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Train-the-trainers (ToT) toolkit

WP4, Task 4.2

Train-the-trainers (ToT) toolkit

Module 1: Climate Resilience: Adapting Buildings to Climate Change

Responsible Partner: ULUND (Lund University)

WP4, Task 4.2

Developed by: Urban Systems and Dynamics research group, Department of Building and Environmental Technology, Lund University

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Abbreviations and acronyms

Table 1: Abbreviations and acronyms

Acronym	Description
BEM	Building Energy Modelling
EPW	EnergyPlus Weather file
GCM	Global Climate Model
PBL	Problem Based Learning
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
TMY	Typical Meteorological Year

1. Introduction

This Train the Trainers toolkit supports educators who will deliver Module 1, Climate Resilience: Adapting Buildings to Climate Change. The module combines climate science, future climate data, building-performance assessment, and climate-responsive design. It is designed around problem-based learning: participants investigate a defined problem, select and interpret evidence, and use the results to justify adaptation and mitigation responses.

1.1.1.1. Module Overview:

- **Topic and content summary:** The module examines how buildings and urban environments can remain functional, comfortable, and energy efficient under typical and extreme future climate conditions. The four parts cover: (1) climate change fundamentals, global warming, IPCC assessments, and scenario frameworks; (2) climate models, downscaling, climate-file formats and uncertainty; (3) climate adaptation, resilience and mitigation in the built environment; and (4) climate-resilient urban infrastructure, urban form and microclimatic variation.

- **Teaching methodology:** Problem Based Learning (PBL), implemented through self-paced online study, formative quizzes, an individual climate-data investigation, interactive plenary teaching, and a group EnergyPlus simulation project.

- **Software and resources:** EnergyPlus for building energy simulations; Elements for viewing and editing weather files; Google Colab notebooks for climate-data and simulation-output analysis. The notebooks are provided, so prior Python knowledge is not required. Students may use their own code or another suitable method when they have the relevant skills.

- **Suggested delivery:** Four self-paced online parts followed by one full in-person day. The online phase includes quizzes and an individual assignment. The in-person day

includes a concise synthesis lecture, interactive activities, group simulation work, and project reporting.

For further information or to request additional teaching and learning materials, please contact Prof. Kavan Javanroodi at kavan.javanroodi@byggtek.lth.se .

All available materials can be provided upon request to evaluators, educators, learners, and members of the wider public.

2. Teaching Methodologies

This section describes the teaching approaches used in the module, including the PBL method. It provides step-by-step guidance on how to apply PBL, strategies for engaging lectures, and a sample lecture outline.

2.1. Learning Objectives

After completing the module, participants should be able to:

- Explain the main drivers and observed consequences of climate change, and distinguish climate-change mitigation, adaptation and resilience in relation to buildings and urban systems.
- Interpret the role, strengths and limitations of GCMs, RCMs, emissions scenarios, downscaling and climate-projection uncertainty.
- Read and critically compare historical and future EPW climate files, including differences associated with climate scenario and climate-model source.
- Use EnergyPlus to assess the effects of historical and future climate conditions on heating demand, cooling demand, peak loads, operative temperature and unmet hours.
- Interpret simulation results critically and propose design or retrofit responses that address climate risks and thermal comfort.
- Communicate analysis clearly in figures, tables and concise written reports.

2.2. PBL Teaching method

The module uses a staged PBL process. The problem begins with a practical question: how may changing climate conditions affect building energy demand, thermal comfort and suitable design responses? Learners first develop a shared conceptual basis through the four online parts. They then investigate future climate data individually and use the findings as preparation for the in-person simulation work.

I. **Orient and define the problem:** Introduce the relationship between future climate, building performance, comfort and design. Use the four online parts to establish key concepts, including climate scenarios, GCMs and RCMs, climate-data uncertainty, resilience, mitigation and urban microclimate.
II. **Investigate climate data individually:** Students analyse nine 2035 EPW files for Madrid from three climate models and three RCPs. They compare temperature, wind speed and solar radiation using the supplied Google Colab notebook, Elements, or another appropriate method.
III. **Apply and test in groups:** Groups of four use predefined EnergyPlus models of a 144 m2 one-storey house in Madrid and Stockholm. They run the models with historical TMY and assigned future climate files, analyse the output, and connect results to climate sources, building properties and design choices.
IV. **Discuss and reflect:** Groups select evidence that supports their conclusions, compare the two cities, and reflect on climate adaptation and design strategies. They present the key findings in up to two slides and submit a group report.

2.3. Interactive in-person teaching

The in-person day begins with a summary of the four lectures. Around half of this session should be reserved for active participation rather than presentation. Recommended activities include Mentimeter questions to check conceptual understanding and expose contrasting interpretations, short minute papers asking learners to identify an uncertainty or design implication, and brief peer discussion before the group work begins. These activities allow the trainer to identify misconceptions before students interpret the simulation results.

2.4. Suggested delivery sequence

Table 2 summarizes the suggested delivery sequence, within the structure of the nZEBRA course and program.

Table 2: Suggested delivery sequence within the structure of the nZEBRA course

Phase	Learning activity	Trainer role
Online	Four self-paced lecture parts and 10 Blackboard quiz questions after each part. Learners may make multiple attempts before progressing.	Provide clear sequencing, quiz feedback and access to software and notebooks.
Online individual work	Climate-data assignment: analyse the Madrid future EPW files and upload an individual report of up to 1,000 words or five pages.	Clarify file naming, expected plots/statistics, academic integrity and submission arrangements.
In person	Summary lecture with Mentimeter questions, minute papers and discussion, followed by PBL group work.	Connect the online content to the group problem and guide interpretation without solving it for the groups.
Group project	EnergyPlus simulations, output analysis, short presentation and group report.	Support software issues, prompt evidence-based comparison and facilitate feedback across groups.

3. Tool Tutorials

This section provides a tutorial on the tools used in Module 1 including EnergyPlus, the primary software used in the module. It includes an installation guide, relevant features, examples, and troubleshooting tips.

3.1. Software: EnergyPlus

EnergyPlus is the primary building energy simulation engine used in the group project. Students work with prepared Input Data Files (IDFs), where the geometry and systems are already defined. The purpose is to assess the effects of different weather files and building properties, rather than to teach model construction from scratch.

3.1.1. **Installation and preparation**

Students should install EnergyPlus during the online period, before the in-person day. The EnergyPlus installation page and the tutorial series should be shared through the course platform. The recommended tutorial sequence is Parts 1, 2 and 12 of the EnergyPlus for Beginners series by Dr Matheus Soares Geraldi:
EnergyPlus tutorials on YouTube
EnergyPlus downloads and installation
Before the in-person session, trainers should confirm that students can open EnergyPlus, locate the provided IDF and EPW files, and run a test simulation. The project does not require students to create geometry or HVAC systems.

3.1.2. **Relevant features and outputs**

- Use of EPW weather files for historical TMY and future climate conditions.
- Simulation of the predefined Madrid and Stockholm single-family house models.
- CSV outputs for heating and cooling energy, heating and cooling unmet hours, operative temperature, and outdoor dry-bulb temperature.

- Comparison of annual demand, peak hourly demand, unmet hours and hourly patterns under different climate files.

3.1.3. **Supporting analysis tools**

Google Colab notebooks are supplied for both assignments. The online notebook reads EPW files and provides time series, boxplots and summary statistics for temperature, wind speed and solar radiation. The group-project notebook reads EnergyPlus CSV outputs and produces an Excel summary table, detailed statistics, selected hourly data and standard plots. Students may use these tools directly in a browser or develop their own analysis when appropriate.

3.1.4. **Troubleshooting tips**

- EnergyPlus does not run: confirm that the installed version is compatible with the supplied IDF and that the simulation folder has write permission.
- Weather file is not found: check the EPW path in the simulation setup and retain meaningful city and scenario names in file names.
- Expected output is missing from the CSV: check that the relevant output variable or meter is requested in the IDF before running the simulation.
- Colab upload or plot fails: upload EnergyPlus CSV result files, not IDF or EPW files, and run the notebook from the first cell.
- Results appear inconsistent: first check units, period of aggregation, file labels and whether values are total or normalised by floor area.

4. Assessment Strategies

4.1. Online lecture and quiz assessment

Each of the four online parts includes 10 Blackboard quiz questions. Students may make multiple attempts and must complete the quiz before moving to the next part. The quizzes serve as formative assessment: they check essential concepts such as scenario frameworks, downscaling, climate uncertainty, adaptation and resilience, while giving students repeated opportunities to correct misunderstandings.

4.2. Individual climate data assignment

Students individually analyse nine future 2035 EPW climate files for Madrid, representing three GCM sources and three RCPs. They use Elements and the provided Google Colab notebook, or another suitable analysis method. The report has a maximum length of 1,000 words or five pages and should include a brief introduction, methods, results, and discussion/conclusion.

At minimum, the report should use plots to compare air temperature and wind speed, include summary statistics for temperature, wind speed and solar radiation, relate differences to climate scenario and climate-model source, and reflect on likely implications for the energy performance and indoor comfort of a typical Madrid apartment.

4.3. In-person EnergyPlus group project

Groups of four receive predefined EnergyPlus models of a 144 m2 single-storey house in Madrid and Stockholm. Each group runs both models using the historical TMY and assigned future EPW files. The group report may be up to 2,500 words or six pages, excluding references, and should normally include an abstract, introduction, methodology, results and analysis, discussion, conclusions and references.

The report should critically compare weather conditions, annual and peak heating/cooling demand, unmet hours and operative temperature. It should also compare the implications for Madrid and Stockholm, discuss climate-responsive design strategies, and use at least two references per city to support discussion of the thermal properties and the possible effect of current new-build or deep-renovation standards. Groups prepare up to two slides presenting their main findings and conclusions.

4.4. Evaluation criteria

Table 3: Evaluation criteria for Module 1

Assessment item	Criteria	Weight
Online Quizzes	All quizzes must be completed before the in-person week. Multiple attempts are permitted.	Mandatory requirement
Individual Assignment on Climate data	Individual report assessing future climate files, including a clear structure, critical analysis, discussion and reflection.	20%
Group Assignment on Energy and Climate analysis	Structure, clarity and appropriate selection of figures and tables	20%
	Critical analysis and presentation of results	35%
	Discussion and reflection on results, including design responses	25%

Completion of the online quizzes and submission of the individual assignment are mandatory requirements for assessment of the group EnergyPlus assignment. Students who do not complete these requirements will not receive a grade for the group assignment. The group is assessed on both the report quality and the effectiveness of collaboration. The provided notebooks support the work but do not limit it. Any use of generative AI for text editing, coding support or plots must be acknowledged as specified in the assignment brief.

5. Additional Resources

- Core module resources: the four online lecture parts; future EPW files; prepared EnergyPlus IDF models; Elements; and the two Google Colab notebooks for climate-data and EnergyPlus-output analysis.
- Recommended tutorial videos: EnergyPlus for Beginners, Parts 1, 2 and 12, Dr Matheus Soares Geraldi.
- Recommended reference sources: IPCC Sixth Assessment Report; EnergyPlus documentation; EURO-CORDEX documentation and relevant national climate-data services; literature on climate-resilient building design, building energy modelling and urban microclimate.

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Train-the-trainers (ToT) toolkit

Module: 2 , Responsible Partner: H. Norrström, Halmstad University, WP4, Task 4.2

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Abbreviations and acronyms

Table 1: Abbreviations and acronyms

Acronym	Description
SDG	Sustainable development goals
EU	European Union
KPI	Key Performance Indicator

1. Introduction to Module 2 Circular economy

The topic's importance and relevance are quite clear. The linear way of production and consumption has led to mountains of waste, polluted soil, air and fresh water, loss of biodiversity and ocean acidification and of climate change.

We have one planet, but live as if we had five, ending the conditions for the life we live. Four limits of the nine planetary boundaries have already been exceeded, loss of biodiversity, altered land use, altered biogeochemical flows of nitrogen and phosphorus. Extraction from finite layers in the ground must stop and renewable sources should be used to the extent they grow to avoid over-extraction. This is the basis for circular economy as means to possibly mitigate the climate change and to achieve the sustainable development goals (SDG).

The aim of micromodule 2 is making students aware of the basis and the strategies for changing the linear direction to a circular one. Awareness of one's own carbon footprint is a first step. The second step is to be aware of the systemic hierarchy for circularity assessment. Case based learning, CBL, with examples will be utilized and the mixed/interdisciplinary teams of students will cooperate in finding energy efficient circular solutions and company symbiosis where one industry's waste becomes another's raw material in the chosen cases. No specific software will be used, but a method for learners is introduced and a website will be used for calculating one's own carbon footprint as a starting point in the course.

Recommended teaching duration for Module 2 is one week. This module can be tutored and learned in one week if there will be no study visits. For this Module a study visit is recommended though, if possible, in a company working with recycling or uses industrial symbiosis or with any other connection to the Module's topic.

2. Teaching Methodologies

2.1. Module 2 Learning Objectives

The learners will be introduced to the concept of carbon footprint and make and the R:s of circular economy for learning how to define them and use them.

These are usually explained as being five or seven, but there are actually ten R:s used within circular economy and in some literature, there are 12 R:s.

1. Refuse – prevent raw materials' use
2. Reduce – decrease raw materials' use
3. Redesign – reshape product with a view to circularity principles
4. Reuse – use product again (as second hand)
5. Repair – maintain and repair products
6. Refurbish – Revive product
7. Remanufacture – make new from second-hand product
8. Re-purpose – reuse product but with other function
9. Recycle – salvage material streams with highest possible value
10. Recover – incinerate waste with energy recovery

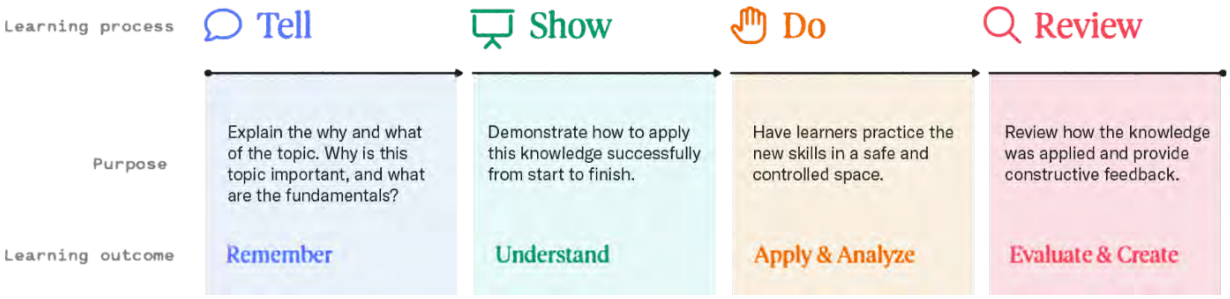
Furthermore, knowledge in the need for industrial symbiosis and how it can be framed, planned and working is one specifically important learning objective.

The four levels of circular economy; macro, meso, micro and nano will be introduced, explained and then implemented in the cases by the learners.

2.2. Learning a new skill or behaviour is a multi-step process that takes time and practice

Learning is a process described by various pedagogics and B. Bloom´s taxonomy gives the basics used by most lecturers. It is about framing and planning learning experiences. In contrast, the Kirkpatrick Model of training is about measuring of a learning experience, but this will not be explained here.

The learning process is an act of changed behaviour resulting in making use of new knowledge. Bloom´s taxonomy is a hierarchy with six levels starting with the remembering followed by understanding, applying, analysing, creating and evaluating. There are many simplified variations of the taxonomy. One is a practical method named Tell, Show, Do, Review incorporating a variety of modalities to create effective learning that mirrors the way learners learn. For learning professionals, this is a helpful tool.



The figure is from the newsletter Maestro Abstract.

As a learning professional, to *tell,* is about instructing, lecturing or otherwise explaining. Examples in experiencing this step are; reading books, articles, doing lecture or making eLearning. All are useful instructional tools, but unlikely to create lasting change on their own.

To *show* is about practical applications of the abstract or conceptual ideas from the *tell* step, to set them in a context for better understanding. This is where behaviours are modelled and skills are demonstrated, not just explained. Showing a learner is important, but to internalize the material, learners need to practice as well.

The third step *do* is about practising a skill, performing a behaviour or applying new knowledge in a real-life scenario. This step grants learners to practice in a safe, controlled environment using simulations or scenarios. It is a rehearsal before they showcase their new skill.
Testing new skills are critical, but equally important is to include the *review* to provide feedback to the learners. This is the step where they can make amendments, assess their progress and explore ways in which they can continue to improve. It includes self-reflection, coaching and providing written or oral feedback.

This framework is one that works because learners learn by doing just like in case-based learning, CBL, which is compatible with the Tell, Show, Do, Review method.

3. Tool Tutorials

3.1. Website #1:

The site ClimateHero will be used for calculating the carbon footprint. It is available in English, German, Swedish, Italian, Spanish, Portuguese and French. It has questions divided in three sections: housing, travel and consumption for one's own footprint and is easy to use.

3.1.1. Guide

Address: https://miljo-kalkylator.climatehero.org/

3.2. Website #2:

The site for The Good Tribe will be visited for use of the *Circular Business Development Canvas Pack*. It can be downloaded as a PDF-file or on Miro. This collection of 34 canvases is crafted to support organisations in identifying, implementing, and refining circular strategies that align with their unique business models and industry needs. It will be used by the learners planning of a real or fictional company.

3.2.1. Guide

Address: https://www.thegoodtribe.com/circular-business-development-canvas-pack

4. Assessment Strategies

In the Kirkpatrick Model, there are multiple levels of evaluating training. The model has four levels of learning evaluation. It is a tool we need to evaluate training and learning and understand its impact from multiple viewpoints.

1. Reaction

   At the reaction level, the goal is to understand whether the training was well-received. It is about user feedback. How did learners react? Were they positive, negative, or indifferent? Ways of measuring learners' reactions to training are pre-and post-training surveys, asking them to review the training and providing comments or interview learners individually or in groups.

2. Learning

   At the learning level we want to know if they learned what we intended them to. Ways of measuring are quizzes and assessments. Knowledge checks allow us to understand whether learners have gained a stronger knowledge base.

3. Behaviour

   The learning level was about learned theory, but behaviour answers the question; Did what they learned change their behaviour? Ways of measuring includes scenario learning or case learning for seeing what someone learned and how it is affecting their performance in a group.

4. Results

   Results is the final level of Kirkpatricks' four level training evaluation model is the most important. What is measured is how well the learning met the objectives. The results are what determines whether the training served its intended purpose or not. Ways of measuring results are made through KPIs and strict measurements.

4.1. Module lectures

By using the practical method named Tell, Show, Do, Review, one can start with a lecture or online lecture, and also talking about the Module's literature (see additional resources) that they should read. Study questions for the mandatory literature will be provided and in a special session any remaining questions on the literature will be sorted. To use the Kirkpatrick Model on this first part it is a question of the learners' reactions to it.

Next step will be to demonstrate and Show how the concepts from the literature can be implemented and used in a case. If it is possible, this Show step is where a study visit would be perfect. At this step it is a question about the learning. Did they learn something here?

The third step includes using *The Circular Business Development Canvas*. Learners will brainstorm together in groups and think of a possible business case and how to plan it for a sustainable, circular and profitable outcome. The Do step is evaluated by their behaviour. Did what they learned change it?

Finally, their presentation of the business chosen and planned for will be reviewed for possible improvement, showing them that there is always assessment for progress and continued learning. These are the results that will be thoroughly evaluated with strict measurements.

4.2. Assessment of Problem-Solving Tasks

Not applicable.

4.3. Grading and Evaluation Criteria

As the Module is planned for learners who already have a Bachelor's degree or equivalent e.g. many years of practical experience or other, the grading could be, but nor necessary, A to F where A is the top grade and F correspond to Fail.

- **Research and Analysis (30%):** Students 'or learners' performance is assessed based on the quality and depth of their research, their ability to analyze information, and their understanding of the big question and challenge (the Tell step).
- **Collaboration and Participation (20%):** Evaluation includes the effectiveness of teamwork, communication, and each student's contribution to the project (the Show and Do step).
- **Solution Design (30%):** The creativity, and feasibility of the proposed solutions are key criteria for assessment (the Do step).
- **Presentation and Defense (20%):** The clarity, persuasiveness, and professionalism of the final presentation are important factors in the evaluation (the Review step).

5. Additional Resources

An additional resource will be the Ellen MacArthur Foundation website.

https://www.ellenmacarthurfoundation.org/

The EU Circular Economy Action Plan will be important to visit for showing the topic's necessity

https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en

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Train-the-trainers (ToT) toolkit

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Train-the-trainers (ToT) toolkit

Module: Green construction: LCA of buildings

Responsible Partner: TUHH

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Abbreviations and acronyms

Table 1: Abbreviations and acronyms

Acronym	Description
GA	Grant Agreement
EU	European Union
LCA	Life Cycle Assessment
CBL	Challenge-Based Learning
STEM	Science, technology, engineering, and mathematics

1.Introduction

This Train-the-Trainers (ToT) Toolkit is designed to support educators in delivering the micromodule **"**Green Construction: LCA of Buildings" using the Challenge-Based Learning (CBL) methodology. The module focuses on teaching participants how to conduct Life Cycle Assessments (LCA) for buildings, with an emphasis on sustainability and environmental impact reduction.

Module Overview:

- **Topic & content summary**: LCA of buildings, to empower students with LCA methodologies specific to buildings, develop their ability to critically evaluate the environmental impacts of different construction materials, and acquired the skills to assess buildings with a strong focus on sustainability. It is expected that this module will enable graduates to develop their skills to contribute to the field of green construction and expand their knowledge dedicated to mitigating climate change through sustainable building practices.
- **Teaching Methodology:** CBL, where participants solve a real-world challenge related to sustainable building practices.
- **Software**: OpenLCA (open-source) will be used for LCA modelling and analysis.
- **Duration**: Recommended teaching duration is 26 hours, including lectures, hands-on software tutorials, and group problem-solving sessions.

2. Teaching Methodologies

This section describes the teaching approaches used in the module, including the CBL method. It provides step-by-step guidance on how to apply CBL, strategies for engaging lectures, and a sample lecture outline.

2.1. Learning Objectives

The module "Green construction: LCA of Buildings" aims to provide Masters students in Architecture, Civil and Energy Engineering and related fields with the knowledge and skills to conduct LCA of buildings. The primary objective is to promote an in-depth understanding of the environmental impacts associated with building materials in different construction processes. Students will learn how to assess building materials in construction process for sustainability and whether they meet carbon neutral standards.

2.2. CBL Teaching method

CBL is a collaborative, hands-on approach where learners engage with real-world challenges. The challenge-based learning module has three main phases (Hermsen & Ambrosi, 2023):

1. Engage:

Problem Identification: Students start by exploring the introduced big question. They engage with available resources like literature reviews, expert interviews, case studies and so on.
Initial Research: Each team conducts research and try to understand different aspects of the big question and find the challenge that they want to explore considering their scientific background, interests and available resources.

2. Investigate:

Challenge Analysis: After choosing the challenge, teams perform a detailed analysis of challenge. To do so, they should define the guising questions, the available resources to answer these questions and also the guiding activities for an effective data collection.

Brainstorming of solutions: According to the collected information from previous stage, teams propose their initial ideas in a presentation session. Tutors and students will asses the solutions and provide feedback.

3. Act:

Solution Design: According to the collected information from previous stage, teams propose their solutions in a presentation session. Tutors and students will assess the solutions and provide feedback.

Prototype and Test: Teams create prototypes or pilot projects for key elements of their plan (e.g., a model for a green public transportation system, a community recycling program).

Final Presentation: Teams present their proposed solutions and prototypes to the class. It is advised to invite some experts in this stage to assess the solutions and criticize them. Teams must defend their solutions, demonstrate the impact of their proposed solutions, and address any challenges or limitations.

Strategies for Engaging Lectures:

- Use interactive discussions to explore real-world case studies.
- Incorporate group activities where participants collaborate to solve problems.
- Provide hands-on software tutorials to reinforce learning.

Sample Lecture Outline:

- Introduction to sustainability (3 hours): Concepts and innovations related to the sustainability topic with a focus on green construction sector
- Introduction to LCA (3 hours): Overview of LCA principles and applications in green construction.
- CBL Challenge Introduction (3 hours): Present the real-world challenge and form teams.
- Software Tutorials (3 hours): Hands-on training with OpenLCA.
- Group Problem-Solving (8 hours): Teams work on their solutions using OpenLCA.

- Presentations and Reflection (6 hours): Teams present their solutions and reflect on the learning process.

3. Tool Tutorials

This section provides a tutorial on OpenLCA, the primary software used in the module. It includes an installation guide, relevant features, examples, and troubleshooting tips.

3.1. Software: openLCA

OpenLCA is an open-source software for LCA, widely used for modelling and analysing the environmental impacts of products and systems.

3.1.1. Installation guide

- Download: OpenLCA can be downloaded from the official website: https://www.openlca.org/.
- Installation**:** The installation process is very easy and after opening the downloaded file, with a few clicks, the software will be installed. For more information watch this video: https://www.youtube.com/watch?v=UFXOIMqX_0Y

3.1.2. Relevant features

- Database Integration**:** Supports various LCA databases (e.g., Ecoinvent, ELCD).
- Modelling Tools**:** Create and analyse life cycle models for buildings and materials.
- Impact Assessment**:** Evaluate environmental impacts using methods like ReCiPe and CML.

3.1.3. Examples

- **Example 1**: Modelling the life cycle of a concrete building.

In this example, participants will use OpenLCA to model the life cycle of a concrete building, from raw material extraction to construction, use, and end-of-life disposal. The goal is to assess the environmental impact of the building, focusing on key factors such as carbon emissions, energy consumption, and resource use**.** Participants will input data related to the production of concrete (e.g., cement, aggregates, water), transportation, construction processes, and demolition. By analyzing the results, they can identify the stages with the highest environmental impact (e.g., cement production) and propose

mitigation strategies, such as using alternative materials or improving energy efficiency during construction.

- **Example 2**: Comparing the environmental impact of different insulation materials.

In this example, participants will compare the environmental impact of two insulation materials (e.g., fiberglass and cellulose) using OpenLCA**.** They will create separate life cycle models for each material, considering factors such as raw material extraction, manufacturing processes, transportation, and disposal. The analysis will focus on global warming potential (GWP)**,** energy use**,** and water consumption**.** By comparing the results, participants can determine which material has a lower environmental footprint and justify their choice based on LCA data. This exercise will also encourage participants to explore trade-offs, such as cost versus sustainability, and consider the broader implications of material selection in green construction.

3.1.4. Troubleshooting tips

- Issue**:** Software crashes during installation.
  Solution**:** Ensure that the correct version of Java is installed and compatible with your operating system.
- Issue**:** Database not loading.
  Solution**:** Check if the database files are correctly placed in the OpenLCA folder.

4. Assessment Strategies

4.1. Module lectures

Assessment Method:

To gauge participants' understanding during lectures, trainers should employ group discussions and interactive conversations. These methods encourage active participation and allow trainers to assess how well participants are grasping key concepts. Group discussions can be structured around real-world scenarios or case studies related to LCA, prompting participants to apply theoretical knowledge to practical problems. Interactive conversations, on the other hand, can be used to clarify complex topics, address questions, and ensure that participants are following the material. These approaches not only help trainers identify areas where participants may need additional support but also foster a collaborative learning environment.

Example:
After a lecture on LCA principles, trainers can define a simple problem to test participants' understanding of key concepts. For instance, participants could be asked to identify the main phases of an LCA (e.g., goal and scope definition, inventory analysis, impact assessment, and interpretation) and explain how each phase contributes to the overall assessment. Alternatively, trainers could present a scenario, such as comparing the environmental impact of two building materials (e.g., concrete vs. timber), and ask participants to discuss which material has a lower carbon footprint based on LCA principles. This type of problem-solving exercise reinforces learning and provides immediate feedback on participants' comprehension.

4.2. Assessment of Software and Problem-Solving Tasks

Assessment Method:

To evaluate participants' proficiency in using OpenLCA and their problem-solving abilities, trainers should design tasks that require the application of LCA principles and software tools. Participants should be given real-world problems related to green construction, such as assessing the environmental impact of building materials or optimizing the life cycle of a building. These tasks should encourage participants to use OpenLCA to model, analyze, and interpret data, ensuring they can apply the software effectively to solve practical problems. Trainers can assess participants based on their ability to navigate the software, generate accurate results, and propose sustainable solutions.

Example:
A practical assessment task could involve asking participants to compare the environmental impact of two building materials (e.g., steel and timber) using OpenLCA. Participants would need to create a life cycle model for each material, input relevant data, and analyze the results to determine which material has a lower carbon footprint. Trainers can evaluate participants based on the accuracy of their models, the quality of their analysis, and the clarity of their conclusions. Additionally, participants could be asked to propose ways to reduce the environmental impact of the chosen material, demonstrating their ability to think critically and creatively. This type of assessment ensures that participants not only understand how to use the software but also how to apply it to real-world challenges in green construction.

4.3. Grading Rubric and Evaluation Criteria

- **Research and Analysis (30%):** Students ‘performance is assessed based on the quality and depth of their research, their ability to analyze information, and their understanding of the big question and challenge.
- **Collaboration and Participation (20%):** Evaluation includes the effectiveness of teamwork, communication, and each student’s contribution to the project.
- **Solution Design (30%):** The creativity, and feasibility of the proposed solutions are key criteria for assessment.

- **Presentation and Defense (20%):** The clarity, persuasiveness, and professionalism of the final presentation are important factors in the evaluation.

5. Additional Resources

Online training videos:

- https://www.youtube.com/watch?v=DI_Pe3ZEzrY
- https://www.youtube.com/watch?v=eQtIiOtSYuw&t=380s
- https://www.youtube.com/watch?v=kEosW6PceVg

Books:

Life cycle assessment- Theory and Practice, written by Michael Z. Hauschild • Ralph K. Rosenbaum Stig Irving Olsen (2018)

References

- ISO 14040:2006. "Environmental management — Life cycle assessment — Principles and framework."
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- OpenLCA installation guide available at https://www.youtube.com/watch?v=UFXOIMqX_0Y

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Train-the-trainers (ToT) toolkit

WP4, Task 4.2

Train-the-trainers (ToT) toolkit

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

Responsible Partner: University of Freiburg

Mohammadreza Aghaei

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Abbreviations and acronyms

Table 1: Abbreviations and acronyms

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.

Module lead: Prof. Dr.-Ing. Mohammadreza Aghaei, University of Freiburg. Contact: mohammadreza.aghaei@imtek.uni-freiburg.de.

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/

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[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.

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Train-the-trainers (ToT) toolkit

WP4, Task 4.2

Train-the-trainers (ToT) toolkit

Module: 5

Responsible Partner: Mohsen Soleimani-Mohseni,

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WP4, Task 4.2

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1. Introduction

Module 5 will empower the student with cutting-edge knowledge and technologies regarding energy efficiency in buildings. State-of-the-art research on energy-efficient buildings will be raised and discussed. The keywords of this module are energy balance calculations, energy-efficient buildings, and indoor climate.

The student will develop competencies in understanding energy use in buildings and performing advanced energy balance calculations, with a focus on the latest technological advancements that enhance energy efficiency and indoor climate. Additionally, you will learn how to design buildings that meet energy-efficiency requirements.

The teaching is based on practical energy calculations for buildings, the development of temperature-duration curves, instruction in using two different software tools, and the analysis of energy-efficiency measures and their potential impact on building performance.

The teaching is supported by a problem-based learning (PBL) approach. Rather than relying solely on predefined calculation procedures, students are presented with realistic and relatively open-ended problems that require them to apply their theoretical knowledge to practical situations. They are expected to identify the necessary input data, make reasonable assumptions where data are unavailable, select appropriate methods and software tools, carry out the required simulations and calculations, and critically evaluate and reflect on their results.

This approach encourages students to take greater responsibility for their own learning and to develop their ability to make well-founded technical decisions. The assignments therefore focus not only on obtaining numerical results, but also on the quality of the modelling process, the justification of assumptions, the level of detail in the simulations, and the students' ability to interpret and critically reflect on the results.

2. Teaching Methodologies

2.1. Learning Objectives

The module will empower students with cutting-edge knowledge and technologies regarding energy efficiency in buildings. State-of-the-art research on energy-efficient buildings will be raised and discussed. The keywords of this module are HVAC, energy balance calculations, energy-efficient buildings, and indoor climate. Learning objectives include:

- Develop in-depth knowledge of energy-smart solutions in the built environment.

- Design heating-, cooling- and ventilation systems for various kinds of buildings.

- Calculate and account for energy in buildings and energy efficiency measures without negative impacts on the indoor climate. perform energy balances and carry out energy calculations.

- Account for the relationship between a building's indoor climate and the dweller's well-being.

- Critically analyze the energy efficiency from a holistic and sustainability perspective.

2.2. Teaching method

Teaching will be based on highly interactive walk-trough lectures, exercises, hands-on exercises and assignment review. The assignment will be based on CBL where tutors will be guided by the teacher.

The assignments are designed in accordance with a problem-based learning (PBL) approach. Rather than following a predefined calculation procedure, students are presented with complex, realistic problems that require them to identify the necessary input data, make justified assumptions where data are unavailable, select appropriate modelling approaches and software tools, and critically evaluate and reflect on their results.

3. Tool Tutorials

3.1. Software #1

The site Energiberakning.se offers a free energy calculation for buildings. The program checks whether the house can be approved by the municipality according to the National Board of Housing, Building and Planning's regulations. BBR 29, 30, 31.

3.1.1. Installation guide

The internet address: https://www.energiberakning.se/default.aspx

3.1.2. Relevant features

Calculation of: U-value, primary energy number, space heating, domestic hot water, electricity

3.2. Software #2: PHPP

PHPP (Passive House Planning Package) is a comprehensive energy calculation tool used to design and evaluate high-performance, energy-efficient buildings. Developed by the Passive House Institute, PHPP helps architects and engineers optimize building performance by assessing heating and cooling demand, energy consumption, indoor comfort, and overall sustainability. It is widely used in Passive House projects and supports the design of buildings with low energy use and high occupant comfort.

3.2.1. Installation guide

Excel-based program, no installation is required.

3.2.2. Relevant features

Calculation of: U-value, space heating, primary energy, primary energy renewable

4. Assessment Strategies

The assessment is based on how well and comprehensively the students have completed their assignments and reflected on their work. The course includes two substantial assignments that students are required to complete using two different software tools for each assignment. The assignments require a considerable amount of input data. Some of these data are provided, while others must be estimated based on reasonable assumptions.

The assessment focuses on how carefully and thoroughly the students have carried out the simulations, including the extent to which they have justified their assumptions, selected appropriate input parameters, and documented the simulation process and results.

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Train-the-trainers (ToT) toolkit

WP4, Task 4.2

Train-the-trainers (ToT) toolkit

Module: SMART BUILDINGS: Modern technologies and systems integration
Leading the course topics in WP3.5.: HEP-ESCO
WP4, Task 4.2. Development of Train-the-trainers (ToT) toolkit and carrying out pilot training

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Abbreviations and acronyms

Table 1: Abbreviations and acronyms

Acronym	Description
GA	Grant Agreement
EU	European Union
SRI	Smart readiness indicator
PBL	Problem-based learning
IPMVP	International Performance Measurement and Verification Protocol

1. Introduction

This Train-the-Trainers (ToT) Toolkit is designed to support educators in delivering the micromodule 'SMART BUILDINGS: Modern technologies and systems integration' using the Problem-based learning (PBL) methodology. This module will develop your foundational knowledge of smart buildings and examine the role of integrated technologies in enhancing building performance. We will focus on understanding the systems that make buildings intelligent and the broader implications of these technologies in the context of sustainability and digital transformation.

Module Structure This module is organized into five key parts, each addressing a specific aspect of smart buildings:

1. Concept of Smart Buildings and Their Significance in the Modern World
2. Smart Readiness Indicators of Buildings
3. Energy Management of Buildings and Its Implication on Building "Smartness"
4. New Technologies and Human Factor in Smart Buildings
5. Examples of Smart Buildings

The goal is to provide a foundational understanding of smart buildings, their readiness indicators, energy management, new technologies, and the human factor, along with examples that illustrate these concepts. By the end, the students will understand the essential aspects of smart buildings and the importance of smart readiness indicators in the context of smart buildings.

Module Overview:

- **Teaching Methodology:** Problem-based learning (PBL) is an educational approach where students learn subject concepts by solving open-ended, real-world problems. Instead of listening to lectures and memorizing facts, learners work in small groups to research independently, apply critical thinking, and collaborate on solutions under a teacher's guidance.

- **Duration**: Recommended teaching duration is 25 hours, including lectures, hands-on software tutorials, and group problem-solving sessions.

2. Teaching Methodologies

This section describes the teaching approaches used in the module, including the PBL method. It provides step-by-step guidance on how to apply PBL, strategies for engaging lectures, and a sample lecture outline.

2.1. Learning Objectives

The module 'SMART BUILDINGS: modern technologies and systems integration' aims to provide Masters students in Architecture, Civil, Energy Engineering and other technical disciplines with the knowledge and skills on the smart building concept as well as specific understanding and knowledge on the technological systems of the buildings, particularly those related to the 'smartness' of a building. Smart buildings use integrated technologies to enhance performance and sustainability. They feature automated systems for HVAC, lighting, security, and more, offering benefits like energy savings, cost reduction, comfort, and safety. The Smart Readiness Indicator (SRI) is an EU framework that evaluates smart technologies in buildings, focusing on energy efficiency, comfort, and flexibility across nine domains. Efficient energy management in smart buildings aims for cost savings, reduced environmental impact, and enhanced comfort, incorporating concepts like nZEB, ZEB, BMS, smart meters, and M&V. Take-home Learning Messages: Smart buildings use IoT, AI, and data analytics to optimize performance and sustainability, significantly reducing energy consumption and operational costs. Automated systems enhance occupant comfort and productivity. Despite high initial costs and cybersecurity risks, the benefits outweigh the challenges. Future trends include deeper integration with smart cities, advanced connectivity, AI, and sustainable practices. Applying SRI methodologies improves smart readiness evaluation, requiring ongoing assessment and adaptation

2.2. PBL Teaching method

Problem-based learning (PBL) is a student-centered teaching method where learners confront open-ended, real-world scenarios before acquiring all the necessary knowledge. Unlike traditional instruction where a teacher provides facts first in this method acts as a facilitator who scaffolds the learning process, allowing students to take ownership of their education Working in small collaborative groups, students identify what they need to know, research independently, and apply their findings to develop viable solutions. The Problem-based learning module has three main phases (Sukacke, et al., 2022):

1. **Understand the problem**: Problem Identification: Students analyze the problem presented in the kick-off session by engaging with resources such as literature reviews, expert interviews, and case studies. Their goal is to develop a comprehensive understanding of the problem's scope and underlying issues. They engage with available resources like literature reviews, expert interviews, case studies and so on.

2. **Explore the curriculum:** Information collection: After analyzing the, after the core problem is defined, students start to examine the necessary content, identifying the problem, generating hypotheses, and pinpointing knowledge gaps. Sharing opinions among students is crucial, as it drives the development of action plans and helps in identifying the root causes of problems

3. **Resolve the problem**: Solution development: In developing solutions, group members collaboratively assess the most likely hypotheses, reviewing their information critically. If multiple hypotheses are present, students should prioritize them based on likelihood and impact.
Test: Teams create pilot projects for key elements of their proposed solutions (e.g., SRI indicators and recommendations for measures).

Final Presentation: Teams present their proposed solutions to the class and their approach before experts, who is competent to provide critical feedback. It is advised to invite some experts in this stage to assess the solutions and criticize them. Teams must defend their solutions, demonstrate the impact of their proposed solutions, and address any challenges or limitations such as cost-benefit.

Learning outcomes:
Students gained an understanding of the smart building concept and its significance in today's world, recognizing the importance of integrating advanced technologies for enhanced efficiency and sustainability. They learned about smart metering and data collection, and how these tools contribute to effective energy management in buildings. Students explored various energy management tools and the concept of the Smart Readiness Indicator (SRI), understanding its role in evaluating a building's capability to adapt to advanced technologies. They grasped the basic principles of new technologies and processes, such as demand-side management, that contribute to building smartness. Additionally, students studied examples of buildings that have successfully incorporated various smart technologies and processes, analysing how these innovations improve building performance and sustainability.

At the end of the module, students are also expected to be able to:

- define the concept of a smart building and explain its historical development, main benefits, limitations and future trends, including integration with smart grids and smart cities;
- identify the relevant EU policy and regulatory context for smart buildings, including the Energy Performance of Buildings Directive, the Energy Efficiency Directive and the EU Smart Readiness Indicator framework;
- explain the Smart Readiness Indicator (SRI), its objectives, its relation to Energy Performance Certificates, the seven impact criteria, the nine technological domains and the difference between Method A and Method B;
- perform a structured preliminary SRI self-assessment of a selected home, apartment building or place of residence by reviewing heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, electricity, EV charging and monitoring/control;
- analyse how energy management, BMS/EMS platforms, smart metering, data analytics, demand response, occupant engagement and cybersecurity/privacy requirements contribute to building smartness;
- explain measurement and verification (M&V) as a feedback mechanism for energy management, including baseline definition, adjustments, reporting and IPMVP Options A, B, C and D, supported by ISO 50001, ISO 50006 and ISO 50015 concepts;
- propose feasible technical improvements for a real building, such as improved controls, metering, photovoltaics, batteries, demand-response capability or grid

integration, while considering comfort, energy efficiency, cost-benefit priorities and possible constraints such as protected buildings;
- present, discuss and defend the assessment results, and reflect on how user behaviour, commissioning and maintenance influence the real performance of smart building technologies.

The online Blackboard part is structured for independent preparation and reflection. The introductory online instructions estimate approximately 19 academic hours for the online component; together with on-site work, preparation and student self-assessment, the total workload remains aligned with the planned 25-hour module. The online content is divided into the following thematic parts:

Part 1 - Concept and importance of smart buildings: module introduction, initial self-evaluation questionnaire, smart building definition and evolution, basic technologies, EU regulatory framework, case studies and state-of-play/future perspectives;
Part 2 - Smart Readiness Indicators (SRI): SRI objectives, relation to EPC, SRI methodology, building type and climate relevance, Method A and Method B, key functionalities, technological domains, example building types and instructions for group assignments;
Part 3 - Energy management and smartness: energy management in buildings, smart metering and data collection, data analytics and visualisation, communication protocols, demand response, cybersecurity, privacy, retrofitting and measurement and verification of energy savings;
Part 4 - New technologies and human factor: technological milestones, sensors and real-time systems, comfort, user expectations, energy awareness, AI/digital twins, zero-emission buildings, design, commissioning, maintenance and system usage.

Online in Blackboard:
- Smart building concept, definition and significance
- Global overview and historical view on the legislation and technological evolution that lead to the concept of smart buildings
- Regulatory framework of EU
- Technological development and reflection on buildings
- Goals and benefits of smart building
- Example of EU funded project – 3 Smart (Smart building, smart network, smart city)
- Smart readiness indicators SRI
- Relevance of building type and climate for SRI
- Existing methodologies for SRI calculation
- Key functionalities and technological domains of SRI
- SRI - examples of buildings
- Energy Management building tools and introduction into BIM
- Smart metering and data collection – technologies and application
- International Performance Measurement and Verification Protocol (IPMVP)
- Indoor environmental quality
- The basic principles of how new technologies and processes are used towards building smartness
- Human factor, systems maintenance and building use

On site (Duration: 6 hours)
The training is delivered through a combination of short lectures, practical exercises, individual work, student presentations and expert discussion. It includes the following activities:

- Opening recap of the online material and clarification of the task, based on the prepared SRI self-assessment of the student's own home, apartment building or place of residence;
- Short lecture and discussion on SRI, including definition, objectives, calculation logic, seven impact criteria, nine technological domains, Method A/Method B and examples of functionality levels;
- Short lecture and discussion on systematic energy management, including remote meter reading, LoRaWAN, NB-IoT, consumption analysis and optimisation, heating-curve optimisation, BMS/EMS dashboards and operational feedback;
- Short lecture and exercise on M&V, including the measurement challenge, IPMVP, connection with ISO standards, savings equation, baseline/reporting period, adjustments, Options A-D and reporting plan using practical case examples;
- Individual SRI calculation and self-assessment for a selected building/place of residence, with review of the relevant technological domains;
- Individual student presentations of the selected building/place of residence and explanation of preliminary SRI domain-level observations;
- Recommendations for specific new technologies that could make the building smarter, presented in order of priority and with cost-benefit reasoning where possible;
- Joint expert discussion in which students and trainers identify feasible improvements, prioritise measures and discuss constraints, including protected buildings and technical/legal grid conditions;
- Consideration of typical measures such as smart controls, improved metering, PV systems, batteries and possible grid participation where conditions allow it;
- Final presentation and defence of assignment results;
- Feedback and interactive evaluation of student preparation, technical understanding, feasibility of recommendations, presentation quality and active participation in discussion.

3. Assessment Strategies

3.1. Design of the module

Hybrid session:

- Kick-off Session: The module begins by introducing the core elements of the topic to prepare students for understanding the project's theme, which will be detailed in the next step. During this session, the following activities will take place: Project Topic Introduction: The primary problem of the project is introduced and explained in detail.
- Group Formation: Students will form interdisciplinary teams, with each member assigned a specific role. These roles are designed to guide their contributions toward solving the overall project problem.
- Focus Time sessions (Teamwork): In this phase, students actively engage with the topic through research and collaboration. They have the opportunity to ask questions, receive feedback from tutors on their approaches, and get guidance on progressing with the project.
- Presentation Sessions: Students present their research findings and defend their proposed ideas. Tutors provide feedback to help refine and develop their solutions further.

The hybrid session is therefore delivered through the following sequence:

- Initial self-assessment: before the online study, students complete a short questionnaire about their current understanding of smart buildings, EU legislation, smart technologies, smartness indicators and smartness elements in their own home or workplace.
- Independent online preparation: students study the four online parts and complete the SRI self-assessment guide for a selected building/place of residence before attending the on-site session.
- On-site application: the in-person session is used for targeted lectures, individual presentations, peer discussion and trainer feedback. The focus is not only on knowing SRI concepts but also on applying them to real buildings and identifying realistic improvement measures.
- Reflection and feedback: students compare their initial understanding with the final discussion and reflect on the role of technology, occupants, operation and maintenance in achieving real smart building performance.

3.2 Module Competency

Students develop a comprehensive understanding of the smart building concept, with particular emphasis on the technological functions that influence energy efficiency and enable buildings to respond and adapt to changing internal and external conditions. They also learn how to calculate and interpret the Smart Readiness Indicator (SRI), which assesses a building’s level of smart readiness and enables comparison between buildings.

Upon completion of the course, students will have developed the following competencies:

• **Conceptual competency:** the ability to explain smart buildings as integrated socio-technical systems that combine building services, digital technologies, energy management, interaction with the energy grid and the needs of building occupants.
• **Regulatory competency:** the ability to relate smart building concepts to relevant European Union policies and regulatory frameworks, including the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED), SRI regulations, nearly zero-energy building (nZEB) and zero-emission building (ZEB) concepts, and energy management standards.
• **SRI competency:** the ability to map building technologies and services to the relevant SRI domains, estimate their functionality levels, understand and interpret the logic of Method A and Method B, calculate the SRI, and use the results to identify priorities for building improvement.
• **Energy management competency:** the ability to understand the role of smart metering, data collection, building management systems and energy management systems (BMS/EMS), communication protocols, demand-response strategies, cybersecurity and data privacy, as well as the importance of occupant engagement in effective energy management.
• **Measurement and verification competency:** the ability to explain how measured data, energy baselines, adjustments, IPMVP Options A, B, C and D, and the principles of ISO 50001, ISO 50006 and ISO 50015 contribute to the verification of energy savings and support continuous improvement in energy performance.
• **Communication competency:** the ability to present the assessment of a real building in a clear and structured manner, justify and defend the assumptions made, respond effectively to questions, and participate constructively in expert and peer discussions.

3.3 Grading Rubric and Evaluation Criteria

For this module, the grading rubric is applied through the following assessment elements:

- Prepared SRI self-assessment assignment (30%): completeness of the preliminary SRI review for the selected building/place of residence, coverage of the nine domains, and clarity of notes and assumptions.
- Individual presentation of the selected building (25%): ability to describe the actual situation, identify existing smartness elements, explain domain-level observations and communicate findings clearly.
- Improvement recommendations and feasibility reasoning (25%): quality of proposed measures, technical logic, attention to energy efficiency, comfort and quality of living, priority order, cost-benefit reasoning where possible, and recognition of constraints such as conservation protection or technical/legal grid conditions.
- Active participation and reflection (20%): contribution to the joint discussion, ability to compare options, respond to feedback, and demonstrate understanding of how PV, batteries, smart controls, metering, BMS/EMS and demand response could improve SRI and building performance.

The recommended grade scale is A = more than 90%; B = more than 80%; C = more than 70%; D = more than 60%; E = more than 50%; F = 50% or below, unless the host institution requires a different official scale.

In the delivery, students who submitted the initial assignment, presented their own building/place of residence, actively participated in the joint discussion and demonstrated very good understanding were assessed at grade A under this scale.

Other notes:

- Rather than only at the final presentation, experts should be engaged throughout the complete learning process, which would provide quality and more focus on student-driven exploration and solution development.
- To reinforce critical thinking, which is central to PBL, students will have the opportunity to reflect on what they have learned and how their understanding of the problem has evolved after every session.

4. Further Reading and Resources

List of additional resources for students who wish to explore the topic further, Smart Buildings:

1. **Directive 2010/31/EU on the Energy Performance of Buildings (EPBD)**
   https://eur-lex.europa.eu/eli/dir/2010/31/oj
2. **Directive (EU) 2018/844 (Amending the EPBD and EED)**
   https://eur-lex.europa.eu/eli/dir/2018/844/oj
3. **Commission Delegated Regulation (EU) 2020/2155** (Smart Readiness Indicator – SRI definition & methodology)
   https://eur-lex.europa.eu/eli/reg_del/2020/2155/oj
4. **Commission Implementing Regulation (EU) 2020/2156** (SRI implementation procedures)
   https://eur-lex.europa.eu/eli/reg_impl/2020/2156/oj
5. **Directive 2012/27/EU on Energy Efficiency (EED)**
   https://eur-lex.europa.eu/eli/dir/2012/27/oj
6. **Directive (EU) 2024/1275 on the Energy Performance of Buildings**
   https://eur-lex.europa.eu/eli/dir/2024/1275/oj

Standards, protocols and legal documents used in the online and on-site materials include:

7. Directive (EU) 2023/1791 on energy efficiency (recast Energy Efficiency Directive).
8. Decision (EU) 2022/591 of the European Parliament and of the Council of 6 April 2022 on a General Union Environment Action Programme to 2030.
   http://data.europa.eu/eli/dec/2022/591/oj
9. ISO 50001 - Energy management systems - Requirements with guidance for use.
10. ISO 50006 - Energy management systems - Measuring energy performance using energy baselines and energy performance indicators.
11. ISO 50015 - Energy management systems - Measurement and verification of energy performance of organizations.
12. EN 16247 - Energy audits.
13. International Performance Measurement and Verification Protocol (IPMVP), including Options A, B, C and D for quantifying energy savings.
14. GDPR and related privacy requirements for smart metering, data analytics and building operation data.
15.

Software, tools and useful links:

No mandatory calculation software is required for the student assignment. The core practical tool is the SRI self-assessment guide used to structure observations across the nine technological domains.

16. Official European Commission Smart Readiness Indicator page:
    https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator_en
17. Official SRI assessment package / EU Survey tool:
    https://ec.europa.eu/eusurvey/runner/SRI-assessment-package

18. SRI2MARKET platform and resources: https://sri2market.eu/ and https://sri2market.eu/sri/
19. Building operation tools discussed in the module include BMS/EMS platforms, smart metering systems, data analytics and visualisation dashboards, mobile/user interfaces, demand-response tools, digital twins and AI-based predictive maintenance.
20. Communication technologies and protocols mentioned in the materials include ZigBee, LoRaWAN, Modbus, BACnet, Wi-Fi, cellular networks and NB-IoT.
21. Optional software categories for deeper M&V or simulation exercises include calibrated simulation tools for IPMVP Option D, such as DesignBuilder, eQUEST or equivalent building energy simulation tools.
22. Additional smart building case-study links: The Edge - https://edge.tech/buildings/the-edge ; Bloomberg European HQ - https://www.bloomberg.com/company/press/bloomberg-most-sustainable-office-building/

References

- Energy Performance of Buildings Directive EU/31/2010 (revised in 2018)
- The EU Energy Efficiency Directive (Directive 2023/1791)
- ISO 50001 Certification – Energy Management Systems

- Smart readiness indicator (SRI)
- International Performance Measurement and Verification Protocol (IPMVP)

- Directive (EU) 2018/844 amending the Energy Performance of Buildings Directive and the Energy Efficiency Directive.
- Commission Delegated Regulation (EU) 2020/2155 establishing the Smart Readiness Indicator definition and methodology.
- Commission Implementing Regulation (EU) 2020/2156 on the implementation procedures for the Smart Readiness Indicator.
- Directive (EU) 2024/1275 on the Energy Performance of Buildings.
- Directive (EU) 2023/1791 on energy efficiency.
- Decision (EU) 2022/591 on a General Union Environment Action Programme to 2030.
- ISO 50006 - Energy baselines and energy performance indicators; ISO 50015 - Measurement and verification of energy performance; EN 16247 - Energy audits.
- European Commission Smart Readiness Indicator materials and SRI assessment package; SRI2MARKET resources.

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