizing, techno-economic, socio-economic and community-participation assessments for project planning.
PLO9	Support safe installation, inspection, testing, commissioning, startup, shutdown, operation and monitoring of biomass-energy systems.
PLO10	Differentiate preventive and corrective maintenance, use diagnostic information to troubleshoot faults, and contribute to maintenance planning and lifecycle reliability.

Code	Programme learning outcome
PLO11	Apply occupational health, fire/gas, chemical, biological, thermal, mechanical, electrical and environmental risk-control principles to biomass training and technical activities.
PLO12	Use process diagrams, calculations, technical data, monitoring records and structured reports to communicate findings, work collaboratively and demonstrate professional responsibility.

4.2 Competency Domains

Code	Competency domain	Scope
C1	Biomass resources, sustainability and sector context	Biomass role, resource types, availability, sustainable harvesting, environmental/social context and West African applications.
C2	Feedstock characterization, preparation and management	Moisture, calorific value, density, ash, TS/VS, C/N, collection, storage, transport, preprocessing, co-digestion and pretreatment.
C3	Biomass conversion and process engineering	Thermochemical, biochemical, mechanical and chemical conversion; process-flow reasoning; technology selection and optimisation.
C4	Biogas and anaerobic digestion	Digesters, feedstock selection, anaerobic stages, HRT/OLR, gas yield, process monitoring, optimisation, gas use and upgrading.
C5	Gasification and syngas systems	Gasifier design, drying/pyrolysis/oxidation/reduction, operating parameters, syngas quality/cleaning, performance and applications.
C6	Biofuels production and quality management	Biodiesel, bioethanol, purification/upgrading, by-products, quality testing/standards, storage, safety and distribution.
C7	Biomass power, rural energy and project development	Combustion, steam, CHP, generators, mini-grids, resource/demand assessment, sizing, economics and community-energy models.
C8	Installation, O&M, safety, environment and professional practice	Installation, commissioning, monitoring, maintenance, diagnostics, PPE/LOTO, fire/gas/chemical safety, emissions/waste management, inclusion and professional conduct.

4.3 Module-to-Competency Mapping

Module	Primary competency domains	Emphasis
BM-B1	C1, C2, C8	Biomass context, resources, feedstock properties/management and sustainable use.
BM-B2	C2, C3	Conversion pathways, mechanical/chemical processing and technology selection.
BM-B3	C2, C4, C8	Biogas fundamentals, anaerobic digestion, plant components, operating factors and uses.
BM-B4	C1, C3, C5, C7, C8	Gasification fundamentals, syngas, monitoring, rural systems, sizing and feasibility.
BM-B5	C3-C8	Foundational installation, operation, monitoring, maintenance, troubleshooting and safety.
BM-A1	C2, C3, C4, C8	Biogas design/sizing, feedstock preparation, performance analysis, optimisation and utilization.
BM-A2	C3, C5, C8	Gasifier/reactor design, process control, syngas cleaning, efficiency and applications.
BM-A3	C2, C3, C6, C8	Biodiesel/bioethanol production, processing, fuel quality, storage and handling.
BM-A4	C1, C3, C7, C8	Biomass power/CHP, plant components, performance, rural systems, sizing and project evaluation.
BM-A5	C3-C8	Advanced installation/commissioning, monitoring, maintenance, fault diagnosis and OHSE management.

5. Detailed Course Outlines and Module Specifications

The following 10 course outlines translate the supplied Basic and Advanced Biomass materials into curriculum-level specifications. Each outline preserves the source course/chapter sequence, consolidates the main technical topics and subtopics, and adds implementation-level learning outcomes, applied activities, assessment and progression without reproducing the full educational materials.

5.1 BM-B1 - Introduction to Biomass Energy and Energy Resources

Course code	BM-B1
Level	Basic
Coded learning units	5 (BM-B1-1 to BM-B1-5)
Course description	Establish the biomass-energy foundation: sector role, local resources, feedstock characteristics, supply-chain management and sustainable resource use in West African contexts.

Learning Outcomes

- Define biomass energy and explain its role in renewable-energy systems, energy access, waste management and rural livelihoods.
- Identify major agricultural, forestry, animal, municipal and agro-industrial biomass resources and their potential energy uses.
- Explain how moisture content, calorific value, bulk density and ash content affect fuel quality, handling and conversion performance.
- Describe good practices for feedstock collection, transport, storage, drying, size reduction, briquetting/pelletizing and contamination control.
- Assess basic biomass-resource availability and recognise sustainable harvesting, environmental protection and competing-use considerations.
- Connect local biomass resources to realistic energy products and community/industrial applications.

Detailed Course Outline

Topic	Main topics and subtopics
BM-B1-1 Introduction to Biomass Energy	Definition and importance of biomass; energy products (heat, electricity, biogas and biofuels); biomass in the renewable-energy transition; energy access and energy security; global and West African trends; policies, opportunities and development barriers.
BM-B1-2 Biomass Resources and Feedstocks	Agricultural residues; forestry/wood-processing residues; animal waste; municipal and industrial organic waste; energy-conversion options; availability, collection and sustainability considerations for common West African feedstocks.
BM-B1-3 Feedstock Characteristics	Moisture content and drying implications; calorific value and energy potential; bulk density, transport and storage; ash content, combustion/maintenance implications and comparative feedstock selection.
BM-B1-4 Feedstock Management	Collection and transport logistics; storage methods, ventilation and moisture protection; first-in/first-out practice; preprocessing through drying, chopping, grinding/shredding, briquetting and pelletizing; preservation of feedstock quality.
BM-B1-5 Sustainable Biomass Resource Management	Resource-availability assessment; seasonal supply; sustainable harvesting; environmental considerations; avoiding deforestation, soil/nutrient depletion and excessive residue removal; balancing energy use with agriculture, ecosystems and local livelihoods.

Recommended Practical / Simulation Activities

- Conduct a local biomass-resource inventory and classify each feedstock by source, seasonality and possible energy product.
- Compare sample feedstocks using a simple moisture/calorific-value/bulk-density/ash decision matrix based on supplied data or safe demonstrations.
- Develop a collection-storage-preprocessing plan for one locally available feedstock and identify environmental safeguards.

Assessment Approach

Knowledge quiz plus a local feedstock/resource assessment, a feedstock-characteristics interpretation task and a short sustainable-management case.

Progression and Linkage

Provides the resource and feedstock foundation for BM-B2 conversion selection, BM-B3 biogas, BM-B4 gasification/rural systems, and all Advanced modules.

5.2 BM-B2 - Biomass Conversion Technologies Fundamentals

Course code	BM-B2
Level	Basic
Coded learning units	3 (BM-B2-1 to BM-B2-3)
Course description	Introduce the major routes used to convert raw biomass into useful heat, gas, solid fuels and liquid fuels, with emphasis on matching feedstock and energy need to an appropriate technology.

Learning Outcomes

- Explain why biomass often requires conversion before efficient energy use.
- Distinguish thermochemical, biochemical, mechanical and chemical conversion pathways and identify their typical outputs.
- Explain basic oil extraction, transesterification, briquetting and densification concepts at an introductory level.
- Compare the main advantages, limitations, feedstock requirements and application scales of common conversion technologies.
- Select a plausible conversion pathway for a defined feedstock and energy demand using technical, practical and sustainability criteria.

Detailed Course Outline

Topic	Main topics and subtopics
BM-B2-1 Overview of Biomass Conversion Pathways	Energy-conversion concepts; direct combustion, gasification and related thermochemical routes; anaerobic digestion and other biochemical routes; mechanical densification and oil extraction; basic chemical conversion; technology-selection factors such as feedstock condition, scale, product and local capability.
BM-B2-2 Mechanical and Chemical Conversion Processes	Oil extraction basics and methods; introductory transesterification principles and process stages; briquetting and densification; common feedstocks, equipment concepts, benefits, limitations and applications.
BM-B2-3 Comparison of Conversion Technologies	Comparison of thermochemical, biochemical, mechanical and chemical conversion; advantages/limitations; suitable applications; technology-selection considerations based on moisture, scale, desired energy carrier, cost, maintenance, skills and environmental impact.

Recommended Practical / Simulation Activities

- Build a conversion-pathway map linking representative West African feedstocks to heat, electricity, biogas, briquettes/pellets and liquid-fuel outputs.
- Use a structured selection matrix to choose a technology for rice husks, cassava peels, manure, sawdust or food-processing waste.
- Demonstrate or simulate densification/preprocessing and compare the handling implications of loose and densified biomass.

Assessment Approach

Quiz plus a conversion-pathway comparison table and a short technology-selection case requiring justification of feedstock, process and end use.

Progression and Linkage

Prepares learners for the dedicated biogas and gasification modules and for Advanced process-design courses BM-A1 to BM-A4.

5.3 BM-B3 - Biogas Technology Fundamentals

Course code	BM-B3
Level	Basic
Coded learning units	5 (BM-B3-1 to BM-B3-5)
Course description	Develop foundational understanding of anaerobic digestion, biogas-system components, operating conditions and practical end uses before learners move to engineering design and optimisation.

Learning Outcomes

- Explain what biogas is, its main composition and the importance of anaerobic digestion for waste-to-energy applications.
- Describe the main biological stages of anaerobic digestion and the conditions required for stable digestion.
- Identify digesters, inlet/outlet systems, gas storage, piping and appliances and explain their functions.
- Explain how temperature, pH, retention time and feedstock quality influence gas production.
- Recognise common biogas applications for cooking, heating, lighting, agriculture and small-scale electricity generation.
- Apply basic safety and maintenance awareness when discussing biogas components and utilization.

Detailed Course Outline

Topic	Main topics and subtopics
BM-B3-1 Introduction to Biogas Technology	Definition and importance; common feedstocks; biogas and digestate; composition and basic properties; energy/waste-management benefits; advantages and limitations.
BM-B3-2 Anaerobic Digestion Process	Hydrolysis, acidogenesis, acetogenesis and methanogenesis; microbial roles; sequence of conversion; temperature, pH, moisture/nutrients and other conditions for efficient digestion.
BM-B3-3 Biogas Plant Components	Digester function; inlet and outlet structures; gas storage systems; piping, valves and appliances; bio-slurry/digestate handling; routine inspection and maintenance awareness.
BM-B3-4 Factors Affecting Biogas Production	Psychrophilic/mesophilic/thermophilic temperature ranges; pH control; retention time; feedstock quality and loading; causes of poor performance and basic improvement measures.
BM-B3-5 Biogas Applications	Cooking, lighting and heating; agricultural uses and crop drying; small-scale electricity generation; digestate as fertilizer; practical benefits and limitations of biogas utilization.

Recommended Practical / Simulation Activities

- Create an anaerobic-digestion process map showing the four biological stages and required operating conditions.
- Label a biogas-system diagram and trace feedstock, gas and digestate flows from inlet to end use.
- Interpret simple temperature/pH/retention-time scenarios and identify likely effects on gas production.

Assessment Approach

Knowledge quiz plus a process-flow/component-identification task and a short operating-condition case on biogas production.

Progression and Linkage

Provides the direct foundation for Advanced biogas design, sizing, performance analysis and optimisation in BM-A1.

5.4 BM-B4 - Biomass Gasification and Biofuels Fundamentals

Course code	BM-B4
Level	Basic
Coded learning units	6 (BM-B4-1 to BM-B4-6)
Course description	Establish basic gasification and syngas concepts while extending learning to performance monitoring, decentralized biomass-energy systems, resource/sizing decisions and introductory project feasibility.

Learning Outcomes

- Define biomass gasification and explain how limited-oxygen conversion produces syngas.
- Identify updraft, downdraft, crossdraft and fluidized-bed gasifier concepts and compare basic advantages and limitations.
- Describe drying, pyrolysis, oxidation and reduction stages and their relationship to syngas formation.
- Interpret basic plant performance indicators and explain the role of data collection, operational optimisation and grid/energy-system considerations.
- Explain decentralized biomass mini-grids, community systems and productive-use applications relevant to West Africa.
- Conduct a basic resource/demand assessment and recognise system-sizing, cost-benefit, financial and socio-economic considerations.

Detailed Course Outline

Topic	Main topics and subtopics
BM-B4-1 Introduction to Biomass Gasification	Gasification principles and objectives; gasification versus combustion; products and syngas; gasifier types including updraft, downdraft, crossdraft and fluidized-bed systems; basic selection considerations.
BM-B4-2 Gasification Process Stages	Drying, pyrolysis, oxidation and reduction; relationship between stages; formation and purpose of syngas; process understanding for safe and efficient operation.
BM-B4-3 Performance Monitoring and Efficiency Analysis	Plant-efficiency indicators; feedstock-utilization efficiency and capacity factor; operational data collection; performance trends; optimisation and basic grid-integration considerations.
BM-B4-4 Decentralized and Rural Biomass Energy Systems	Mini-grid and community-scale applications; productive use of energy in agro-processing; reliability and local service delivery; women's economic participation; implementation challenges and sustainability strategies.
BM-B4-5 Resource Assessment and System Sizing	Biomass resource assessment and mapping; seasonal supply; demand assessment; technology selection; system-sizing logic; factors affecting capacity; West African rural-energy case analysis.
BM-B4-6 Techno-economic and Socio-economic Evaluation	Project costs and benefits; NPV/IRR/payback/LCOE concepts; employment and livelihood effects; education/health/gender benefits; village committees, cooperatives, PPPs and community-enterprise models; sustainability and governance.

Recommended Practical / Simulation Activities

- Create a gasification-stage diagram and compare gasifier types for at least two feedstocks.
- Interpret a simple biomass-plant monitoring dataset and identify efficiency or operating concerns.
- Complete a mini-grid/resource-sizing case using feedstock availability and community energy demand.
- Prepare a basic cost-benefit and socio-economic assessment for a community biomass-energy option.

Assessment Approach

Quiz plus gasifier/process interpretation, a resource-and-sizing task, and a short rural-project feasibility case.

Progression and Linkage

Builds the foundation for advanced gasification in BM-A2, biofuels in BM-A3 and biomass power/rural-system design in BM-A4.

5.5 BM-B5 - Biomass System Installation, Operation, Maintenance and Safety

Course code	BM-B5
Level	Basic
Coded learning units	5 (normalised BM-B5-1 to BM-B5-5)
Course description	Develop the practical foundation for installing, commissioning, operating, monitoring, maintaining and troubleshooting biomass systems safely under local infrastructure and environmental conditions.

Learning Outcomes

- Describe the main stages of biomass-system site preparation, equipment installation, testing, commissioning and handover.
- Apply basic startup, normal-operation, monitoring and shutdown procedures using checklists and operating records.
- Distinguish preventive and corrective maintenance and describe inspection, component-replacement and documentation practices.
- Use a structured troubleshooting process to identify symptoms, possible causes, diagnostic checks and corrective actions.
- Identify major occupational, fire, gas, thermal, mechanical, electrical, biological and environmental hazards and appropriate controls.
- Explain how infrastructure, climate, spare-parts availability and local technical capacity influence O&M in West African projects.

Detailed Course Outline

Topic	Main topics and subtopics
BM-B5-1 Installation Procedures and Commissioning	Site selection and preparation; biomass availability/access/proximity to users; civil works, foundations, drainage and storage; mechanical/electrical/instrumentation installation; pre-commissioning inspection; cold/hot commissioning; performance verification, documentation and operator handover.
BM-B5-2 System Operation and Monitoring	Pre-start inspections; feedstock/equipment/safety checks; startup, normal operation and shutdown; instrumentation and monitored parameters; operating logs, performance records, data interpretation and response to abnormalities.
BM-B5-3 Preventive and Corrective Maintenance	Preventive versus corrective maintenance; maintenance planning and scheduling; inspection routines; lubrication/cleaning/adjustment; component replacement; spare parts; maintenance documentation and constraints in decentralized settings.
BM-B5-4 Troubleshooting and Fault Diagnosis	Troubleshooting principles; common operational problems; visual, mechanical, electrical and process diagnostic methods; root-cause thinking; corrective action; fault reporting and verification after repair.
BM-B5-5 Occupational Health, Safety and Environmental Practices	Hazard identification and risk control; fire and gas safety; ventilation/leak response; PPE; safe work procedures; biomass waste/ash/digestate and environmental compliance; community health and safety culture.

Recommended Practical / Simulation Activities

- Develop an installation and pre-commissioning checklist for a small biomass system.
- Complete a startup/shutdown and daily monitoring log using a simulated operating scenario.
- Prepare a preventive-maintenance schedule and diagnose a set of common plant faults from symptoms.
- Conduct a classroom/workshop hazard assessment and specify required controls and PPE.

Assessment Approach

Practical checklist and logbook evidence, maintenance/troubleshooting case, safety-risk assessment and targeted quiz.

Progression and Linkage

Provides the operational foundation for Advanced installation/O&M in BM-A5 and supports safe practical work across BM-A1 to BM-A4.

5.6 BM-A1 - Advanced Biogas System Design, Operation and Optimization

Course code	BM-A1
Level	Advanced
Coded learning units	5 (BM-A1-1 to BM-A1-5)
Course description	Develop engineering competence in biogas-system design, feedstock preparation, digester sizing, performance analysis, process optimisation and end-use selection for household, institutional, agricultural and small-industrial applications.

Learning Outcomes

- Select suitable digester technologies using feedstock, climate, scale, maintenance and end-use criteria.
- Characterise feedstocks using TS/VS, C/N, pH, moisture, ash/lignin and biogas-potential considerations, and evaluate co-digestion/pretreatment options.
- Calculate and interpret digester volume, HRT, OLR, gas production/yield and other performance indicators using the course methods.
- Diagnose process instability from trends in gas production, methane content, pH, loading and operating conditions.
- Apply optimisation measures involving feedstock balance, pretreatment, mixing, temperature/process control and nutrient considerations.
- Evaluate cooking/heating, electricity generation, gas upgrading and storage options for defined biogas applications.

Detailed Course Outline

Topic	Main topics and subtopics
BM-A1-1 Biogas System Design Principles	Design criteria and airtight/structural/corrosion/maintenance requirements; West African climate considerations; feedstock selection; fixed-dome, floating-drum, plug-flow and CSTR concepts; slurry input, HRT-based digester sizing and gas-production estimation.
BM-A1-2 Feedstock Assessment and Preparation	Moisture, TS, VS, C/N, pH, ash and lignin; feedstock availability and inhibitors; co-digestion and mixing ratios; mechanical, thermal, chemical and biological pretreatment; sorting, cleaning and slurry preparation.
BM-A1-3 Anaerobic Digestion Performance Analysis	Organic Loading Rate, Hydraulic Retention Time, gas production, methane content, gas pressure/flow and gas yield; performance trends; low gas production, acidification/odour and foaming; monitoring cycle and corrective response.
BM-A1-4 Process Optimization Techniques	Critical process parameters; temperature, pH, VFAs, OLR and HRT; co-digestion, pretreatment, mixing, temperature control and nutrient strategies; troubleshooting low yield, acidification, scum and gas leakage.
BM-A1-5 Biogas Utilization Systems	Biogas cooking/heating, water heating and crop drying; engine-generator electricity production; gas upgrading and methane enrichment concepts; storage options; matching gas quality, demand and safety requirements to end use.

Recommended Practical / Simulation Activities

- Design and size a community or agro-processing biogas system using a supplied feedstock and HRT scenario.
- Characterise two or more feedstocks and develop a justified co-digestion/pretreatment plan.
- Calculate OLR/HRT/gas-yield indicators and diagnose a declining-performance dataset.
- Compare biogas utilization options and prepare an optimisation and safety recommendation.

Assessment Approach

Engineering design/sizing task, feedstock-assessment exercise, performance-analysis/troubleshooting case and technical quiz.

Progression and Linkage

Integrates Basic biogas competencies and supports advanced rural-energy design in BM-A4 and lifecycle operation/maintenance in BM-A5.

5.7 BM-A2 - Biomass Gasification Systems Design and Performance Analysis

Course code	BM-A2
Level	Advanced
Coded learning units	5 (BM-A2-1 to BM-A2-5)
Course description	Develop advanced competence in gasifier/reactor selection, operating control, syngas cleaning and quality, efficiency/energy-balance analysis, troubleshooting and application assessment.

Learning Outcomes

- Explain gasification reactions, stages and syngas properties and select suitable reactor types for defined feedstocks and applications.
- Analyse the effects of temperature, pressure, air-fuel ratio and feedstock properties on gasification performance.
- Identify major syngas contaminants and select appropriate tar/particulate/gas-cleaning approaches at curriculum level.
- Calculate and interpret gasification efficiency, energy balances, heat losses and performance indicators using course methods.
- Diagnose common performance problems and recommend process-control or maintenance responses.
- Evaluate thermal, power-generation and industrial-process-heat applications using technical, environmental and techno-economic criteria.

Detailed Course Outline

Topic	Main topics and subtopics
BM-A2-1 Gasification Fundamentals and Reactor Design	Thermochemical principles and reactions; drying/pyrolysis/oxidation/reduction; syngas composition/properties; fixed-bed and fluidized-bed gasifiers; reactor selection by feedstock, scale, gas quality, complexity and application.
BM-A2-2 Operating Parameters and Process Control	Temperature and pressure effects; air-fuel ratio; moisture, particle size, ash and feedstock consistency; process sensors/control systems; maintaining stable conversion and reducing tar/operating problems.
BM-A2-3 Syngas Production and Cleaning	Syngas composition; particulates, tar, moisture and other contaminants; tar-removal concepts; cyclones/filters/scrubbing or other cleaning stages in the source material; gas-quality assessment for end use.
BM-A2-4 System Performance Evaluation	Gasification efficiency; energy-balance calculations; heat-loss analysis; feedstock and syngas performance indicators; troubleshooting low efficiency, unstable temperature and poor gas quality.
BM-A2-5 Gasification Applications	Thermal use, electricity generation and industrial process heat; environmental benefits/constraints; fuel substitution; application matching; basic techno-economic assessment and operational trade-offs.

Recommended Practical / Simulation Activities

- Compare fixed-bed and fluidized-bed gasifiers for selected feedstocks and operating scales.
- Analyse temperature/AFR/feedstock scenarios and identify expected effects on syngas and process stability.
- Design a conceptual syngas-cleaning train for a defined end use and justify each stage.
- Complete a simplified energy-balance/efficiency case and troubleshoot a poor-performance scenario.

Assessment Approach

Reactor-selection/design exercise, process-control and syngas-quality case, efficiency calculation and targeted technical quiz.

Progression and Linkage

Builds directly on BM-B4 and supports gasification-based power generation/project design in BM-A4 and advanced O&M in BM-A5.

5.8 BM-A3 - Biofuels Production Technologies and Quality Management

Course code	BM-A3
Level	Advanced
Coded learning units	5 (BM-A3-1 to BM-A3-5)
Course description	Develop advanced understanding of biodiesel and bioethanol production pathways, process equipment and control, purification/upgrading, fuel-quality management, and safe storage/handling/distribution.

Learning Outcomes

- Evaluate suitable oils/fats and other feedstocks for biodiesel production and explain the transesterification process and required equipment.
- Explain bioethanol feedstock preparation, fermentation control, distillation and dehydration stages.
- Describe purification, upgrading, by-product recovery/utilization and process-optimisation principles for liquid biofuels.
- Interpret key fuel-quality parameters and explain the purpose of laboratory testing and applicable fuel standards.
- Apply safe storage, handling and transportation principles, including contamination control, fire/chemical hazards and quality preservation.
- Assess process yield, efficiency, quality and operational trade-offs using source-based calculations and case data.

Detailed Course Outline

Topic	Main topics and subtopics
BM-A3-1 Biodiesel Production Technologies	Oil/fat feedstock selection; triglycerides/free-fatty-acid considerations; transesterification principle; alcohol/catalyst roles at conceptual engineering level; process equipment, separation and recovery; yield and process-performance calculations.
BM-A3-2 Bioethanol Production Technologies	Sugar/starch/lignocellulosic feedstock preparation as covered in the source; fermentation process and controls; contamination/temperature/pH issues; industrial troubleshooting; distillation and dehydration to achieve required ethanol concentration.
BM-A3-3 Biofuel Processing and Upgrading	Purification techniques; removal of residual water/impurities; by-product utilization; process optimisation, yield and energy/resource efficiency; integration of recovery and quality-improvement steps.
BM-A3-4 Fuel Quality Control and Standards	Density and other fuel-quality parameters in the source; sampling/testing procedures; interpreting laboratory results; quality acceptance; role of national/international fuel standards and documentation.
BM-A3-5 Storage, Handling and Distribution	Storage-system selection and capacity; material compatibility and quality preservation; fire/chemical safety; transfer and handling procedures; transport efficiency, contamination prevention and distribution planning.

Recommended Practical / Simulation Activities

- Prepare process-flow diagrams for biodiesel and bioethanol production and identify critical control/quality points.
- Interpret a set of process-yield or fuel-quality data and determine whether corrective investigation is required.
- Develop a safe storage/handling checklist for a small biofuel facility without performing unsupervised chemical production.
- Compare local feedstock options for biodiesel or bioethanol using availability, quality, sustainability and cost criteria.

Assessment Approach

Process-flow and feedstock-selection task, quality-control data interpretation, storage/safety case and technical quiz/calculation exercise.

Progression and Linkage

Builds on basic conversion concepts in BM-B2/BM-B4 and connects to integrated biomass power, fuel logistics and lifecycle management in BM-A4 and BM-A5.

5.9 BM-A4 - Biomass Power Generation and Rural Energy Systems Design

Course code	BM-A4
Level	Advanced
Coded learning units	6 (BM-A4-1 to BM-A4-6)
Course description	Integrate biomass conversion with power/CHP plant engineering, decentralized energy-service design, resource and demand assessment, sizing, financial feasibility and community implementation.

Learning Outcomes

- Explain biomass combustion-based electricity generation, steam systems and Combined Heat and Power (CHP) configurations.
- Identify fuel handling, boilers, turbines, generators and electrical systems and explain their interaction in a biomass power plant.
- Calculate and interpret basic plant efficiency, fuel-use and availability/performance indicators using source methods.
- Design a conceptual decentralized or mini-grid biomass-energy solution that links reliable feedstock supply to community or productive-use demand.
- Conduct biomass-resource and demand assessment and select/scope system capacity and technology for a defined site.
- Apply cost-benefit, financial and socio-economic evaluation concepts and propose appropriate community participation/ownership arrangements.

Detailed Course Outline

Topic	Main topics and subtopics
BM-A4-1 Biomass Power Generation Technologies	Combustion-based power generation; biomass preparation and combustion stages; steam generation; steam turbine concepts; Combined Heat and Power; matching electricity and useful heat to industrial/community demand.
BM-A4-2 Biomass Power Plant Components and Operation	Fuel receiving/handling and feeding; boilers and steam systems; turbines and generators; electrical generation and distribution; component interactions, operating checks and efficiency considerations.
BM-A4-3 Performance Monitoring and Efficiency Analysis	Plant efficiency indicators; electrical/thermal performance; feedstock consumption and energy output; availability and operational records; loss identification and operational optimisation.
BM-A4-4 Decentralized and Rural Biomass Energy Systems	Mini-grids, community-scale systems and productive use; agriculture/agro-processing applications; reliable service, local enterprises and livelihoods; system availability, governance and rural implementation issues.
BM-A4-5 Resource Assessment and System Sizing	Available biomass estimation and seasonal supply; demand/load assessment; technology selection; sizing to match resource and energy demand; logistics, storage, redundancy and scalability considerations.
BM-A4-6 Techno-economic and Socio-economic Evaluation	Cost-benefit analysis; capital/operating costs and revenues/savings; NPV, IRR, payback and LCOE concepts; job creation and local enterprise; community participation/ownership models; feasibility and sustainability decisions.

Recommended Practical / Simulation Activities

- Draw a biomass power/CHP energy-flow diagram and identify the main plant components and loss points.
- Calculate a simple fuel-use/efficiency case using the formulas and data structures provided in the course material.
- Design a rural biomass mini-grid concept from a supplied resource inventory and demand profile.
- Prepare a concise technical, financial and socio-economic feasibility comparison for two technology options.

Assessment Approach

Power/CHP system analysis, resource-and-sizing exercise, efficiency calculation, and integrated mini-grid feasibility/project-design case.

Progression and Linkage

Integrates learning from the full programme and provides the project/system-design context for advanced commissioning, O&M and lifecycle management in BM-A5.

5.10 BM-A5 - Biomass System Installation, Operation, Maintenance and Safety

Course code	BM-A5
Level	Advanced
Coded learning units	5 (BM-A5-1 to BM-A5-5)
Course description	Consolidate advanced practical competence in installation and commissioning, operating control, performance monitoring, maintenance planning, fault diagnosis and occupational/environmental risk management across biomass technologies.

Learning Outcomes

- Plan and verify site preparation, mechanical/electrical installation, system inspection, testing, commissioning and handover against technical requirements.
- Apply structured operating procedures and use instrumentation, logs and performance indicators to monitor plant condition and output.
- Develop preventive and corrective maintenance plans using inspection routines, component criticality, spare-parts needs and maintenance records.
- Use systematic fault diagnosis to connect symptoms with process, mechanical, electrical or control causes and verify corrective action.
- Apply OHSE risk assessment and controls for fire, combustible/toxic gases, pressure, hot surfaces, chemicals, biological materials, rotating machinery and electricity.
- Integrate environmental compliance, waste/emissions management, documentation and continuous safety improvement into biomass plant lifecycle management.

Detailed Course Outline

Topic	Main topics and subtopics
BM-A5-1 Installation Procedures and Commissioning	Site preparation and equipment placement; mechanical and electrical installation; alignment and connection checks; instrumentation; system testing; commissioning sequence; performance verification; documentation and handover.
BM-A5-2 System Operation and Monitoring	Operating procedures and safe startup/shutdown; feedstock/process control; instrumentation and monitoring; performance recording, plant availability and trend interpretation; abnormal-condition response.
BM-A5-3 Preventive and Corrective Maintenance	Maintenance planning and schedules; inspection routines; lubrication, cleaning, calibration and wear checks; component replacement; spares; corrective maintenance and documentation for reliability.
BM-A5-4 Troubleshooting and Fault Diagnosis	Common process, mechanical, electrical and control problems; diagnostic tools/methods; root-cause analysis; corrective action and post-repair verification; maintenance effectiveness and fault documentation.

Topic	Main topics and subtopics
BM-A5-5 Occupational Health, Safety and Environmental Practices	Hazard identification/risk assessment; fire and gas safety; PPE and safe-work procedures; chemical/biological/thermal/electrical controls; emissions, ash, digestate and waste management; environmental compliance and safety culture.

Recommended Practical / Simulation Activities

- Prepare a commissioning and acceptance plan for a selected biomass technology, including safe test sequencing and documentation.
- Interpret operational logs/KPIs and identify emerging performance or maintenance problems.
- Build a risk-based preventive-maintenance plan and diagnose an integrated process/mechanical/electrical fault scenario.
- Conduct an OHSE risk assessment for a biomass facility and define engineering, administrative and PPE controls.

Assessment Approach

Integrated commissioning/O&M portfolio, performance-monitoring case, fault-diagnosis exercise, OHSE risk assessment and technical quiz.

Progression and Linkage

Capstone operational module that consolidates the programme and prepares learners for supervised workplace application, trainer pilots and later certification assessment under WP4.

6. Teaching, Learning and Practical Training Guidelines

6.1 Delivery Model

Delivery should use a blended VET model in which digital/self-paced learning and instructor-led sessions are integrated with calculations, visual process mapping, laboratory/workshop demonstrations, case-based problem solving and supervised field or work-based learning. Practical depth should increase from Basic identification and safe procedure-following to Advanced design, optimisation, diagnosis and project decision making.

6.2 Recommended Learning Sequence within a Module

Stage	Trainer guidance
1. Activate prior knowledge	Connect the topic to a local feedstock, plant, waste stream, energy need or workplace problem.
2. Explain the technical core	Use concise teaching, diagrams and source course material to establish concepts, terminology, process relationships and safety conditions.
3. Demonstrate or model	Use safe demonstrations, samples, process diagrams, calculations, data or simulations to make the process observable.
4. Guided application	Learners complete structured feedstock, design, sizing, monitoring, maintenance or troubleshooting tasks with trainer feedback.
5. Independent evidence	Learners complete a quiz, calculation, case, practical record or design/evaluation task aligned with learning outcomes.
6. Reflect and connect	Link the module to the next course, workplace practice, environmental responsibility and the learner portfolio.

6.3 Practical Training Categories

Practical category	Examples in the Biomass programme
Feedstock and resource work	Resource inventory; moisture/bulk-density/ash interpretation; feedstock characterization; collection/storage planning; co-digestion and pretreatment decision making.

Practical category	Examples in the Biomass programme
Process and conversion work	Anaerobic-digestion process mapping; gasifier-stage diagrams; converter/process selection; biofuel process-flow mapping; energy and mass-related calculations from course data.
Design and sizing	Biogas digester sizing; OLR/HRT calculations; gasifier selection; resource/demand matching; mini-grid or biomass-power system sizing; conceptual plant layout.
Monitoring and diagnostics	Gas/plant performance trends; pH/loading scenarios; syngas-quality cases; plant efficiency; logbooks; fault symptoms; root-cause and corrective-action exercises.
Installation and O&M	Site/installation checklists; commissioning sequences; startup/shutdown; inspection routes; preventive-maintenance schedules; spare-parts planning; safe troubleshooting.
Project and sustainability	Technology-selection matrices; cost-benefit and socio-economic cases; community participation; sustainable feedstock management; environmental and OHSE risk assessment.

6.4 Work-Based and Field Learning

Where partner capacity and safety arrangements allow, learners should observe or undertake supervised tasks at farms, livestock facilities, rice/cassava/palm-oil or other agro-processing sites, sawmills, municipal organic-waste facilities, biogas plants, briquetting operations, gasification systems, biomass boilers/CHP facilities or rural energy projects. Field activities should have defined learning outcomes, responsible supervision, prior hazard assessment and a structured observation/work log.

6.5 Digital and Simulation-Supported Learning

- Use short digital lessons and diagrams to explain biomass supply chains and conversion pathways before practical application.
- Use spreadsheet or calculator exercises for resource estimates, digester sizing, HRT/OLR, gas yield, gasification efficiency, plant efficiency, energy demand and project-evaluation calculations contained in the course materials.
- Use process-flow and system-layout tools to represent digesters, gasifiers, biofuel processes, boilers/CHP, mini-grids and installation/O&M workflows.
- Use simulated operational datasets when live plant data or laboratory facilities are unavailable, while clearly identifying the data as training material.
- Use quizzes and short case tasks for formative checks before learners proceed to higher-risk practical work.

6.6 Practical Delivery Limits

Practical learning must be scaled to the equipment, facilities, supervision and legal requirements of each provider. High-temperature gasification, pressurised/combustible gas systems, live electrical equipment, rotating machinery, chemical biofuel processing, concentrated acids/alkalis or alcohols, biological waste handling and confined-space work should only be conducted in appropriately equipped facilities under competent supervision. Where those controls are unavailable, trainers should use demonstrations, process simulations, samples, videos, calculations and case-based alternatives.

7. Assessment and Certification Alignment

7.1 Assessment Principles

- Assess the stated learning outcomes and competency domains rather than recall of isolated definitions alone.
- Combine formative checks with applied evidence such as feedstock/resource assessments, calculations, diagrams, design tasks, logbooks, maintenance plans and diagnostic cases.
- Require safe behaviour and correct risk controls as part of practical competence; an unsafe practical act should not be treated as satisfactory performance.
- Increase assessment complexity from Basic identification/explanation to Advanced design, optimisation, data interpretation, diagnosis and project evaluation.
- Use clear marking criteria and retain assessment evidence for trainer review, QA and later certification alignment.

7.2 Recommended Assessment Methods

Assessment method	Suitable evidence
Knowledge quiz / short answer	Terminology, process stages, component functions, feedstock properties, safety principles and technology comparisons.
Technical calculation	Moisture/solids, digester sizing, HRT/OLR, gas yield, efficiency, resource/demand sizing or economic indicators using formulas provided in course materials.
Process or system diagram	Biomass conversion pathway, anaerobic digestion, gasification stages, biofuel process flow, power/CHP flow, commissioning or O&M workflow.
Design / selection task	Digester/gasifier/technology selection, feedstock/preparation plan, mini-grid concept, plant layout or storage/handling plan.
Data / fault case	Operational trends, gas quality, plant efficiency, alarms/symptoms, root-cause analysis, corrective action and maintenance response.
Practical observation	Safe feedstock handling, measurement/demonstration, inspection, checklist use, maintenance procedure or supervised equipment familiarisation.
Project / feasibility case	Resource assessment, sizing, cost-benefit, socio-economic/community model and sustainability recommendations.

7.3 Certification Alignment

WP4 establishes the competency-based certification framework, assessment tools and procedures for the biomass energy field. This D3.1 curriculum therefore defines outcomes and evidence types that can be mapped to WP4 once the certification framework is finalised. The supplied Biomass course materials do not define a formal programme pass mark, accreditation level or certification threshold; these should not be invented at D3.1 stage.

7.4 Assessment Records

Providers should retain assessment briefs, marking criteria, learner evidence, practical observation records, attendance/completion information and feedback in an organised project/institutional record system. Where digital learning is used, completion and quiz evidence should be retained in a form suitable for quality review and project reporting.

8. Training Resources, Health and Safety, Environment and Inclusion

8.1 Indicative Training Resources

Resource category	Indicative resources
Digital/classroom	Projector/display, internet or offline LMS access, Biomass course files, process diagrams, calculators/spreadsheets, case datasets and worksheets.
Feedstock samples and basic testing	Representative safe biomass samples; weighing/volume tools; moisture-testing demonstration equipment where available; containers and PPE for clean feedstock handling.
Biogas learning	Digester/component models or pilot unit where available; pH/temperature/gas-flow demonstration instruments; safe piping/valve examples; process and performance datasets.
Gasification/thermal learning	Gasifier/boiler models, diagrams or supervised training rigs; temperature/process measurements and syngas/efficiency datasets. Live high-temperature systems require specialist facilities and supervision.
Biofuel learning	Process diagrams, safe sample containers, laboratory glassware/instruments and quality data where approved. Chemical production activities require suitable laboratory controls and competent supervision.
Power/O&M learning	Plant component diagrams or de-energised training components; logbooks, checklists, maintenance tools, diagnostic instruments and commissioning/fault scenarios.
Field/WBL	Approved host site, supervisor, induction, PPE, risk assessment, observation/work log and defined learner tasks.

8.2 Health and Safety Requirements

- Conduct a risk assessment and safety briefing before every laboratory, workshop, plant or field activity.
- Treat biogas and syngas as combustible gases; prevent leaks and ignition sources, provide ventilation, and use appropriate gas detection/monitoring where required by the facility.
- Recognise carbon monoxide and other gas hazards in gasification/combustion environments; never use live gas-producing equipment in inadequately ventilated training spaces.
- Control fire, hot-surface, pressure, steam and burn hazards around digesters, gasifiers, boilers, engines and CHP equipment.
- Use safe procedures for chemical biofuel-processing materials and for acids/alkalis or alcohols; only approved laboratory activities should be conducted with appropriate ventilation, storage, spill controls and PPE.
- Control biological exposure from manure, sewage, food waste and digestate through hygiene, suitable PPE and safe handling/cleaning practices.
- Use guarding, isolation and lockout/tagout principles for rotating machinery and electrical/mechanical maintenance tasks.
- Provide emergency procedures, first-aid/fire response arrangements, clear supervision and stop-work authority during practical training.

8.3 Environmental and Sustainability Requirements

- Prioritise residues, wastes and sustainably available biomass and avoid training messages that encourage deforestation, unsustainable harvesting or removal of residues needed for soil health and other essential uses.
- Consider seasonal availability, competing uses, transport distance, moisture/quality losses and long-term feedstock supply when evaluating projects.
- Manage digestate, ash, wastewater, tar/condensate, spent process materials and other residues according to applicable environmental requirements and safe disposal/reuse practices.
- Consider air emissions, smoke/particulates, odour, noise, water protection, soil impacts, greenhouse-gas implications and community health in technology and site decisions.
- Include circular-economy benefits such as waste reduction, nutrient recovery, productive use of residues and local value creation where technically and environmentally appropriate.

8.4 Inclusion and Accessibility

Training should provide equal opportunity for women and underrepresented learners, use inclusive language and participation methods, and avoid assigning practical roles on the basis of gender. Trainers should adapt digital access, language support and practical task organisation so that learners can participate safely and meaningfully while preserving the same technical competency expectations.

9. Trainer and Learner Guidelines

9.1 Trainer Guidelines

- Use this curriculum as the controlling teaching plan and the BM-B/BM-A educational materials as the detailed technical content source.
- Check prerequisite knowledge at the start of each level and provide bridging explanation in basic science, chemistry, biology, mathematics, electricity or mechanics where necessary.
- Explicitly connect Basic resource/process concepts to Advanced design, optimisation, power-system, diagnostic and lifecycle applications rather than repeating content without progression.
- Use local feedstocks and realistic West African cases while maintaining technical accuracy and sustainability safeguards.
- Use calculations, process diagrams, design worksheets, operational datasets, maintenance records and safety cases to develop applied engineering reasoning.
- Conduct a safety briefing before practical or field activity and stop any activity that cannot be performed safely with available facilities, controls and competent supervision.
- Use assessment results and learner feedback to identify topics requiring reteaching or curriculum/material revision.
- Keep course records, assessment evidence and versioned materials organised in the project/shared institutional repository.

9.2 Learner Guidelines

- Complete modules in the recommended sequence unless the trainer confirms equivalent prior competence.
- Participate in theoretical, digital, practical and case-based learning and ask for clarification when technical or safety concepts are unclear.
- Follow all feedstock, biological, chemical, fire/gas, hot-process, mechanical and electrical safety instructions and use required PPE.
- Keep calculations, process diagrams, design worksheets, monitoring records and assessment evidence organised as part of a learning portfolio where used by the provider.
- Do not operate or modify live biomass, gas, thermal, chemical or electrical equipment without explicit trainer/site authorisation and supervision.
- Apply professional conduct, teamwork, respectful communication, environmental responsibility and good housekeeping during training and workplace exposure.

9.3 Suggested Learning Portfolio Evidence

Level	Example portfolio evidence
Basic level	Local biomass-resource map, feedstock-characteristics/management task, conversion-selection matrix, biogas process/component exercise, gasification/rural-system case, installation/O&M checklist and safety task.
Advanced level	Biogas design/sizing and performance analysis, gasifier/process-control and syngas-quality case, biofuel process/quality task, biomass power/mini-grid feasibility study, commissioning/maintenance portfolio and OHSE risk assessment.

10. Quality Assurance, Monitoring and Curriculum Review

10.1 Quality Assurance Objectives

Quality assurance should ensure that the curriculum remains technically accurate, pedagogically coherent, industry-relevant, inclusive, assessable and consistent with project requirements. Quality checks should cover both this curriculum and the detailed Biomass educational materials used to deliver it.

10.2 Curriculum QA Cycle

Stage	Required action
1. Pre-delivery review	Confirm module codes/titles, learning-unit sequence, outcomes, current course materials, activities, assessment tasks, safety requirements and trainer readiness.
2. Stakeholder validation	Collect structured input from VET institutions, biomass/energy companies, agro-industries, waste-management actors and relevant authorities on workforce needs, technology relevance and local constraints.
3. Course testing	Pilot modules with trainers/partner VET providers; record implementation issues, learner questions, timing, practical feasibility and resource gaps.
4. Feedback analysis	Review learner/trainer feedback, assessment performance, practical feasibility, safety observations and inclusion/access issues.
5. Technical/pedagogical revision	Correct inaccuracies, reduce duplication, improve Basic-to-Advanced progression and update activities/assessment while preserving document control.
6. Version control and approval	Issue a new controlled version, archive superseded versions and retain evidence of review/approval.

10.3 Monitoring Indicators for Training Delivery

- Completion of planned modules and learning units within the agreed delivery schedule.
- Learner participation and completion, including monitoring of gender participation and inclusive access.
- Assessment performance by learning outcome and identification of recurring knowledge or skill gaps.

- Learner and trainer feedback on clarity, relevance, practical value and digital accessibility.
- Availability and adequacy of feedstock samples, training equipment, instruments, digital resources and safe practical-learning opportunities.
- Number and quality of industry/VET stakeholder contributions to curriculum review and work-based learning opportunities.
- Correct use of project visibility, document control, data-protection and record-keeping procedures.

10.4 Curriculum Review Triggers

- Material changes in biomass feedstock availability, conversion technologies, digester/gasifier/boiler/biofuel equipment, monitoring methods or industry practice.
- Changes in environmental, waste, fire/gas, chemical, electrical, occupational-safety, energy or certification requirements.
- Repeated learner/trainer feedback showing unclear sequencing, duplication or insufficient practical application.
- Assessment evidence indicating learning outcomes are not being reliably achieved.
- Changes in VET infrastructure, laboratory/workshop capability, digital tools or industry partnership opportunities.
- Formal feedback from WP3 course testing, WP4 certification development or project quality-assurance review.

11. Implementation, Document Control and Relationship to Educational Materials

11.1 Recommended Implementation Sequence

Phase	Implementation guidance
Phase 1 - Prepare	Confirm trainers, learner cohort, facilities, digital access, safety controls, language needs and current Biomass course-file versions.
Phase 2 - Deliver Basic level	Complete BM-B1 to BM-B5 in sequence, using formative assessment and practical evidence to confirm readiness for Advanced work.
Phase 3 - Deliver Advanced level	Complete BM-A1 to BM-A5 in sequence, increasing emphasis on engineering design, optimisation, data interpretation, power/project evaluation, diagnosis and lifecycle O&M.
Phase 4 - Practical/WBL consolidation	Where feasible, use laboratories/workshops, supervised field exposure, industry mentoring or applied projects to consolidate competencies.
Phase 5 - Assessment and feedback	Complete module evidence, collect learner/trainer feedback and identify gaps or revisions.
Phase 6 - Certification alignment / reporting	Apply the approved WP4 certification procedures when available and retain required evidence for project reporting and QA.

11.2 Relationship between Curriculum and Detailed Course Materials

Curriculum / Guidelines (this document)	Detailed Biomass Educational Materials (D3.7)
Defines programme purpose, levels, module sequence, learning-unit structure and learning outcomes.	Provides full technical explanations, figures, equations, worked examples, review questions, cases and detailed teaching content.
Defines competency domains and expected evidence.	Provides the subject matter used to build learner understanding and practice.
Defines delivery, practical training, assessment, safety and QA principles.	Provides module/chapter-specific content that trainers adapt into lessons, digital resources and activities.
Controls coherence and Basic-to-Advanced progression.	Supports implementation but should not independently change approved curriculum outcomes or programme structure.

11.3 Document Management and Version Control

- Store the approved DOCX master and PDF submission copy in the PRISTINE VET shared project repository using clear versioned filenames.

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- Use the PDF version as the fixed-layout submission/distribution copy and retain the DOCX as the controlled editable master.
 - Archive superseded versions so that only the current approved files remain active for delivery and reporting.
 - Maintain the required EU visibility elements, funding acknowledgement and disclaimer on official/public versions.
 - Retain curriculum, delivery, assessment, feedback and approval records in accordance with project record-keeping requirements.