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Train-the-trainers (ToT) toolkit

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Module 4: Energy and Building: Advanced Energy Management and Production

Responsible Partner: University of Freiburg

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Table of contents

Abbreviations and acronyms 4
1. Introduction 5
2. Teaching Methodologies 6
2.1 Learning Objectives 6
2.2 CBL Teaching method 7
2.3 Suggested delivery sequence 7
3. Tool Tutorials 8
3.1 PV generation and building integration 8
3.2 Storage and demand-side management 9
3.3 Model calibration and validation 10
4. Assessment Strategies 11
5. Additional Resources 12
6. References 14

List of Tables

Table 1: Abbreviations and acronyms 4

Abbreviations and acronyms

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Acronym	Description
BAPV	Building-Applied Photovoltaics
BEMS	Building Energy Management System
BESS	Battery Energy Storage System
BIPV	Building-Integrated Photovoltaics
CBL	Challenge-Based Learning
DHC	District Heating and Cooling
DSM	Demand-Side Management
EV	Electric Vehicle
HVAC	Heating, Ventilation and Air Conditioning
IoT	Internet of Things
KPI	Key Performance Indicator
nZEB	Nearly Zero Energy Building
PV	Photovoltaics
PVGIS	Photovoltaic Geographical Information System
SOC	State of Charge
SRI	Smart Readiness Indicator
ToT	Train-the-Trainers
V2B / V2G	Vehicle-to-Building / Vehicle-to-Grid

1. Introduction

This Train-the-Trainers (ToT) toolkit supports educators delivering Module 4, “Energy and Building: Advanced Energy Management and Production”. It connects the module’s energy-production content with practical teaching on renewable integration, energy storage and intelligent building operation. Trainers guide learners from understanding individual technologies to evaluating an integrated building energy strategy.

Module Overview

Topic and content summary: Renewable and conventional energy supplies; solar PV and solar thermal systems; wind energy, geothermal heat pumps and district heating and cooling; BIPV and BAPV; PV monitoring and losses; battery storage; DSM; smart buildings, nZEB concepts, digitalisation, grid interaction and energy flexibility. Modelling, calibration and validation connect system choices with measured performance.

Teaching methodology: A suggested Challenge-Based Learning (CBL) approach combines short interactive lectures, guided calculations, group investigation, scenario testing and reflection. The central challenge is to reduce grid imports and peak demand while maintaining occupant comfort and practical operating constraints.

Target learners and preparation: Suitable for learners in building, energy, architecture and related disciplines. Before delivery, check their understanding of energy balances, power and energy units, basic renewable technologies and spreadsheet calculations. Provide a short bridging exercise where needed.

Suggested tools: PVGIS for PV-resource exploration and an instructor-prepared spreadsheet for load, storage and control calculations. Equivalent analysis tools may be used. These are proposed teaching tools; the exercises can also use prepared CSV data.

Suggested duration: 26 hours, comprising 8 hours of interactive teaching, 4 hours of guided tool work, 10 hours of group investigation and 4 hours of presentations and reflection. Trainers may distribute these hours across online and in-person sessions.

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2. Teaching Methodologies

2.1 Learning Objectives

After completing Module 4, learners should be able to:

• Explain how energy efficiency, renewable production and digital control contribute to sustainable building operation.

• Compare solar, wind, geothermal, biomass and district-energy options against building demand, local resources and integration constraints.

• Distinguish BIPV from BAPV and explain how orientation, shading, temperature and system losses influence PV performance.

• Analyse time-varying demand and generation, distinguish kW from kWh, and calculate grid exchange and PV utilisation.

• Propose storage sizing and DSM strategies with explicit energy, power, comfort and service constraints.

• Develop a transparent building-energy model, compare it with measurements, and distinguish calibration from independent validation.

• Assess smart controls, grid interaction and V2B opportunities while recognising data quality, interoperability and operational limitations.

• Defend a feasible integrated energy strategy using reproducible calculations, sensitivity analysis and clear communication.

2.1.1 Strategies for engaging lectures

Begin with a daily load curve and a PV-generation curve. Ask learners to identify the mismatch before introducing storage or load shifting. Use paired discussion, short calculations and prediction questions, then revisit the same curves after each intervention.

Use photographs of roofs and façades to discuss BIPV versus BAPV. Ask teams to explain which building function an integrated PV element replaces. Rotate technical, analysis and reporting roles to support participation across disciplines.

Teaching distinction: Nearly-zero energy buildings, annual net-zero energy balances and zero-emission buildings describe different concepts. An annual balance does not establish hourly self-sufficiency, off-grid operation or regulatory compliance. Require learners to state their energy boundary and accounting period.

2.2 CBL Teaching method

Challenge: How can a selected teaching, office or residential building use local renewable electricity and flexible demand to reduce grid imports and peak demand while meeting occupant needs? Use one consistent building and analysis period for all scenario comparisons.

Engage: Present the building, its demand pattern and site constraints. Teams of three or four define the problem, identify stakeholders and agree measurable success criteria. The trainer checks whether the proposed boundary includes electricity only or also heating and cooling.

Investigate: Teams establish a baseline, compare supply options and identify suitable PV surfaces and flexible loads. They document data sources, missing inputs and assumptions. Trainers ask learners to justify technology choices and assess the limits of their evidence.

Act: Teams compare four scenarios: baseline; PV only; PV plus storage; and PV plus storage and DSM. They test at least two battery sizes and one alternative control schedule, then present a recommendation with quantified benefits and limitations. Peer feedback should lead to one documented revision.

2.3 Suggested delivery sequence

Interactive teaching — 8 hours: Energy transition and building supply options (2 h); PV integration and performance (2 h); BESS and DSM (2 h); smart buildings, nZEB principles and grid interaction (2 h). Use PDF pages 3–49, 50–69, 70–86 and 87–101 respectively.

Guided tool work — 4 hours: PV-resource and generation exercise (2 h); time-step energy balance, battery operation and DSM demonstration (2 h). Learners save one verified baseline before beginning group work.

Group investigation — 10 hours: Define the case and audit inputs (2 h); build and check the baseline, including calibration where measurements exist (3 h); compare scenarios and sensitivities (3 h); prepare the report and presentation (2 h).

Presentation and reflection — 4 hours: Team presentations and questions (2 h); peer feedback, trainer-led synthesis and revision (2 h). For large classes, use parallel presentation groups.

3. Tool Tutorials

3.1 PV generation and building integration

- Installation and preparation

Suggested software: PVGIS, the European Commission Joint Research Centre's online PV tool [3]. Open it in a browser and prepare the building location, installed capacity, tilt and orientation. Test access before teaching and retain offline example data.

- Relevant features

Compare candidate surfaces using PV-production estimates and hourly data. Record the dataset, period and settings for reproducibility. Consult the official manual for interface and data definitions [3–4].

- Guided exercise

• Define a roof-mounted BAPV option and a façade or roof-integrated BIPV option. Record the available area and the building function replaced by BIPV.
• Enter location, PV capacity, tilt, azimuth and loss assumptions. Check the tool's angle conventions. Record mounting assumptions and any shading limitations.
• Generate and export a PV time series. Keep the source metadata with the results. Confirm whether output power is in W before converting to kW.
• Compare annual energy, specific yield and seasonal patterns. Use both an equal-capacity comparison and a feasible-area comparison where useful.
• Explain differences in generation and integration. Discuss access, ventilation, shading, architectural function and maintenance before selecting the option.

- Examples and troubleshooting

Compare façade and roof yield against demand, integration, ventilation and maintenance needs. If results are implausible, check capacity units, angle conventions and losses. Align load and PV timestamps before combining them. Site-specific shading and integrated-module behaviour require further assessment.

3.2 Storage and demand-side management

- Preparation and model structure

Use an instructor-prepared spreadsheet or equivalent code. Define inputs for time, building load, PV output, electricity prices, battery capacity, charge/discharge power, efficiency and operating limits. Use one consistent time step. Keep input assumptions, calculations and result summaries separate.

- Guided calculation

1. Baseline: Let L and G denote average load and PV power in kW over a time step of Δt hours. Without storage, direct PV use = min(L, G); grid import = max(L − G, 0); grid export = max(G − L, 0). Energy for each interval equals power × Δt.
2. Battery: Set usable energy bounds Emin and Emax, initial stored energy E, maximum charge/discharge power and separate efficiencies ηc and ηd. For PV-only charging, charge power C = min(max(G − L, 0), Cmax, (Emax − E)/(ηc × Δt)). Discharge power D = min(max(L − G, 0), Dmax, (E − Emin) × ηd/Δt).
3. Update: Enew = E + ηc × C × Δt − D × Δt/ηd. Calculate grid import = max(L + C − G − D, 0) and export = max(G + D − L − C, 0). Verify that bounds are respected and that charging and discharging do not occur together. Compare scenarios with equivalent initial and final stored energy, or account for the difference.
4. DSM: Shift a defined flexible load into a permitted operating window. Preserve its required service or energy, check maximum power and completion time, and recalculate the full balance. For HVAC flexibility, include a justified comfort model or restrict the exercise to non-thermal loads.

- Outputs and worked check

Report demand, PV generation, grid exchange, peak import, battery losses and cost. Self-sufficiency is the share of demand met by on-site PV, including PV-origin battery discharge. Distinguish PV retained on-site, including losses, from useful PV delivered to loads. Check energy bounds and one interval manually.
Illustrative check: During a one-hour interval, load is 4 kW and PV is 6 kW. A battery with sufficient headroom charges at 2 kW with ηc = 0.95. Stored energy rises by 1.9 kWh; 4 kWh serves the load, 0.1 kWh is lost, and grid exchange is zero.

3.3 Model calibration and validation

- Advanced modelling workflow

Use a time-step electricity balance for PV, storage and appliance scheduling. Add a dynamic thermal model when testing temperature-dependent HVAC demand or comfort. State the model boundary; an electrical balance is not a complete building-performance simulation.
Verification: Check units, signs, timestamps, missing records and interval lengths. Confirm that demand plus charging plus exports equals PV generation plus discharging plus imports at each time step. Check battery losses and energy bounds separately.
Calibration: Compare predictions with measurements over a defined period, using daily profiles and totals. Adjust only physically defensible parameters, such as schedules or PV losses, within stated bounds. Record and justify each adjustment.
Validation: Freeze the calibrated parameters and test them against a separate measured period. Compare totals, peak demand and time-series errors using consistent units and aggregation. Report mean bias and a measure of error magnitude, such as root-mean-square error. Set acceptance criteria before fitting and explain their relevance to the exercise.
If independent measured data are unavailable, report that limitation. Testing against the calibration period is not independent validation. Synthetic profiles support verification but cannot establish real-building calibration.

- Sensitivity and interpretation

Vary at least two influential assumptions, such as battery capacity, PV capacity or load availability. Distinguish sizing effects from control effects. Evaluate energy, cost and emissions separately, stating emission factors, export accounting and cost assumptions where used.

- Smart-building extension

Identify sensors, control actions, grid signals and occupant overrides. V2B requires vehicle availability, bidirectional capability and departure charge limits. Backup operation requires suitable islanding and protection. Use SRI for discussion; a classroom checklist is not an official rating.

4. Assessment Strategies

4.1 Module lectures

Use formative questions and brief calculations to identify misconceptions. Ask learners to explain BIPV versus BAPV, distinguish kW from kWh, identify a flexible load, and explain why annual PV generation equal to annual demand does not guarantee zero grid imports. Provide feedback before group modelling begins.

4.2 Assessment of software and problem-solving tasks

Suggested submission: A team report of 2,000–2,500 words, calculation files and a 10-minute presentation. Include inputs, baseline, checks, scenario comparisons, sensitivities and recommendations. Each learner adds a short reflection on their contribution and one revised technical decision.

Compare all four scenarios on the same boundary and period. Assess reproducibility and correct energy accounting. With measured data, require calibration and independent validation; otherwise require verification and a validation plan.

4.3 Grading rubric and evaluation criteria

Suggested weights for local adoption:

• Research and analysis — 30%: Appropriate inputs and assumptions; correct baseline and energy balances; credible verification, calibration or validation; meaningful sensitivity analysis.

• Collaboration and participation — 20%: Shared responsibility, documented individual contributions, constructive peer feedback and evidence of joint decision-making.

• Solution design — 30%: Feasible PV, storage and DSM choices; consistent scenario comparisons; respect for comfort and service constraints; recognition of economic and operational trade-offs.

• Presentation and defence — 20%: Clear figures and conclusions, reproducible supporting files, justified recommendations and thoughtful responses to questions.

5. Additional Resources

- **Core module materials**

Module 4 course overview [1] and the 102-page lecture slide set by Prof. Dr.-Ing. Mohammadreza Aghaei [2]. Use the overview to maintain the full scope, including modelling, calibration and validation, alongside the technology-focused slides.

Lecture navigation: Energy transition and building-energy challenges, PDF pages 3–32; energy sources and supply systems, pages 33–49; BIPV/BAPV and PV performance, pages 50–69; DSM and battery storage, pages 70–86; smart buildings, nZEB, SRI and grid flexibility, pages 87–101. Page numbers refer to the PDF file order.

- **Trainer resource pack**

Prepare a building description and annotated system diagram; time-stamped load and PV profiles; a battery specification sheet; operating windows for flexible loads; tariff assumptions; a blank scenario-comparison sheet; a worked calculation; and an assessment brief. Include measured data for calibration and validation if available.

Provide a short glossary before teaching. Ask learners to record the location, year, interval, units and source of every time series. If a profile or price is illustrative, label it in the case brief and limit conclusions to the teaching scenario.

- **Supporting resources**

PVGIS official website and documentation [3–4] support the PV exercise. European Commission guidance on nearly-zero and zero-emission buildings [5] supports terminology and policy context. Consult the official SRI materials [6] when developing the smart-building discussion.

Use the slides' case studies as prompts for evaluating assumptions rather than as universal performance guarantees. Discuss how climate, occupancy, system configuration and control affect whether a proposed benefit is realised.

6. References

[1] nZEBRA. Module 4: Energy and Building: Advanced Energy Management and Production. Course overview. Supplied Word document.

[2] Aghaei, Mohammadreza. Module 4: Energy and Building: Advanced Energy Management and Production. University of Freiburg. Supplied lecture slides, 102 PDF pages.

[3] European Commission, Joint Research Centre. Photovoltaic Geographical Information System (PVGIS). https://photovoltaic-geographic-information-system.ec.europa.eu/

[4] European Commission, Joint Research Centre. PVGIS 5 user manual. https://joint-research-centre.ec.europa.eu/photovoltaic-geographical-information-system-pvgis/using-pvgis-5/pvgis-5-user-manual_en

[5] European Commission. Nearly-zero energy and zero-emission buildings. https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/nearly-zero-energy-and-zero-emission-buildings_en

[6] European Commission. Smart readiness indicator. https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/smart-readiness-indicator_en

Online resources accessed 22 September 2026.