EXPERT ARTICLES

Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026)

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Martijn Rietbergen • Lenny van Onselen

SEED
sustainable energy education

Expert Articles

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Utrecht, the Netherlands, 24-25 March 2026

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Prologue SEED Proceedings 2026

This volume presents peer-reviewed **Expert articles** from the Second International Conference on Sustainable Energy Education (SEED 2026) held in Utrecht, the Netherlands, 24-25 March 2026. The conference was hosted by the Centre of Expertise Smart Sustainable Cities at Utrecht University of Applied Sciences.

Since its inception, the SEED conference has established itself as an international forum for lecturers in vocational training and higher education, researchers, policymakers, and practitioners. SEED provides a platform for exchanging ideas, sharing experiences, and collectively addressing the challenges of the energy transition. Central to this mission is the preparation of well-equipped learners, students, and professionals, and the development of sufficient and future-ready labour capacity in the context of the energy transition.

The 2026 conference focused on four interrelated themes: the energy sector labour market, innovative energy education, the region as a university campus, and skills for the sustainable energy transition. Together, these themes framed discussions on how education systems, regions, and industries can collaborate to address current and future societal needs.

The conference programme combined academic rigour with practical engagement and included a dedicated student track, as well as sessions connected to the CoVE SEED project. Over the course of two days, the conference welcomed more than 200 participants from 25 countries worldwide. The programme featured 30 academic papers, 35 expert papers, and 20 poster presentations, alongside 23 workshops, several student contributions, excursions, and exhibitions showcasing innovative practices and regional initiatives.

Keynote speeches were delivered by Arash Aazami, who spoke on *Trends and innovations in the field of the energy transition*, and Marcel Koenis, who addressed the topic of *Strategic regional collaboration in the energy transition*. A panel discussion, moderated by Remko van der Lugt, brought together perspectives from education (Mark Tammer), policy (Marsha Wagner), and industry (Jop Amelsfoort) exploring the topic *Aligning energy education and training with evolving energy labour market needs*. The conference concluded with a reflective wrap-up by Marsha Wagner, synthesising key insights and outlining directions for future collaboration.

The SEED Conference is a platform for transnational learning and cooperation within the CoVE SEED project (Centre of Vocational Excellence – Sustainable Energy Education). CoVE SEED is funded by the European Union through Erasmus+ and the European Solidarity Corps (grant agreement No. 101056147). The CoVE SEED consortium consists of educational providers (EQF levels 2-7), working professionals, and policymakers from Spain, the Netherlands, Greece, Germany, and Finland. The project focuses on delivering high-quality, innovative education to support the energy transition. The project aims to equip learners and professionals with the skills needed to accelerate the energy transition; strengthen regional innovation through stakeholder collaboration; share and scale best practices in sustainable energy education; build an international learning community; and ultimately establish a Centre of Vocational Excellence in each participating region.

The organising committee would like to thank our supporters and sponsors, including the Province of Utrecht and Rabobank, whose contributions were essential to the success of the conference. We also warmly thank the keynote speakers, authors, programme committee members, reviewers, session chairs, presenters, supporters, and all participants for their engagement and commitment. Finally, our appreciation goes to Utrecht University of Applied Sciences for its support and for helping to make SEED 2026 a truly impactful event.

Martijn Rietbergen & Lenny van Onselen

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Conference on Sustainable Energy Education – SEED 2026
Utrecht, The Netherlands, 2026

This expert article presents a comprehensive hydrogen training system that effectively bridges the gap between theoretical classroom knowledge and real-world industrial applications. The system integrates a PEM electrolyzer, hydrogen storage unit, fuel cell, and advanced PLC-based control platform to deliver hands-on learning experiences using authentic operational parameters within controlled, safe educational environments. Real-world performance analysis and safety protocols provide students with competencies essential for Europe's hydrogen transition. This approach shows how hybrid learning solutions effectively prepare the workforce for emerging energy technologies.

Closing The Hydrogen Skills Gap For Net-Zero: A Hands-On H_2 Training System For Engineers And Technicians

Name	**Expertise**
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Markus Osternmeier	Markus Osternmeier holds a degree and doctorate in mechanical engineering from the Technical University of Munich (TUM). He gained extensive industry experience in various roles within the energy division of MAN Diesel & Turbo and later shaped business units and products at a power-to-gas start-up. In 2021, he founded together with his brother the start-up OHS.
Nikunj Mathukiya	Nikunj Mathukiya is currently completing his degree in energy systems engineering at Deggendorf Institute of Technology. He joined OHS in 2024 and is responsible for developing and optimizing the H_2 training systems.

How to cite: Mückenhausen, V., Osternmeier, M., Mathukiya, N. (2026). Closing the Hydrogen Skills Gap for Net-Zero: A Hands-On H2 Training System for Engineers and Technicians. In: Expert Articles. Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026). Utrecht, the Netherlands, 24-25 March 2026. DOI: https://doi.org/10.48544/cfd4d144-fa44-429e-9cc5-7b442dd7a224.

Preparing the Workforce for Hydrogen Deployment

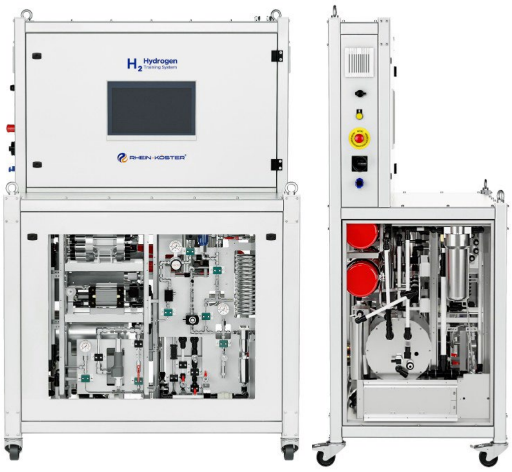
Hydrogen (*H_2*) technologies are moving from pilot projects into real deployment, but skilled people to design, operate and maintain these systems are still in short supply. Despite growing investment into hydrogen applications, companies and training providers face a growing competence gap: engineers and technicians often lack hands-on experience with system integration, diagnostics, and safety procedures. Current curricula often deliver strong theoretical insight, yet fail to provide access to authentic hydrogen technologies. Industrial installations are typically inaccessible for students due to high safety requirements, while simplified laboratory demonstrators rarely reflect the operational constraints of real systems. As a result, learners graduate without the confidence or skills required to engage with hydrogen equipment in practice.

This contribution introduces a H_2 training system designed specifically to bridge this gap. Built around a PEM electrolyser (1 kW), hydrogen storage, a fuel cell, and a PLC-based control platform, the system integrates industrial-grade components into an educational framework. It allows engineers and technicians to gain hands-on practice with real process parameters, digital monitoring, and safety interlocks, thereby creating a transparent link between classroom learning and industrial operation. This article highlights the key technical and teaching features of the system that support skill development in vocational and higher education, and shares how the first educational institution is already using it in practice.

H_2 Training System Architecture

The H_2 training system provides a comprehensive platform for applied research and technical education in hydrogen technologies. Its modular design integrates production, storage, and fuel cell conversion, enabling systematic study of both fundamental principles and advanced applications.

Figure 1. H_2 training system.



Source: Rhein Köster (2025).

System Components and Learning Objectives

The water treatment unit demonstrates the critical relationship between process water purity and electrochemical stack longevity—a practical consideration often overlooked in industrial operations but essential for comprehensive understanding. The hydrogen storage component introduces regulatory frameworks and pressure vessel engineering principles, creating direct educational connections to real-world safety standards and compliance requirements.

The PEM electrolyzer and fuel cell allow students and trainees to explore both sides of the hydrogen energy cycle: the conversion of renewable electricity into hydrogen and its reconversion into usable electric power. Integrated monitoring functions (e.g. single-cell voltage measurement) provide diagnostic insights, making the system well suited for performance evaluation and efficiency analysis in educational contexts.

Finally, the PLC-based Beckhoff control system with SCADA and Modbus TCP connectivity ensures seamless laboratory integration while developing essential digitalization competencies. Through data logging, parameter visualization, and comprehensive safety interlocks, the system trains learners in increasingly vital industry skills: data-driven analysis, system integration, and safe operation in advanced energy environments.

Table 1. Key Technical Features of the H_2 training system.

Subsystem	Key Features	Relevance for Teaching
Water Supply & Treatment	Integrated deionized water unit (from potable water, >3 bar inlet); compliant with German Drinking Water Ordinance	Ensures optimal electrolyser stack performance and longevity; teaches importance of water purity in electrolysis.
Hydrogen Storage	Up to 10 liters per cylinder at max. working pressure of 20 bar; compliant with EU Pressure Equipment Directive	Demonstrates safe hydrogen handling; enables practical training in storage under regulated safety standards.
Electrolyzer	Liquid-cooled PEM stack; H_2 production up to 0.2 Nm^3/h at 20 bar; includes single-cell voltage monitoring and integrated safety (relief valves, H_2 leak detection)	Provides real-time diagnostics for system performance
Fuel Cell	Liquid-cooled PEM stack; electrical output up to 400 W, 15–30 V DC; lifetime ~2000 h / 200 cycles	Demonstrates hydrogen-to-electricity conversion; suitable for efficiency and durability studies.
Control & Interfaces	PLC-based Beckhoff system; industrial touchscreen HMI; Modbus TCP protocol; supports SCADA/data logging	Allows integration into lab automation; provides real-time monitoring and safe, transparent training operation.

Source: Ostermeier H2ydrogen Solutions GmbH (2024).

Didactical Benefit of the H_2 Training System

Bridging Theory and Practice Through Authentic Learning

The training system creates meaningful connections between theoretical knowledge and practical application by providing learners with authentic datasets from real electrochemical processes. Students work directly with voltage-current characteristics from both electrolysis and fuel cell operations, enabling them to observe how cell voltage responds to current density variations and environmental factors such as temperature and relative humidity. This direct engagement with real-world data transforms abstract electrochemical principles into tangible, measurable experiences.

Developing Analytical Competencies Through Performance Evaluation

The systematic evaluation of polarization curves serves as a cornerstone for developing analytical thinking in electrochemical systems. Students can identify and quantify three distinct loss mechanisms: activation losses dominating at low current densities, ohmic losses that increase linearly with current, and mass transport limitations at high loads. Through this structured analysis of authentic measurement data, students learn to calculate system efficiency and understand the fundamental trade-offs governing electrochemical performance. This analytical framework extends beyond simple data interpretation. Students develop the ability to diagnose system performance, identify optimization opportunities, and understand the physical origins of energy losses.

Building Engineering Competencies for Professional Practice

The integration of real-world measurement techniques with theoretical foundations cultivates essential engineering competencies. Students develop systematic approaches to problem-solving, safety-conscious operational practices, and the ability to interpret complex electrochemical behaviour. The training methodology emphasizes diagnostic thinking, where learners must correlate measured performance with underlying physical processes.

Deployment Example: Furtwangen University

The H_2 training system is already implemented at Furtwangen University's Campus Tuttlingen (Germany) within the framework of the AuToS project (Automotive Transformation Strategy for Southwest Baden-Württemberg). The Schwarzwald-Baar-Heuberg region, with more than 25,000 employees in the automotive industry, faces substantial structural change as small and medium-sized Tier-2 and Tier-3 suppliers are under pressure to adapt to low-carbon technologies. In this context, the H_2 training system provides a shared learning infrastructure that enables both students and regional enterprises to gain hands-on experience with hydrogen processes. For example, students can tackle concrete technical challenges such as integrating Modbus TCP clients into the Beckhoff controller, conducting structured fault diagnostics on communication protocols, and configuring cascaded hardware safety modules that comply with industrial standards. The system also offers practical exercises in CAN bus monitoring between the

PLC and the fuel cell, allowing learners to analyse real-time data transmission to better understand control behaviour and optimize performance parameters. Through these practice-oriented learning activities, the system reinforces workforce qualification and accelerates technology transfer, contributing to greater regional innovation capacity and long-term competitiveness.

Future Outlook

As part of the Hydrogen Valley Vocational Excellence Hub (H2VE) project, the H2 training system will be further developed over the next three years and may serve as a core element within innovative energy education curricula across Europe. Beyond the physical setup, digital modules will complement the system to create a hybrid learning environment. Thereby hydrogen education gets more accessible to a wide range of learners, and it becomes easier to support responsive curricula tailored to Europe's heterogeneous education landscape. By doing so, the project aims to equip the next generation of innovators, engineers, and specialists with the practical and digital competences required to advance the hydrogen sector with confidence and expertise (Green Skills For Hydrogen, 2023; World Economic Forum, 2025).

Conclusion

The H_2 training system illustrates how industrial technologies can be transformed into meaningful learning tools that are both safe and accessible for education. By engaging directly with real process parameters, students and trainees build confidence in handling hydrogen systems and develop key competences in diagnostics, optimization, and safety practice. As a hybrid platform, it not only bridges the persistent skills gap but also supports lifelong learning by making hydrogen education more flexible and inclusive. In this way, the system contributes to Europe's vocational excellence agenda and helps prepare a workforce capable of driving the hydrogen transition forward.

Acknowledgements

No funding has been received for the development of the H_2-training system.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper. They do, however, work for the company producing these H_2 training systems.

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The YouthEnergy project in Argentina is empowering a new generation to drive a just energy transition by providing comprehensive education, practical skills, and fostering active participation in energy debates. Addressing significant challenges like high youth unemployment and gender disparities in technical fields, the project integrates innovative pedagogical approaches with real-world application, ensuring young people become informed, skilled, and politically active leaders. This initiative showcases how strategic educational interventions can build capacity for a sustainable and equitable energy future.

Empowering Youth Through STEM Skills To Drive A Just Energy Transition In Argentina

Name	Expertise
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Cristian Siukscius	SIEMENS Foundation – Argentina. Project Manager - Implementing partner for the YouthEnergy project. Focuses on developing and adapting educational materials, training teachers, and establishing partnerships with provincial education authorities to support the implementation of energy transition learning initiatives.
Luciana Proietti	500RPM Foundation – Argentina. Co-founder of 500RPM - Implementing partner for the YouthEnergy project. Focused on the development of hybrid (wind-solar) technologies. Specializes in the design, construction, installation, and maintenance of decentralized renewable energy solutions for educational and rural development purposes.

How to cite: Bonet, M. C., Siukscius, C., Proietti, L. (2026). Empowering Youth through STEM Skills to Drive a Just Energy Transition in Argentina. In: Expert Articles. Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026). Utrecht, the Netherlands, 24-25 March 2026. DOI: https://doi.org/10.48544/ae485812-1356-40db-a2c3-3a5935144e5c.

Introduction

The global energy sector is undergoing a rapid transformation, yet it faces significant challenges: a shortage of skilled professionals, outdated knowledge, and the urgent need for a just energy transition. In Argentina, this transition is particularly critical. Around 86% of the country's energy supply comes from fossil fuel sources (Laguzzi & Mercure, 2025), despite its vast untapped renewable potential. Moreover, traditional energy debates often lack representation from young people. Meanwhile, social inequalities, such as high youth unemployment and gender gaps in technical fields (INDEC, 2025), risk being exacerbated rather than alleviated by the transition.

The YouthEnergy Project

The YouthEnergy project, an IKI initiative, addresses these challenges by activating the potential of young people to become leaders in Argentina's just energy transition (Energía Joven, 2025);(Wisions, 2025).

Working with technical schools and youth organisations, the project focuses on three core areas:

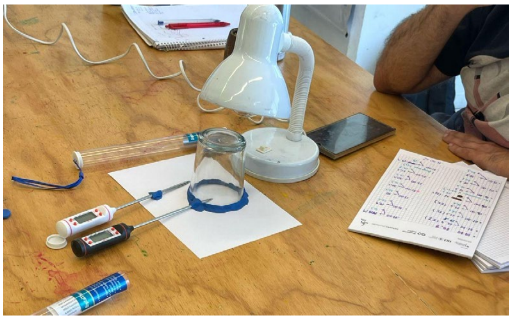
- Developing educational materials on Climate Change and Just Energy Transitions (**Activating Knowledge**),
- Providing hands-on experience with decentralised renewable energy systems (**Activating Innovation**), and
- Creating platforms for youth engagement in regional, national and international energy dialogues (**Activating Political Participation**).

Activating Youth as Knowledge Carries and Disseminators

YouthEnergy promotes innovative energy education through comprehensive learning sequences on climate change and just energy transition, incorporating gender dimensions within the Argentine context. To date, over 100 teachers from technical and secondary schools have been trained in applying these materials. What makes these materials innovative is their hands-on, experimental approach (Figure 1). Simple and easily accessible experiments allow students to grasp complex theoretical concepts, increasing comprehension and engagement.

Training workshops have deepened teachers' understanding of climate change issues as well as the multidimensional nature of a just energy transition. Continuous support from the YouthEnergy team ensures effective classroom application and replication throughout the school year (IKI, 2025).

Figure 1. Experiment illustrating the greenhouse effect during the "Train the Trainers" seminar.



Source: YouthEnergy team (2024).

Additionally, regular co-evaluation sessions with school directors and provincial authorities are held to provide feedback on the implementation process, address challenges, and discuss opportunities for replication and scaling up. These sessions have been key to advancing the replication of the project's educational methods and materials, which have already been successfully reproduced in some regions, extending the project's reach beyond its original scope.

Cultivating Innovators through Practical Experience with Renewable Energy Technologies

This component represents the project's experimental learning approach, designed to immerse students in renewable energy technologies through practical, hands-on experiences. It addresses Argentina's high youth unemployment rate – 13,1% among 14-29 year olds (IDESA, 2025) – by equipping young people with technical skills and STEM knowledge essential for emerging opportunities in the energy sector.

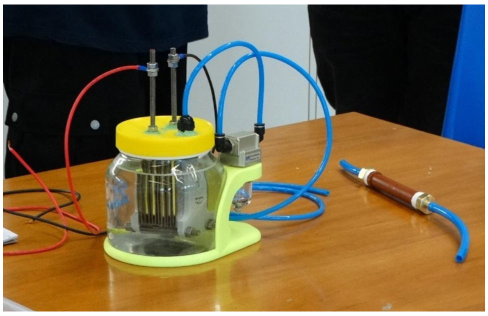
The experimental component is structured around two main methodologies:

Training on Renewable Energy Technologies

Teachers from technical schools receive training on key topics such as introduction to renewable energies, green hydrogen, and hybrid systems (solar and wind), enabling them to replicate these materials in their classrooms and ensure knowledge transfer and scalability.

Students participate in specialized sessions that combine theory with hands-on practice, working with small-scale experimental kits developed by local partners (Figure 2). Using these kits, they build demonstrators of renewable energy solutions – including small wind turbines, and hydrogen electrolysers – strengthening STEM understanding and problem-solving skills.

Figure 2. Green Hydrogen Kit built by provincial referents' during capacity-building activities.



Source: YouthEnergy team (2025).

Construction of Decentralized Hybrid Renewable Energy Systems

A significant initiative within this component is the installation of fully functional hybrid systems – combining solar PV, small wind turbines, a battery bank, and balance-of-system components – at three technical schools in Argentina. These installations serve as educational laboratories, providing students with the opportunity to engage in the entire process: from design and construction to operation and maintenance (Figure 3). The goal is not only to involve students in building these systems but also to ensure that, once completed, they have real, working systems to experiment with and learn from.

To make this possible, teachers are guided through construction workshops on facilitating the design and assembly of these decentralized renewable energy systems. Maintenance workshops follow installation to strengthen capacities for repair and upkeep among both teachers and students.

Through this approach, students gain practical skills in energy planning, generation, and storage, while developing management and leadership capabilities. By fostering innovation and collaborative problem-solving, this component positions young people as "energy system innovators", ready to contribute to Argentina's transition towards a cleaner energy future.

Figure 3. Students constructing and installing a small-scale wind turbine, which will serve as a laboratory for experimentation with renewable energy technologies.

Source: YouthEnergy team (2024).

Amplifying Youth Voices in Energy Dialogues and Governance

YouthEnergy ensures that young people shape the energy transition by strengthening regional and national dialogue platforms, offering opportunities for active participation. Three regional forums and one national forum are co-designed with youth organizations, combining scientific inputs on climate governance, just energy transitions, and gender-sensitive approaches with participatory activities. The project also promotes international networking through online exchanges with German youth and a strong presence at COP30 to share results, encourage replication, and foster global connections among Argentinean youth.

Innovative Partnerships and Pedagogies Driving Success

One of the key elements of the project that has enabled its successful implementation is its multi-actor nature, bringing together private entities, NGOs, and academia in the co-design and implementation of activities. This diverse partnership combines technical expertise, pedagogical innovation, and on-the-ground experience, ensuring that the project responds to local needs while fostering high-quality educational outcomes.

Equally important has been the strong collaboration with provincial education authorities, which guarantees alignment with government priorities and anchors the project within the formal education system. This collaboration is reinforced by operational referents — former teachers now working within the governmental structure — who act as vital bridges between schools and policymakers. Their unique position allows them to combine classroom experience with policy objectives, facilitating the integration of innovative teaching methodologies and learning materials, and ultimately strengthening both the legitimacy and the impact of the project.

Another key factor behind the project's successful execution is its distinctive pedagogical approach, which emphasizes learning by doing and the translation of abstract concepts into tangible experiments. YouthEnergy moves beyond traditional lecture-based instruction by introducing problem-based learning (PBL) and experimental kits that enable students to reproduce energy technologies at a small scale. This approach not only makes complex concepts such as the greenhouse effect or hydrogen production easier to grasp, but also empowers students to actively explore solutions on their own. Teachers have reported that the combination of hands-on experimentation with accessible materials and opportunities for social reflection has significantly increased student motivation and classroom engagement. It is precisely this merge between practical experimentation and the integration of social dimensions that positions YouthEnergy's pedagogy as state-of-the-art in the field of energy education.

Conclusions

YouthEnergy demonstrates how innovative pedagogical approaches and strong cross-sector collaboration can transform energy transition challenges into opportunities for learning and empowerment. By introducing state-of-the-art teaching methodologies, including problem-based learning and hands-on experimentation with accessible, small-scale technologies, the project enables students to grasp complex theoretical concepts while developing problem-solving and critical thinking skills.

The project's multi-actor design — bringing together private entities, NGOs, government actors, and academia — has been key to its success. These partners jointly contribute expertise in technical training, didactic material development, and institutional integration, bridging the gap between policy, pedagogy, and practice, and positioning teachers and students as active participants in Argentina's just energy transition.

By combining practical experimentation with inclusive dialogue and multi-actor collaboration, YouthEnergy provides a replicable model for activating young people as innovators, knowledge disseminators, and leaders in shaping a just energy future.

Acknowledgements

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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SEED sustainable energy education

Conference on Sustainable Energy Education – SEED 2026
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This paper presents lessons from the Erasmus+ Blended Intensive Programme (BIP) on Positive Energy Districts (PEDs). The BIP-PED course combines onsite lectures, site visits, gamification, and collaborative assignments with cloud-based simulations and digital learning tools. Results from the 2024 and 2025 editions demonstrate enhanced student engagement, with increased use of virtual learning platforms and simulation activities. Key challenges include managing cross-border collaboration and ensuring access to digital infrastructure, while successes reveal the potential of BIPs to bridge educational gaps.

Advancing Energy Education With Lessons From Blended Intensive Programs On Positive Energy Districts

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Xingxing Zhang	Prof. Zhang is a full professor at the School of Information and Engineering, Dalarna University, 791 88 Falun, Sweden. He has a strong interest in bridging research and education in urban energy transition. He initiated the concept and the programme, as well as the writing and review of the paper.

How to cite: Shen, J., Zhang, X. (2026). Advancing Energy Education With Lessons From Blended Intensive Programs On Positive Energy Districts. In: Expert Articles. Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026). Utrecht, the Netherlands, 24-25 March 2026. DOI: https://doi.org/10.48544/2bead37a-7666-4173-8447-ba79a9cff1ee.

Introduction

The energy sector is undergoing a rapid transformation, accordingly facing the shortage of skilled professionals, outdated expertise, financial constraints, and complex systemic barriers. However, the traditional education programmes cannot contain all the needs required by the development.

On the other hand, the Erasmus+ programme launched by European union supports a wide range of education initiatives. It works as a key driver in modernizing and internationalizing energy education across Europe and partner countries (Enescu et al., 2024). Through organized three key actions, it offers resources for collaborative projects, curriculum development, and mobility opportunities. The Erasmus+ presents a great educational opportunities in training of students, teachers, and professionals in renewable energy, energy supply, and sustainability. Under the umbrella programme of Erasmus+, the Blended Intensive Programme (BIP) exhibits a flexible and inclusive international learning experiences in an efficient learning format.

The BIP in this paper was designed to focus on positive energy districts (PEDs), due to the need of capacity building for complex urban energy transition. It was in collaboration with 11 academic partners across the Europe. The proposed educational initiative consists of 3 ETCS and has been launched successfully in 2024 and 2025, engaging a total of 52 students from 9 different European universities (shown in Figure 1). Accordingly, good practices are reported from the following aspects of course content design, teaching practices, challenges and course evaluation.

Figure 1. Pictures taken in both 2024 and 2025 cohorts.

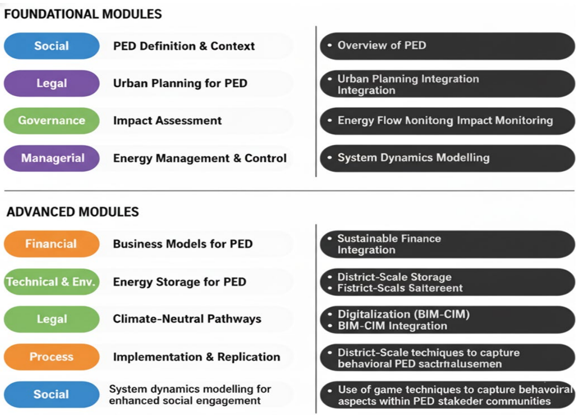
Course curriculum development and teaching practices

The traditional siloed training is insufficient in a fragmented learning landscape (Kirejev et al., 2025), especially in the context of PEDs. Due to interdisciplinary and transdisciplinary features regarding PEDs, it is necessary to gather multiple partners to work on a collaborative and digital platform expanding intercultural competence and teamwork. In general, these integrated approaches should equip students with the comprehensive knowledge from technical, economic, environmental, social, and policy aspects for urban energy system.

BIP as part of Erasmus+ mobility framework, this programme's main focus is on blending the mobility with both physical and virtual collaboration to maximize accessibility, flexibility, and innovation in international education. This BIP-PED has innovative teaching features in terms of topic-based learning, peer-to-peer transdisciplinary teamwork and a collaborative and digital platform. The whole programme contains a total of 18 distinct sessions that span across five days' onsite study, including 13 expert lectures, laboratory visits, technical exercises, site visits, game play, poster sessions, and practical assignments. Meanwhile, it offers extra five days practice remotely through both the cloud simulation service and the simulation tutorial. The target students are postgraduate students with a wide range of background from architecture, urban planning, construction engineering, electrical engineering, energy engineering to mechanical engineering. After two weeks' intensive study, the final assessment includes a group project assignment and a project presentation, followed by a Q&A session with designated peer opponents.

The programme covers both basic and advanced topics (Figure.2), presenting scope and depth across the main sessions and practical activities. The foundational areas aim to introduce core PED concepts and key urban energy challenges, while the advanced areas aim to supplement technical applications, modelling, technology deployment, and replication. In addition, group exercises, gamification, poster sessions, and participant presentations to apply concepts all highlight real-life and practical elements.

Figure 2. Both topics featured in the BIP-PED.



Results and discussion

Gender, age and geographical distribution

There is a traditional challenge in the energy education programmes that female students are often far less than male students. We observed a good trend in this BIP. In 2024, a total of 22-student shows a healthy balance of gender and age, with Italian dominance but strong representation from Latvia, Turkey, and France. The students' age range is from 21 to 35 years old with a pattern of mix between fresh academic perspectives and mature experiences in classroom study. In 2025, a total of 30-students presents a rich mix of countries, spreading across Northern, Southern, and Western Europe, and a nearly balanced gender. It has a wider age range from 21 to 41 years old with the median age around 24-25 years old. Such even distributions in age and geography also demonstrate urgency in the development of PED in may EU countries. As a result, there are strong needs in the relevant capacity building and education.

Cross-border challenges

As both lecturers and students from different countries work together in a short time, BIP-PED has to face multiple cross-border challenges to push all to work effectively beyond their national or cultural comfort zones. When looking into the selected assignment track on Canvas platform, the designer track are usually more culturally and gender diverse who have more focus on light-weighted designs associated PED tasks. The assignment grading status proved that the designer track is good at team collaboration with more adaptability and creative exchange. Following similar demographic characteristics as the traditional Science, Technology, Engineering, and Mathematics program (STEM) has, the engineer tracks are more male-heavy and nationally homogeneous. Due to the limited working time, students prioritized more on cohesive technically collaboration with sacrifice of limited intercultural learning. Meanwhile, in the mixed group, southern European representation (Italy, Spain, France) takes the leading role with complementary participations from both northern and eastern European students (Latvia, Sweden, Germany, Turkey, Portugal).

Virtual learning

The virtual learning environment consists of Canvas learning system, Padlet interactive learning board and the City Energy Analyst (CEA) cloud simulation platform.

According to the Canvas' s playback data, there were 135 and 92 player impressions, resulting in 63 and 82 plays in 2024 and 2025, respectively. Figure 3 illustrated the record of 2025 cohort as an example. This indicates that while the number of impressions decreased from 2024 to 2025, the number of actual plays increased, suggesting higher engagement among viewers in 2025. The 'Video On Demand' analytics show that the total minutes viewed in 2025 were approximately 3.7 times higher than in 2024. Especially the number of students increased by a factor of 1.36 in 2025, the resulted average minutes viewed per viewer is around 82.2 minutes more in 2025, it further indicates a successful rise in overall student engagement as class sizes grow on virtual exchange capacity.

The most possible contributing driver is the use of cloud-based simulation for real-world PED modelling. The CEA cloud service allows students to access the advanced simulation tool through a web browser. This enables students and educators to run complex energy and urban simulations from anywhere with an internet connection, while getting rid of complex and unpredicted issues of local installation or high-performance computers.

Figure 3. Statistics of learning activities in 2025 cohorts.

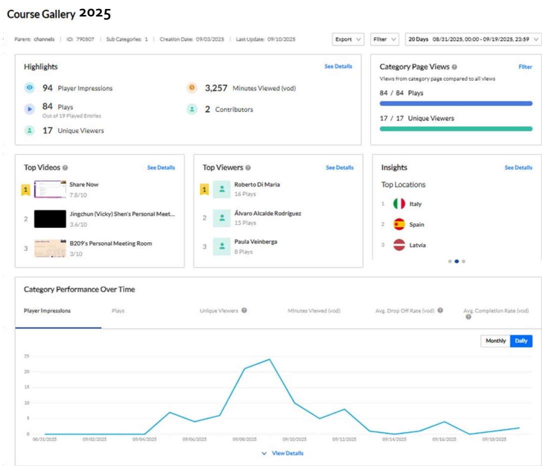
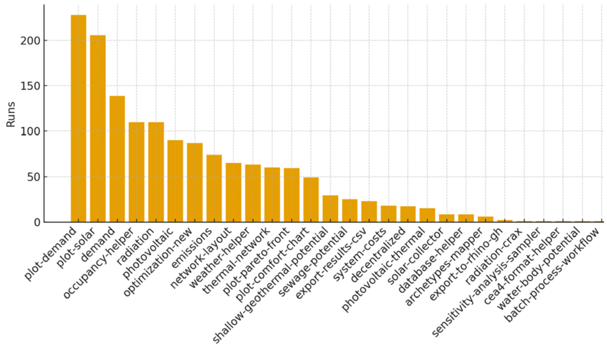


Figure. 4 presents the total CEA simulation activities. There are a total of 1496 simulation activities run by 18 unique students from the introduction of the CEA cloud service in 2025. In accordance with tasks in both tracks, the simulation activities of "plot-demand", "plot-solar" and "demand" have the top three highest runs as those align with the core tasks required in both the designer and engineer tracks. When categorizing simulation activities by track, the designer track had 5 unique users who completed 440 simulation runs, while the engineer track had 11 unique users who completed 784 simulation runs. This suggests that both tracks had highly active users, but the engineer track demonstrated broader participation.

Figure 4. Statistics of simulation activities from CEA.



Feedback from students

In 2024, all the students completed in the hard-copy course evaluation form, resulting in a 100% feedback ratio. The feedback was overwhelmingly positive: students highly appreciated the course's well-structured planning, engaging and approachable instructors, high-quality and up-to-date content, timely responses to questions, and a well-developed final assignment. The evaluation covered 13 teaching aspects, all of which received excellent ratings. Students noted that the course content was directly linked to recent research projects, making the learning experience both current and informative. The instructors provided immediate answers to questions, stayed after lectures for individual discussions, and maintained communication via email, WhatsApp group chat, and the BIP Padlet. As a result, most students rated the course as excellent across all modules and unanimously (100%) stated they would recommend it to others. One of the most common suggestions was that students encountered difficulties with the software during the final assignment collaboration, largely due to differences in laptop operating systems and varying levels of user acceptance of the new software.

In 2025, the paper format course evaluation was replaced with a environmental friendly approach of a wooclap questionnaire, resulting a 48% response rate. The feedback was still highly positive: 87% rated the instructor's knowledge as excellent, and 86% found the course content useful or very important for practical application. Assessments were considered effective by 80% of students. The pace and workload were generally seen as high but acceptable, and 67% rated the learning resources as rich. The overall quality of course materials was rated as best or very good by all students. Students especially appreciated the diverse and international teaching team, the interdisciplinary approach, well-organized structure, and engaging lectures. Suggestions for improvement included more practical lessons, larger classrooms, and a slightly slower pace. Nevertheless, 100% of students reported that they would recommend the course to others.

Conclusion

This PED education initiative demonstrates that blended intensive programs can effectively bridge disciplinary, cultural, and digital gaps in energy education. By integrating onsite and cloud-based learning, it equips students with practical, intercultural, and technical skills essential for advancing sustainable urban energy systems.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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Small and medium-sized enterprises (SMEs) in the automotive aftermarket are under increasing pressure to remain competitive while transitioning to circular business models, in line with Dutch sustainability goals. These SMEs, operating in areas such as auto parts, battery systems, maintenance, and damage repair, are directly affected by this shift. They face dual challenges: adapting their operations to meet sustainability directives and responding to intensified competition from low-cost, imported Chinese electric vehicles (EVs).

Emergence Of Chinese EVs In The Netherlands: What Needs To Be Considered For The Automotive Aftermarket?

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Introduction

"The West was sleeping. Now we have a lot of catching up to do."

"The house is on fire, and we don't know if we can survive this."

Participants, Drive Forward Conference, 2025

Such manifestations of frustration are not uncommon among the business leaders in Dutch automotive industry. The automotive aftermarket in the Netherlands is facing intensified pressure.

SMEs operating in areas such as auto parts, battery systems, maintenance, and damage repair, faces mounting pressure on two fronts of adapting their operations to meet sustainability directives (e.g. The Circular Economy Action Plan), and responding to intensified competition from low-cost, imported Chinese electric vehicles (EVs).

The emergence of Chinese EVs is not simply a market phenomenon but the result of a highly coordinated industrial policy and changing supply-chain presence. For Dutch aftermarket SMEs, the challenge lies not just in adapting to EV technologies but in navigating an volatile geopolitical environment.

This article explores the geopolitical, policy-driven, and logistical contexts, drawing from both market developments and research into China's EV policy ecosystem

Geopolitics and market developments

To understand why Chinese EVs are reshaping the aftermarket, we must first examine the geopolitics and market forces that enable their expansion.

In 2025, Chinese electric vehicle sales have grown markedly, with expanding market share and rising volumes even in the face of tariffs, capturing 5.4% of the market as of the second quarter (Bargeron, 2025). Chinese original equipment manufacturers (OEMs) are continuing to expand across Europe by learning from policy landscapes and consumers demands (Ahlander and Manekar, 2023). Their influence reaches beyond vehicle sales, reshaping technologies, supply chains, parts distribution networks, particularly in key transit hubs like the Netherlands.

Since Chinese brands that enter the European market are fully focussing on delivering new vehicles, the warranty period deserves attention for SMEs. Warranty repairs have to be performed by the authorized partners of the OEMs, which indicates limited work other than "simple" maintenance work available for the aftermarket. As OEMs only allow original parts during the warranty period, it significantly narrows down opportunities for the aftermarket. However, beyond warranty restrictions, broader geopolitical tensions are compounding aftermarket challenges.

EU–China relations have become increasingly strained. Following the EU's anti-subsidy investigation in 2023, provisional tariffs were introduced on Chinese battery-electric vehicles. In response, Chinese OEMs have strategically shifted their exports toward plug-in hybrids (PHEVs), which face lower tariffs. BYD, for instance, sold 3,269 PHEVs in March 2025—up sharply from mid-2024 (Parodi, 2025).

In the mid of EU-China relations, the Netherlands is heavily exposed to these shifts. As a major logistical hub, it imported €1.1 billion of Chinese EVs in 2023 (Statistics Netherlands, 2024), much of which was re-exported. Tariff changes or supply chain disruptions could have immediate consequences for Dutch import levels and aftermarket service demands.

Meanwhile, China continues to develop advanced circular economy systems for EV batteries, exploring alternative chemistries and recycling methods (Ezell, 2024). With global demand for battery materials growing rapidly (IEA, 2024), China's dominance in upstream supply chains remains a critical geopolitical concern.

These geopolitical and market developments highlight the urgent need for flexibility and strategic planning within the automotive aftermarket sector.

Policy Landscape

So what drives Chinese EV expansion? According to Lin (2024), the three major drives for the growth of China's EV sector include:

1. experimenting in adjacent industries,

2. encouraging operational solutions,

3. doubling down on core technology.

Owing their advance to government policies, the Chinese OEMs have demonstrated more confidence and experiences to take the leap to Europe.

Based on the analysis and observation of China's policies on electric vehicles since a decade, the author identifies the key findings, suggesting that China's electric-vehicle policymaking is shaped by extensive multi-ministerial coordination, with over thirty central government bodies involved. The most influential include the State Council, which provides overarching strategic direction, as well as Ministry of Industry and Information Technology, the Ministry of Finance, the State Taxation Administration, and the National Energy Administration.

Since 2020, policy priorities have gradually shifted from primarily environmental goals toward technological self-reliance, and industrial competitiveness. China's EV strategy has also become increasingly integrated with related sectors such as battery manufacturing, rare earth processing, digital and charging infrastructure, cybersecurity, and even satellite systems.

The state continues to cultivate the market by promoting EV procurement within public institutions and among civil servants. Meanwhile, engagement with international automakers and participation of global rule-making is encouraged, though without coherent framework guiding cooperation, underscoring the largely domestic orientation of the strategy.

Together, these dynamics help explain the competitiveness of Chinese EV manufacturers in Europe, whose expansion is underpinned not only by cost advantages but by a highly coordinated national industrial policy.

Supply Chain Uncertainty

Geopolitical tensions directly shape logistical vulnerabilities. The rapid growth of Chinese EVs exports to Europe has introduced not only competitive shifts but also growing vulnerabilities within the European automotive supply chain, including components, battery systems, software platforms, and aftersales services.

A recent case illustrating these vulnerabilities is the Nexperia case (Race, 2025). In late 2024, the Dutch government intervened at Nexperia, a Chinese-owned semiconductor firm, over concerns related to improper transfers of assets, technology, and knowledge, and the potential risk this posed to Dutch and European semiconductor security. In response, China halted some chip exports, revealing how quickly geopolitical tensions can translate into supply disruptions. Although the Dutch government later suspended its intervention after "constructive talks" with Beijing, the episode exposed Europe's heavy reliance on Chinese chip supply (Race, 2025).

For the aftermarket, where semiconductors are essential for EV power electronics, battery management systems, and diagnostics, the Nexperia case shows how geopolitical disputes can turn into operational risks, threatening repair continuity, parts availability, and service reliability.

Overall, Europe's dependence on China for batteries, rare earth minerals, semiconductors, and key components makes the supply chain fragile. Disruptions, whether political, economic, or logistical, can affect vehicle and parts availability (Kelly, 2025).

The concentration of these upstream activities within China creates a fragile supply chain that is highly susceptible to geopolitical shifts, export restrictions and trade measures.

For Dutch SMEs in the automotive aftermarket, these logistical uncertainties have concrete consequences such as delays in OEM-certified parts, inconsistent component flows in servicing the growing Chinese EV fleet, as well as challenges in integration of end-of-life vehicle.

Conclusion

Traditional aftermarket models built for internal combustion engines are becoming less viable. EVs contain fewer mechanical components, require less routine servicing, and depend heavily on digital and battery technologies. SMEs must therefore redesign their offerings and invest in new forms of technical and strategic capacity.

To remain resilient in this rapidly evolving environment, Dutch SMEs must prioritize in market forecasting focused on Chinese EV import patterns, supply chain risk analysis, and collaborative models with OEMs, local suppliers.

Translating these transitions into workforce readiness, the Dutch automotive ecosystem must focus on targeted upskilling for SME employees, in the areas of EV diagnostics and advanced troubleshooting, end-of-life management, supply chain literacy and circular business competencies. By embracing these strategies, SMEs can then shift from vulnerability to resilience, contributing to a competitive and sustainable Dutch automotive aftermarket.

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Europe's energy transition is gradually reshaping the labour market, with renewables generating new types of jobs and shifting skill requirements. In Greece, the process is underway, but regional disparities remain, particularly in areas like Western Macedonia, where the move away from lignite brings both opportunities and pressures. This article offers a brief overview of how labour trends in the energy sector are evolving across Europe and Greece, with an emphasis on local realities. The aim is to highlight emerging patterns and raise key questions about how education, training, and policy can respond.

One Transition, Two Realities: Energy Labour Markets In Europe And Greece — A Focus On Western Macedonia

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Introduction

Europe's shift toward clean energy is transforming more than just infrastructure — it is also redefining the labour market. Across the continent, opportunities in solar, wind, storage, and smart grids are multiplying, pushed forward by fresh investment, supportive policies, and ongoing innovation. Yet while the direction is shared, the pace and readiness vary, especially in countries like Greece, and more specifically in regions such as Western Macedonia, which faces a double transition: from fossil fuels to renewables, and from structural unemployment to a skills-based economy. This article explores how the energy labour market is evolving across Europe and Greece, placing particular emphasis on Western Macedonia, a region at the frontline of the just transition.

Figure 1. The fields of the lignite-fired power plants, in Ptolemaida, Western Macedonia.

Source: https://kede.gr/.

This expert article is based on a synthesis of recent European and national labour market diagnostics, complemented by regional studies for Western Macedonia and expert consultations conducted within EU-funded transition projects. While it does not present primary survey data, it integrates quantitative indicators from Eurostat, EURES, IEA, and national transition planning documents, alongside qualitative insights from vocational education and regional development stakeholders. This mixed evidence base supports the analytical interpretation that follows.

Labour Market Shifts in a Changing Energy Landscape: Europe and Greece Side by Side

A European Labour Market in Transition

Across Europe, the clean energy transition is changing not only the way the energy sector operates but also the people driving it. Germany, the Netherlands, and Denmark stand out for preparing their workforce, weaving green skills into vocational training and steadily boosting jobs in solar, wind, and grid technologies. By late 2023, solar employment alone had climbed past 648,000 positions across the EU. These numbers are expected to grow even faster in the coming years, as energy policies tighten and new technologies mature. What stands out is the growing demand for practical, technical roles — from installation and maintenance to systems integration and automation. Vocational training and lifelong learning programmes are at the heart of this shift, ensuring workers can adapt quickly and employers can find the talent they need.

Greece in the Picture: Shared Goals, Unequal Readiness

Greece is on the same transition path — but the pace and conditions vary. While national targets are ambitious and investment in solar and wind is increasing, the labour market still faces structural barriers. Employment remains below the EU average, and the connection between training systems and real job needs is not yet strong enough. In many cases, job roles exist but the skills don't. The issue becomes even more acute when viewed through the lens of Western Macedonia — the country's historical energy heartland, now undergoing a dramatic economic transformation. Large-scale energy investments are underway, especially in this region, but the local workforce isn't always prepared to take them up. The result? Opportunities that risk being outsourced or left unfilled. Yet, this gap is not only about missing skills, but also about how slowly the governance and planning systems adapt. While investments in energy infrastructure are moving fast, education and workforce planning still operate at a much slower pace. This creates a clear time mismatch between how quickly new projects appear and how ready people on the ground actually are to work in them.

So, while both Europe and Greece share the same overall energy transition goals, the conditions on the ground tell two different stories — and Western Macedonia often reveals the sharpest contrast. The table below outlines some of the key contrasts that shape their respective labour market dynamics — from employment rates and workforce readiness to skills availability and policy coordination.

Table 1. Labour Outlook at a Glance: Europe vs Greece.

Aspect	Europe (EU27 Average)	Greece
Employment Rate (2023)	~70.4%	~61.8% (below EU average; lower for youth and women)
Unemployment Rate (2023)	~5.9%	~11.1% (rising to 27% in Western Macedonia post-lignite)
Renewable Energy Jobs	Over 1 million expected by 2025 (solar, wind, storage)	Rising sharply in solar & wind; workforce mismatch remains
Training–Labour Match	Strong in many countries (e.g. DE, NL, DK); VET systems integrated	Fragmented links between training and job market
Skills Gaps	Focused on emerging tech (AI, automation, green hydrogen)	Gaps in technical skills, digital literacy, and applied problem-solving
Policy Alignment	Generally high — national strategies link education & energy	Improving, but slow alignment between NECP and skills planning

Sources: Eurostat 2023 data for employment and unemployment (employment rate; unemployment rate); SolarPower Europe jobs outlook (renewables jobs projection); EU EURES and regional diagnostics reports on training-labour gaps and skills needs.

Western Macedonia: From Lignite Legacy to Renewable Future

For decades, Western Macedonia has been the heart of Greece's energy system — hosting PPC's lignite mines and power stations, along with thousands of jobs linked directly to fossil fuels.

Now, as lignite is phased out, the region is navigating a profound economic and social transition. The stakes are high: unemployment is already at 27%, and without rapid action, it could rise further. Recent regional diagnostics

(SDAM 2020, IEA 2022) indicate that over 60% of lignite-related workers in Western Macedonia possess medium-level technical skills, yet fewer than 25% meet the current requirements for renewable energy, automation, or digital energy systems. This mismatch highlights the urgency of targeted reskilling pathways rather than generic employment schemes.

Figure 2. The fields of the lignite-fired power plants, in Ptolemaida, Western Macedonia.

Source: Photo by Christos Labrianidis, entitled "No pollution please" in Western Macedonia lignite plants, that won first prize in the international Coolclimate competition.

But there's also momentum. Over 2 GW of solar projects are in the pipeline, and new infrastructure like hydrogen plants and battery storage units is being planned. What's missing is a matching skills base. A recent skills scan showed gaps not only in technical areas like energy systems, automation, and hydrogen technologies — but also in softer skills like initiative, problem-solving, and digital readiness.

Skills, Training, and the Role of Vocational Excellence

The creation of a regional Centre of Vocational Excellence (CoVE) in Western Macedonia is a step in the right direction. It reflects a shared understanding that training must be locally driven, tightly linked to industry, and built around actual labour market needs.

Challenges remain. Many VET providers find it difficult to update their curricula quickly, and cooperation between schools, employers, and policymakers is often inconsistent. What's still missing is a steady feedback loop linking the labour market with education providers, backed by regular skills forecasts and joint planning.

As the region's key academic institution, the University of Western Macedonia plays a strategic role in the just transition. Through specialised undergraduate and postgraduate programmes in energy, environmental engineering, and digital technologies — as well as its involvement in national and EU-funded projects — the university acts as a bridge between research, education, and the evolving labour market. Its contribution to vocational excellence, upskilling, and regional innovation ecosystems is essential for aligning workforce capabilities with the demands of a cleaner, smarter energy economy.

A Just Transition — But for Whom?

Europe's energy transition has often been described as a "just transition." But justice isn't automatic. For regions like Western Macedonia, it requires targeted support, inclusive planning, and real investment in people , not just in megawatts.

Conclusion: Turning Parallel Paths into Shared Progress

The success of Europe's clean energy transition depends as much on its people as on its technology.

While the path is shared, the pace and preparation vary widely, and Greece, especially regions like Western Macedonia, stands at a critical crossroads. With targeted investment, stronger coordination, and a real commitment to workforce development, the energy shift can become a catalyst for inclusive growth , not just in numbers, but in dignity, opportunity, and local empowerment. The challenge now is to turn transition into transformation, for all.

Figure 3. Operation of the last lignite-fired power plant, in Ptolemaida, Western Macedonia.

Source: https://www.oryktosploutos.net/2024.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Abbreviations

NECP: National Energy and Climate Plan

PPC: Public Power Corporation

VET: Vocational Education and Training

For 40 years now, students at Technische Universität Berlin have been shaping their own learning through self-organized "project labs". These interdisciplinary formats link academic knowledge with real-world sustainability challenges and foster skills essential for future professionals in the energy sector and beyond. By combining student agency with innovative didactics, project labs have become a pioneering model of Education for Sustainable Development. This article explains how this didactic concept works, why it can be considered a best practice example for the education of future professionals, and which conditions enable its successful transfer to other universities.

Student Self-Organized Project Teaching As Training For Future Professionals – The Project Labs ("Projektwerkstätten") At Technische Universität Berlin As A Best Practice Example

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Introduction

For 40 years now, since 1985, students at Technische Universität Berlin (TU Berlin) have had the possibility to conduct their own teaching and research in "project labs" – student-initiated, student-designed, and student-led, in cooperation with other students and fully integrated in the general curriculum. How this works and what possibilities student-organized teaching offers for the education of future professionals in the energy sector and other sustainability-related fields of practice will be discussed in the following article.

We argue that project labs at TU Berlin are a pioneering best-practice case of Education for Sustainable Development, and that they offer transferable lessons for universities worldwide. In doing so, we aim to demonstrate not only their relevance for the energy sector but also their potential to inspire systemic innovation in higher education.

The TU Berlin Project Labs

Now, what are these project labs? Project labs originated as a result of a student strike in the 1980s as a self-help initiative to improve the academic education system. The participants mainly criticized the lack of practical experience in their technical study programs and the lack of contextualization of technical questions within the accompanying social circumstances and consequences, for example, the environmental impacts of technological developments. As a result, innovation tutorials were established by the university's presidents and committees, which labelled themselves "Projektwerkstätten" (project labs) soon after.

Following this tradition, today project labs are four-semester courses that are independently initiated, designed, and led by students. If students have a project idea, they can receive counselling on it, develop their own course structure, and then submit a proposal to the TU Berlin Teaching Committee and the Vice President for Education. Twice a year, around five of these projects receive funding, which means that the applying students are offered a two-year working contract for student-assistant positions and a material budget. Selection criteria for the projects include innovative teaching methods, as well as an addition to the general teaching offer at TU Berlin, and a connection to questions of sustainability, as well as an interdisciplinary teaching approach or the consideration of gender and diversity aspects. The topics chosen by the students are often linked to their realities, reach beyond the academic world, or involve social actors, which means that most of the projects address non-academic realities and some of them require transdisciplinary approaches and methods.

Some project labs are designed from the outset in cooperation with external actors such as civil society groups or municipal partners. At the same time, students retain full autonomy in selecting and shaping these collaborations, which ensures that projects follow their own learning priorities. This structure supports transdisciplinary practices within the labs and helps students develop skills needed for similar processes in their future professional contexts.

Project labs are open to Bachelor and Master students of all disciplines. Participating students can be credited with 3 or 6 ECTS credits, graded or ungraded, according to the design the initiating students have suggested for their course. Project labs are supported by a chair at TU Berlin and by the science shop kubus, with the chair offering more support on the topic and being the structural anchoring of the course and the tutor's position and kubus supporting the didactic concept and general organizational matters, coordinating the various projects running in parallel, and organizing exchange meetings.

As an innovative teaching format, project labs require concrete project ideas or research questions. Participating students also experiment with new teaching, learning, and research concepts. Successful elements can later be integrated into the regular curriculum at TU Berlin.

Over the years, project labs have addressed a wide range of topics: from community-based renewable energy concepts and sustainable mobility strategies to digital tools for citizen participation in climate action. These cases illustrate how students take responsibility for socially and environmentally relevant issues and build bridges between academic learning and real-world problem-solving.

Since their introduction in 1985, 269 project labs have been implemented at TU Berlin (Technische Universität Berlin, 2025). They can roughly be distinguished into theoretical–analytical formats, which focus on reflection and critique, and practical–experimental formats, which emphasize hands-on implementation and prototyping.

In terms of content, most labs fall into five broad clusters: (1) Energy & Technology, (2) Ecology & Environment, (3) Social Innovation & Participation, (4) Gender & Diversity, and (5) Education & Didactics. This thematic breadth shows that project labs are not limited to a niche, but span across disciplines and societal challenges, thereby strengthening their role as a versatile instrument of Education for Sustainable Development.

The following table gives an overview of how the project labs can be grouped according to their thematic focus. It illustrates the variety of topics that students have chosen over the years and how broadly the project labs address questions of sustainability, social responsibility and innovation across disciplines.

Table 1. Thematic clusters of project labs (1985–2025).

Thematic Cluster	Number of Labs	Share (%)
Energy & Technology	93	34,6 %
Ecology & Environment	48	17,8 %
Social Innovation & Participation	54	20,1 %
Gender & Diversity	22	8,2 %
Education & Didactics	52	19,3 %
Total	**269**	**100 %**

In the following section, we discuss why we consider self-organized teaching and learning as practised in the project labs as relevant for the training of future professionals in the energy sector and other sustainability related fields.

Project Labs as an effective training for future professionals

First of all, students in project labs have the opportunity to run their own projects. This means, they can gain practical experience and skills in project management, but also the experience of designing and implementing a project from the beginning to the – hopefully successful – completion, with all the difficulties and adjustments that come with the complex conditions of project work. Doing this in a responsible position contributes tremendously to the qualification of future professionals, as project work is an essential component of nearly all professional fields.

In contrast to other academic programs, the project labs offer a very practical approach. This establishes a connection between the mostly theoretical parts of academic education and the practical questions that professionals will face in their working life, and allows students to apply their theoretical knowledge to real life problems. That's how the project labs fill a gap between academic education and students' future professional fields.

Although no formal alumni survey exists, long-term experience and informal feedback suggest that former participants draw heavily on competencies developed in the labs - especially self-organisation, multidisciplinary communication, and navigating complexity - in their later professional roles.

The future professionals will have to deal with different stakeholders and conflicting interests in their future life. If we look at the energy sector, these might include policy makers, engineers, energy supply companies, citizens' initiatives, and others. To find a common ground or to develop a common strategy will require extensive communication, negotiation, consultation, and translation between different backgrounds and perspectives. The skills necessary for shaping such processes are not a priori given, but have to be acquired, for example by doing the same in the context of self-organized teaching.

Last but not least, the great challenges that society faces, e.g. in the context of the climate crises, are not to be solved within a single academic discipline, but require close cooperation between different areas of expertise within and beyond academia, as well as a close cooperation between academic and non-academic experts. This is exactly what can be practiced in a project lab, as students from different academic backgrounds work together in interdisciplinary teams, often also with non-academic experts on questions that are not just chosen because of their academic relevance, but because of their relevance in everyday life. This working process is not moderated by someone else but is run by the students themselves, which forces them to take responsibility and navigate the emerging challenges and therefore experience what it means to be an individual with the power to act. We are convinced that students need these training fields to be able to deal with the major challenges as professionals later.

Student feedback repeatedly emphasizes that participants experience a steep learning curve in teamwork, communication, and project management (Dietrich et al. 2014). In this sense, project labs do not just complement academic education; they actively shape employability and professional identity.

Conditions for success

To make sure the educational concept of student-organized teaching as practiced in the TU Berlin project labs can reach its full potential for the qualification of future professionals, some framework conditions should be considered.

First of all, a certain amount of resources must be allocated to the student-organized projects. Students need (paid) time, infrastructure and a material budget to be able to develop and conduct their own projects.

This must be made available by the educational institution.

Second, students must be given as much freedom as possible to realize their ideas and address the existing challenges in their own way. This includes offering them a format that is of a certain duration as well as guaranteeing them the freedom to choose their topics and methods. This further involves offering them a support and consultation structure to come back to if they don't get along on their own, and an organizational culture that embraces tolerance for mistakes.

And last, it requires trust in the students, in their ability and willingness. This also means that in the organizational culture, students need to be seen as the grown-up and self-responsible people they are – which is, in essence, taking serious their role as those who shape our future as future professionals (Bönisch et al., 2023).

In addition, the TU Berlin experience shows that institutional anchoring and continuity are crucial: the science shop kubus provides ongoing didactic and organizational support, while the Teaching Committee ensures quality assurance. This dual structure balances freedom for students with a reliable framework for sustainability and academic standards.

Transferability and Lessons Learned

The long-standing experience of TU Berlin's project labs offers valuable insights for other universities aiming to implement similar formats. Key success factors include: (1) formal recognition of student-led teaching within the curriculum; (2) adequate financial and infrastructural support; (3) accessible counselling and mentoring structures; and (4) an institutional culture that values experimentation and tolerates mistakes. TU Berlin's example proves that with trust, resources, and clear processes, student-organized teaching can flourish as a sustainable element of higher education.

Conclusion

Project labs demonstrate that when students are trusted and supported, they can design innovative learning environments that connect theory and practice, academia and society. For the energy sector in particular, this means training future professionals who are not only technically competent but also capable of negotiating complex stakeholder landscapes and driving sustainable transformation. More broadly, project labs embody the principle that higher education should empower students as active agents of change – a principle that is urgently needed in times of the climate crisis and societal transformation. They therefore serve as a timely reminder that empowering students is not a luxury but a necessity for universities committed to sustainability.

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This article examines how a German University of Applied Sciences "Good Practice" — the Bobby Energy Hub — was implemented within Dutch vocational education and training (VET). Using the Network impact model, the study shows how this practice stimulates student engagement and cross-level collaboration, while also generating teacher enthusiasm and curricular flexibility. The implementation additionally fosters new forms of cooperation between ROC Midden Nederland, HU University of Applied Sciences Utrecht, and regional entrepreneurs. The case demonstrates how an initiative aimed at sustainable mobility can evolve into a broader learning ecosystem. It highlights that sharing a good practice can trigger chains of impact that extend far beyond the initial educational objectives.

Exploring The Impact Of A UAS "Good Practice" In VET

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Introduction

Understanding and enhancing the societal impact of educational innovation remains a persistent challenge. As education increasingly engages with complex societal transitions, it becomes essential to identify where and how our actions create meaningful change. The cross-border implementation of a proven good practice demonstrates how knowledge can flow between educational levels, disciplines, and national contexts — and how such exchanges strengthen our collective capacity to contribute to societal impact.

This article uses the Network Impact Model as an analytical lens to examine the implementation of a German University of Applied Sciences (UAS) good practice within Dutch vocational education and training (VET). By following the introduction of the Bobby Energy Hub into the curriculum at ROC Midden Nederland, we show how a single practice activates ripple effects across students, teachers, institutions, and external partners.

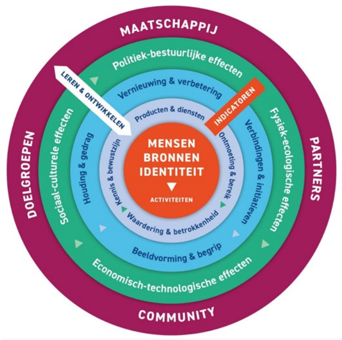
The Network impact model as a Framework

The Network impact model, developed with the Leiden Education Field lab (LEF) and further refined with Tilburg University, provides the conceptual foundation for this analysis. The model visualises impact as a set of concentric rings, representing how activities at the core of a network generate ripple effects outward. It starts from direct results and extends to broader societal influence.

Through rotatable rings, the model supports collective reflection, indicator development, and shared reasoning. In doing so, it enables educational networks to engage in continuous learning and to steer their collaborative efforts more effectively and sustainably (Hemink & Klaster, 2025a; 2025b).

In this article, the model serves to trace the ripple effects of implementing the good practice, and identify impact that extends beyond the initial educational aims.

Figure 1. Visual of the Network Impact Model.



Source: Hemink, M., & Klaster, E. (2025b).

Implementing a "Good Practice"

Within the CoVE SEED network, partners committed to sharing good practices as a way to accelerate innovation in sustainable energy education. This exchange aims to connect regional initiatives, strengthen cooperation between education and industry, and contribute to a European learning ecosystem that supports the energy transition.

One such exchange was the transfer of a successful practice from Bochum University of Applied Sciences (BUAS) — the Bobby Energy Hub, an off-grid photovoltaic charging station developed with SunCrafter — to ROC Midden Nederland. At BUAS, students work through problem-based learning to design solutions for sustainable mobility.

ROC Midden Nederland used this approach as inspiration to develop practice-driven projects for EQF level 4 VET students.

From Inspiration to Contextualisation

Although ROC Midden Nederland has a strong innovation culture, initial hesitation arose among teachers. The German approach is rooted in problem-based learning at EQF level 6, whereas ROC traditionally uses project-based learning at EQF level 4. To bridge this gap and create ownership, a group of staff and students visited BUAS for a guest lecture and hands-on experience with the good practice.

This visit proved decisive: teachers became more committed and jointly redesigned the original assignment into smaller, manageable sub-projects that aligned with VET qualification dossiers. This contextualization ensured that learning outcomes remained relevant while still enabling students to contribute to the broader concept.

The result was a project format that resonated with both teachers and students — and that opened space for new forms of collaboration.

Impact on VET: Insights Through the Network Impact Model

Student Collaboration and Leadership

A notable second-ring impact emerged when EQF level 4 students began collaborating with EQF level 3 peers to construct the structural frame of the Bobby Energy Hub. Although peer collaboration is part of the level-4 qualification, it is typically simulated. In this project, however, it took place authentically. Level-4 students guided level-3 students in building the physical prototype.

This collaboration will continue into the next phase, in which students jointly design and assemble the electrotechnical components. The project thus supports authentic leadership development, cross-level teamwork, and increased engagement.

Teacher Enthusiasm and Cross-Team Flexibility

Even more striking was the impact on teachers. The project generated enthusiasm that transcended team boundaries and fostered flexibility in the curriculum.

A powerful example came from a teacher involved with the Thundu Foundation, who proposed a new assignment: designing and constructing a floating sports field for children in Africa affected by monsoon seasons. Thanks to the flexibility fostered by the Bobby Energy Hub project, this idea was quickly embraced. EQF level 4 students now design the field, while EQF level 2 and 3 construction students will assemble it.

This illustrates how a single good practice can catalyse broader creativity, cross-team collaboration, and new forms of socially oriented education.

Cross-Institutional Collaboration with HU University of Applied Sciences Utrecht

A third-ripple impact concerns the collaboration between ROC Midden Nederland and HU University of Applied Sciences Utrecht. HU students from multiple disciplines work on the societal, entrepreneurial, and research dimensions of deploying the Bobby Energy Hub in Utrecht.

Because HU does not have the resources to build the prototype alone, they engaged local entrepreneurs who became more willing to contribute once ROC students started constructing the physical model. This cross-level and cross-disciplinary cooperation formed a professional learning community where teachers codevelop integrated assignments and supervision models.

The emerging synergy reinforces both institutions and exemplifies the type of ecosystem collaboration that CoVE SEED seeks to stimulate.

Broader Lessons Learned

Bonus dux bonum reddit comitem — a good leader makes a good companion. Or, more broadly: *a good example inspires others to follow*.

The implementation of the Bobby Energy Hub demonstrates that a good practice can generate impact well beyond its initial educational purpose. Some effects emerge unexpectedly, across levels, across teams, and across institutions. Not all impact can be planned; sometimes simply starting is more powerful than perfect preparation.

Taking time to reflect — as done in this article — reveals that impact often unfolds through enthusiasm, engagement, and small shifts in practice. These soft effects can be just as valuable as formal outcomes

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What sparks student motivation in their very first semester? At our university, all Energy and Environmental Engineering 1st year students design, build, and test a biomass cookstove. This playful challenge stimulates belonging, builds teamwork, and gives students a first taste of the competences they will need as energy engineers. The result: a hands-on learning experience that virtually turns sparks into skills.

From Sparks To Skills: A Hands-On Energy Project As A Gateway To Engineering Competence

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Introduction

Engineering education research emphasizes that project-based learning can enhance students' academic achievement (Chen & Yang, 2019), and students' life skills such as problem solving or communication (Wurdinger & Qureshi, 2015). Furthermore, it can be employed as a method for developing sustainability consciousness (Ásványi & Gedeon, 2025).

For first-year students, practical design challenges create opportunities to develop systems thinking, while teamwork may explore students' sense of belonging to engineering (Luk et al., 2024).

To support motivation and sustain interest, real-world tasks can be employed to increase perceived relevance. For example, when students engage with challenges such as biomass cookstoves, they directly encounter the technical, social, and environmental dimensions of energy systems.

Thus, our aim is to introduce first-semester energy engineering students to a hands-on, competence-based challenge, that not only advances technical skills, but also motivation, their sense of belonging, and awareness of the global impact of their future profession.

This framing aligns with international policy priorities such as SDG 7 (IEA, IRENA, UNSD, World Bank, WHO, 2025a), bringing sustainability to life in the classroom.

Case description: The Stove Project

Even though the sustainable development goal 7.1 targets "universal access to affordable, reliable and modern energy services" by 2030, clean cooking technologies will presumably be available to only less than 80% of world's population. In 2023, there were still more than 2 billion people, 25.9% of world's population, without access (IEA, IRENA, UNSD, World Bank, WHO, 2025a).

Clean cooking is referred to as based on electricity as well as on combustion of gas (LPG, natural gas, biogas) or ethanol (IEA, IRENA, UNSD, World Bank, WHO, 2025b), whereas non-clean cooking is related to polluting fuels such as wood, charcoal or (crop) waste. Mainly women and children are exposed to those cooking emissions, experiencing significant health risks, which may be mitigated by more efficient designed biomass cookstoves (Pope et al., 2021).

The development of an improved biomass cookstove is well-suited to address various aspects of energy engineering education: fundamentals of combustion, materials, design and construction, measurements according to international standards, energy justice in terms of "energy for all" and carbon credit mechanisms, as well as socio-economic factors with regard to technology distribution.

To prepare students for this broader context, the project begins with a short research task in which each team analyses a specific country, including cultural aspects, energy use, and local constraints. This early step helps students understand the social dimensions of energy access and typically sparks spontaneous discussions about distributional justice.

Since 2018, in the winter semester, fifteen to thirty first-year students in the Bachelor's programme Energy and Environmental Engineering are introduced to their studies by means of a challenge-based learning project. The assignment: to design, build, and test a biomass cookstove suitable for use in the Global South. Students are divided into teams of 3–5, with the whole cohort working towards the same overarching goal, competing for a low-cost design and a high fuel efficiency.

The project timetable combines weekly workshops, interim presentations, supervisions and deliverables as shown in Table 1.

Table 1. Stove Project outline: Action plan.

Week	Action
1-3	**Task:** draft concept, design stove **Skill Focus:** plan, prototype, communicate **Milestone:** release for manufacturing
4-7	**Task:** manufacture and assemble stove **Skill Focus:** manage problems, keep on track **Milestone :** clearance for "first fire"
8-11	**Task:** test stove, measure efficiency **Skill Focus:** evaluate and document results **Milestone:** results validated & documented
12-14	**Task:** present results, cook a meal **Skill Focus:** competing, bonding **Milestone :** engineering identity experienced

A standardized test protocol, based on international cookstove evaluation methods (Clean Cooking Alliance, 2014), is used to assess the performance of the prototypes. This includes measuring thermal efficiency, fuel consumption, and emissions. Teams also reflect on usability and safety, learning to balance technical design choices with social and environmental considerations.

The objective is to minimize cost in relation to the associated wood or CO_2 savings. Achieved fuel efficiencies range from a mere 15% – similar to an open fire – to 45%. A variety of designs are shown in Figure 1.

The project culminates in a final cooking event, where the student teams use their stoves to prepare a simple meal from a country they have previously selected and presented. This playful but demanding conclusion strengthens team spirit, allows students to showcase their designs, and creates a sense of programme identity.

The assessment rubric is calibrated to balance fairness with educational goals. It takes into account group results as well as individual assignments, including elements such as concept documentation, completed product and measurement reports and result presentations.

Figure 1. Example stove designs and efficiency results.

Material			
Clay	Clay/Metal	Metal	Metal
Efficiency			
15%	32%	20%	22%

Beyond the first semester, the stove project has proven to be a seedbed for follow-up activities: advanced projects on emission measurements, bachelor or master theses on design improvements, and even entrepreneurial initiatives. Although this recurring engagement is not intentionally cultivated within the curriculum, students often return to the topic out of genuine interest. Discussions with guest experts from countries such as Lesotho, Zambia, or Madagascar appear to play a key role in triggering this deeper involvement. One notable example is the student-founded non-profit organization BioPellets Energy, which emerged from earlier iterations of the course and now develops sustainable fuel and stove solutions in Madagascar (see Text Box 1).

Insights and discussion

The stove project has consistently demonstrated its value as a competence-building introduction to energy engineering studies. Several key insights have emerged:

1 Technical and engineering Skills

Students acquire hands-on experience in fundamental engineering practices: planning, design, prototyping, and measurement (see Figure 2). The standardized efficiency test provides a rigorous framework for learning how to evaluate energy systems. In some project cycles, teams developed independent testing criteria, showing early-stage critical thinking about how sustainability should be evaluated in engineering practice.

Figure 2. Trial by fire – measurement in the stove test bed.

2 Soft skills and teamwork

Working in small groups of 3–5 fosters collaboration, communication, and conflict management. The shared challenge of preparing for the final stove test and cooking event strengthens programme identity and student bonding. This onboarding effect is particularly important in the first semester, where many students are still negotiating their academic and social place within the university (see Figure 3).

Figure 3. Shared flame - the final cooking event.

3 Pedagogical benefits

The project serves as a playful contrast to traditional lectures. Rather than passively absorbing theory, students are required to apply concepts immediately in a tangible way. The competitive element — "which team designs the best stove?" — adds motivation, while the diversity of outcomes illustrates the creativity inherent in engineering design.

4 Linking to global challenges

Designing stoves for the Global South exposes students to energy poverty, health impacts, and resource constraints. Sustainability dilemmas such as material choices, durability, and responsible production often emerge organically in group discussions, prompting students to reflect on ethical aspects of engineering decisions. The Madagascar bio-pellet initiative shows how such learning experiences can inspire real-world engagement (see Text Box 1).

Conclusions and outlook

Our biomass cookstove project shows that first-semester students can already act like engineers when given the right challenge. Designing, building, and testing their own stoves develops core competences in problem-solving, experimentation, and teamwork, while also sparking awareness of the social relevance of energy engineering.

Looking ahead, the project could be enriched by hybrid learning elements — for example, digital design tools or virtual collaboration with partner universities. There is also scope for international collaboration, such as joint summer schools or shared stove challenges across institutions, further strengthening the link between local student onboarding and global energy education.

Box 1. From classroom to global impact: A German – Malagasy bio-pellet start-up.

What starts as a playful first-year project can spark real-world change. One of our alumni went on to found BioPellets Energy, a non-profit organisation developing sustainable pellet fuel solutions in Madagascar. In collaboration with the local student association AJPER at the University of Fianarantsoa, they established a pilot energy self-sufficient pellet factory in southwest Madagascar.

This initiative combines efficient cookstoves with locally produced grass pellets, creating both environmental and social benefits. The project is now run almost exclusively by students who, as trainers, generate multiplier effects in local stove-building workshops, combined with international study exchange and continued collaboration shaping its growth. It demonstrates how early, competence-oriented teaching interventions can generate long-term global impact.

https://biopelletsenergy.org/

BioPellets Energy

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Conflicts of interest

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The project ThüLeNa focuses on integrating sustainability topics into engineering studies across multiple universities in the German state of Thuringia. Asynchronous, digital modules offered as electives are complementing the pre-existing curricula, thus allowing for a state-wide exchange of knowledge, transdisciplinary in engineering disciplines, and a greater selection of possible subject matter for engineering students. In addition, completing modules amounting to 15 ECTS allows students to obtain a certificate which signals a deepened engagement with sustainability from an engineering perspective and which will enhance future employment opportunities. ThüLeNa may thus provide a customizable blueprint for integrating sustainable engineering and energy topics as a micro credential into various engineering disciplines within the European university system and in doing so prepare a new generation of engineers for current and future sustainability challenges.

Integrating Sustainability Into Engineering Curricula: A Practical Example From Germany

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Introduction

Integrating sustainability into engineering is essential for minimizing environmental impact while meeting the needs of society. By considering aspects such as resource efficiency, technological impact on society, renewable energy, or long-term ecological balance, engineers across all disciplines can design and implement systems that reduce resource use, waste, and carbon emissions while working toward technological innovation for the sake of humanity.

This submission describes one practical example from a German university network of how this integration of sustainability into engineering programmes can look like. It sketches the project's vision and its current stage of implementation. Ideally, this vision can serve as a customizable blueprint for future projects that strive for cross-university module exchange and small-scale curricular development.

Sustainability in Engineering

The project ThüLeNa (Thüringen lehrt und lernt nachhaltig, i.e. Thuringia teaches and learns sustainably) is a cooperative project including 7 universities in the German state of Thuringia. It is being funded by the Carl Zeiss Foundation and has a designated runtime until 12/2027. The overarching project goal is to integrate sustainability topics, methods, and thinking into all engineering disciplines, not just those with a designated focus on sustainability such as environmental engineering. Sustainability is relevant across all disciplines, and there are plenty of pressing issues at the intersection with engineering – ranging from carbon capture technology to life cycle assessments for products and processes to biodiversity concerns in civil engineering.

Sustainable energy is without doubt a core concern at this intersection of engineering and sustainability and thus forms its own subject area within the project, including for example modules on renewable energy systems, green train propulsion technology, or the transformation of households as well as energy-intensive industries to carbon neutrality. Apart from this designated subject area, multiple modules from other subject areas are concerned with energy issues at least in a secondary manner, such as modules on building information modelling (including the energy-material-nexus), sustainable industry (including the economic principles of the energy and raw material markets), or ecosystem services (including renewable fuels).

Altogether, there are 5 main subject areas around which the modules are clustered: earth system; built environment; energy and mobility; industry and resources; transformation of society. These were determined "bottom-up" by the first module suggestions of the project partners and their respective relevance for engineering. The boundaries between these areas are fuzzy to a certain degree, which highlights the interconnectedness of sustainability issues and "wicked problems" (Schuelke-Leech, 2020). It is precisely this multifacetedness which makes sustainability challenges so hard to overcome and which calls for interdisciplinary approaches and systems thinking not just in engineering, but in all professions.

Project goals and vision

ThüLeNa provides an addition to existing curricula in the form of elective modules which can be combined to a micro credential in order to obtain a sustainability certificate. It thereby does not represent a consecutive energy system curriculum. Rather, it links engineering disciplines, integrates interdisciplinary competencies, provides the option to specialize beyond one's core discipline based on personal interests, and may thus open doors to sustainable energy professions in the future across a broad range of engineering programmes. 7 Thuringian universities offering engineering degrees are cooperating to make this happen; more than 20 elective digital modules as well as the overarching certificate will be realized within the project runtime (2024 – 2027) and offered for a number of years afterwards.

Teaching the Teachers

Aside from developing the aforementioned modules and the certificate for students of engineering, ThüLeNa offers various training opportunities aimed at professors and teaching staff of the cooperating universities as they are shaping the next generation of engineers. Previously, a workshop series linking engineering and the sustainable development goals showed how predominantly social or ecological sustainability areas relate to technological advancements using concrete examples of companies, innovations, and initiatives to highlight this interconnection. Furthermore, these online workshops provided guidance on how to integrate various aspects of sustainability into one's own engineering discipline and teaching settings.

Additionally, individual consultations for integrating sustainability into planned or existing engineering modules are offered to all interested teaching staff, not just those who develop digital modules for the sake of the aforementioned certificate. Competence models such as the Engineering for One Planet Framework (The Lemelson Foundation, 2022) are used as a tool to systematize teaching contents and to uncover the relation of engineering practice to various dimensions of sustainability beyond abstract concepts.

The main pillar of the project is the development of modules for engineering students. However, "teaching the teachers" is another relevant lever for advancing the integration of sustainability topics across engineering programmes, making them more future-oriented in the process.

Difficulties and Uncertainties

Offering the expertise and specializations from one university across multiple others is an ambitious goal and not without its organizational hurdles. For instance, universities have varying numbers of ECTS required for a module, so a building block schema was devised to allow for recognition in the different systems. The project team are currently working on devising solutions for cross-university exam conduction in close consultation with the examination offices.

Furthermore, since it is neither feasible to coordinate timetables across 7 different universities nor to send the students traveling on a weekly basis, the modules are overwhelmingly offered as asynchronous digital modules with no required on-site presence (although exceptions are possible for exams, field trips, lab research etc. if needed).

This asynchronicity allows students to pace themselves, learn independently of the predetermined semester period and register for the examination once they feel equipped. On the other hand, it is well attested that learner attrition rates are high when it comes to self-directed online learning (McIntyre et al. 2025) and students may drop out of the modules much more frequently than in regular modules requiring on-site presence. Attrition thus requires an evidence-based approach that minimizes hurdles and provides learners with structure, an engaging digital environment with opportunities for peer interaction, and approachable teaching staff for technical as well as content-related matters.

As ThüLeNa is an ongoing project, not all organizational details are decided yet; many of them are dependent of the concrete regulations of Thuringian university law and (im)practicabilities within the unique study programmes, not to mention acceptance of the respective study coordinators. That being said, the following section outlines the ThüLeNa principle using the example of one module to clarify the vision of the project, subject to modifications.

An Example Module

Wind power is a fictitious module outlining the principle of how the modules can be assembled to fit the module size of various universities. Its composition of 6 x 1 ECTS building blocks and exemplary module assemblings by two fictitious students, Ngoc and Tim, are outlined in Figure 1.

Ngoc studies renewable energy systems. Sustainable energy generation is her main concern, yet many topics interest her and she wants to obtain the certificate. In order to do this, she will first have to take the introductory mini-course "Sustainability in Engineering" which earns 1 ECTS solely for the certificate and provides an overview of certificate structure and module options, an introduction to the dimensions of sustainability, their relation to engineering, conceptual foundations as well as practical examples.

Figure 1. Example schema of a ThüLeNa module and two options for combining its building blocks.

Example module *Wind power*			
***Wind power* building blocks**		**Selection of blocks**	
Basics of wind power	1 ECTS	Ngoc	
Power generation and energy conversion efficiency A	1 ECTS	Ngoc	Tim
Power generation and energy conversion efficiency B	1 ECTS		Tim
Offshore wind farms	1 ECTS	Ngoc	Tim
Energy economics	1 ECTS	Ngoc	Tim
Legal framework and acceptance	1 ECTS	Ngoc	

Source: Project ThüLeNa (2025).

At the university where Ngoc is enrolled, modules get 5 ECTS each. Ngoc takes the ThüLeNa module "Wind power" within her engineering programme, which means that she chooses 5 out of the 6 building blocks. The remaining 9 ECTS stem from other ThüLeNa modules with at least 3 ECTS chosen per module. Ngoc opts to take Sustainable Industry for 3 ECTS and the full Renewable Energy Systems module with all 6 ECTS, thus completing the certificate. While these two latter modules are not part of her regular study programme anymore, they will be designated on the certificate, attesting her a deepened engagement with sustainability in engineering.

Tim on the other hand is interested in wind power generation, yet he does not want to take on the workload of additional courses and is not necessarily interested in obtaining the whole certificate. Plus, in his mechanical engineering study programme, modules are generally offered for 4 ECTS each. Thus, it is sufficient for him to choose 4 out of 6 "Wind power" building blocks as an elective that counts towards his degree.

Within the ThüLeNa framework, both students are able to "pick and choose" – they select modules that suit them and within those modules, a combination of at least 3 building blocks. Additionally, they can choose whether they want to obtain the certificate for 15 ECTS or just do one module as an elective subject within their regular programmes.

Implications for the Future of Sustainable Engineering Education

The project ThüLeNa came into being because a university network of a federated state with a strong engineering background regarding both student numbers and teaching staff decided that a broad-scale inclusion of sustainability in engineering studies is a worthwhile goal. The project is one of many with this vision – in Germany, in Europe, globally. It is also very much an experiment: How flexible are established study programmes with regards to the incorporation of elective modules or cross-university examinations? Will deans and study committees of conventional engineering degrees be receptive to the idea of opening their programmes to sustainability electives? Similar questions pop up regarding the students – is there demand for a micro credential of a full 15 ECTS? Will the attrition rates be as high as is common for self-study modules, and how can this be prevented?

As ThüLeNa is an ongoing project – the modules are still being devised, evaluation is pending – these questions cannot be answered with certainty as of yet. After all, sustainability is not the only pressing issue – future skills, artificial intelligence, or additive manufacturing are also viral topics competing for the attention of future engineering graduates in an ever more complex and interdisciplinary work environment. Nevertheless, the project team believe in the importance of matching engineering and sustainability and are eager for discussions on the successful implementation of micro credentials, transdisciplinary cooperation, and pathways for future engineering education.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Across Europe, the energy transition demands not only new technologies but new ways of learning. This expert article explores how students from Avans University of Applied Sciences engage directly with real-world energy community projects, learning by doing and co-creating solutions with local partners. By combining applied research, education, and regional collaboration, these projects demonstrate how learning itself can accelerate the transition. The central insight: when students are embedded in practice, they don't just learn about change, they help make it happen.

From Classroom To Energy Community: How Students Accelerate The Energy Transition Through New Perceptions

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Introduction

Europe is undergoing a fundamental energy transition. The rapid growth of renewable energy such as solar and wind power is vital to reduce fossil fuel dependency and greenhouse gas emissions (European Commission, 2023). At the same time, it creates challenges like grid congestion, where demand or supply exceeds network capacity.

To address this, the EU promotes local ownership and cooperation through Renewable Energy Communities (RECs). Dutch projects show that these succeed only when they function as genuine communities: beyond technical fixes, they rely on trust, transparency, and participatory governance (Weeda, 2024).

This paper presents a case study showing how students at a Dutch university of applied sciences contributed to the development of RECs, analysed using the CIMO framework. In this approach, we outline the Context (the setting and conditions), Intervention (the actions taken), Mechanism (how these actions trigger change), and Outcome (the results of the intervention) (Van Aken & Andriessen, 2011).

Context: the social setting of Renewable Energy Communities

The Directive (EU) 2023/2413 has strengthened the framework for Renewable Energy Communities, granting citizens, Small and Medium-sized Enterprises (SMEs), and municipalities the right to co-own, share, and manage local renewable energy projects in areas like onshore wind, district heating and cooling, and renewable energy in buildings, including through public procurement (European Union, 2023).

Renewable Energy Communities (RECs) are legally recognized entities whose primary purpose is to deliver environmental, economic, or social benefits to their members and local areas, rather than maximising profit. Core characteristics of RECs include open and voluntary participation, autonomy in member decision-making, and local control, ensuring projects are effectively managed and steered by members of nearby living stakeholders (Zomer, Verhoeven, Marselis, and Van der Schot, 2025).

The Netherlands introduced the Energy Act, which recognizes RECs (in Dutch: '*energiegemeenschap*') as legal entities and gives them rights to share energy locally via aggregators and dynamic contracts (Rijksoverheid, 2024).

The education sector faces the challenge of preparing future professionals with the skills to navigate the technical, social, and governance dimensions of the energy transition. By engaging students in real-life contexts, they can both accelerate energy projects and learn through doing and reflection.

This ambition is exemplified by the Interreg 'Energie(k) Onderwijs' project (the project name translates to '*Energetic Education*'), where students learned in close collaboration with lecturers, professionals from the field, and a Centre of Expertise. Blurring the boundaries between education, research, and practice provides students direct exposure to real-world challenges while co-creating solutions with external stakeholders.

Intervention: actions to support Renewable Energy Communities

In the region of 's-Hertogenbosch, students from Avans University of Applied Sciences have contributed to two energy community initiatives.

In the ‘Duurzame Polder’ project, different stakeholders work together to establish over onshore local wind turbines between Den Bosch and Oss. As one of the stakeholders, ‘Eijgen Polder Energie’ is an energy cooperative who supports this project and aims to expand its membership. Business Economics students conducted a target-group analysis to help the growth of the cooperative.

In the ‘Spoorzone Den Bosch’ (a redevelopment area around the railway zone in Den Bosch), where opportunities for energy and heat cooperation are being explored, students supported the impact organisation the ‘Green Business Club Den Bosch’ by mapping sustainability initiatives, interviewing local partners, and developing a communication plan to strengthen collaboration.

These key stakeholders (‘Eijgen Polder Energie’ and Green Business Club Den Bosch’) have acted as clients who defined the practical challenges, while the students worked on solutions as part of their curriculum. Meanwhile, researchers from the Centre of Expertise ‘Materials and Energy Transition’ (MNEXT) of Avans University of Applied Sciences facilitated the collaboration.

Mechanism: explaining the impact of actions

Mechanisms help explain desired outcomes. The mechanism theoretically connects the intervention with an expected outcome.

Researchers from MNEXT are embedded in the context of both energy community projects. This enables them to contribute to valuable networks, domain expertise, and continuity between education and practice. Their in-depth knowledge, of Avans University’s programmes, allows them to match students effectively with relevant initiatives and ensure alignment between project goals and learning outcomes.

To prepare students in these two cases of ‘Spoorzone Den Bosch’ and ‘Duurzame Polder’, MNEXT researchers provided introductory workshops on the energy transition, giving them the necessary conceptual grounding before entering the field. Students were guided through a participatory research approach and trained in Design Thinking methods to conduct in-depth interviews, interpret responses critically, and connect insights across disciplines. This structured guidance empowered them to empathise with diverse stakeholders and translate complex findings into actionable recommendations.

Experiential learning research shows that real-world, stakeholder-based assignments help students develop professional skills (Kolb, 1984). The use of participatory research and Design Thinking strengthens mechanisms like empathy, collaboration, and actionable problem-solving.

The workshops were closely connected to the Interreg ‘Energie(k) Onderwijs’ project, which emphasises the importance of developing key competencies, such as systems thinking, collaboration, and communication, alongside technical energy skills (Interreg Vlaanderen-Nederland, n.d.).

Outcome: the resulting changes occur due to the intervention

These case results illustrate a dual benefit. On one hand, the community initiatives gained tangible outputs. For example, a targeted membership growth strategy for 'Eijgen Polder Energie' and a stakeholder communication plan for the 'Spoorzone Den Bosch' project. On the other hand, the students achieved significant learning outcomes by producing those outputs. This learning process started with workshops and knowledge exchange from researchers as preparation in carrying out real assignments (like designing communication strategies and conducting stakeholder analyses). Students developed competencies in community engagement, interdisciplinary collaboration, and translating technical concepts for lay audiences. In other words, the process of delivering value to the community directly fostered the students' professional growth. For instance, by interviewing local entrepreneurs in the polder and crafting engagement tactics, our business students learned how to navigate complex social dynamics, a skill that goes beyond textbook knowledge.

Woody Maijers was the client on behalf of the core team of cooperative 'Eijgen Polder Energie'. "The students have laid a valuable foundation for our board members and the Communication working group. We are now continuing to work on projects to implement the recommendations. The request was to help us grow from 100 to 1,000 members. We received a lot of guidance for that."

The 'Spoorzone Den Bosch' demonstrated most clearly how student perspectives can reframe regional challenges. Chairman of the 'Green Business Club Den Bosch', Marc van der Mark: "With the commitment of dedicated students and the expertise of Avans researchers, we are giving sustainable urban development and business operations in Den Bosch a powerful boost."

According to Reynier Janse, lecturer in Business Economics: "Our students are well-versed in using online tools to reach specific audiences. They already indicated which instruments could be applied to engage partners in the energy transition, such as local entrepreneurs in the polder. While the approach is not yet fully developed, the direction is clear."

In the project reflections, the students indicated that the Polder case gave them the opportunity to experience complex and current challenges of the energy transition up close. They noted that beyond learning about energy hubs in theory, the key lessons concerned the importance of stakeholder analysis, communication, and collaboration in reaching broadly supported solutions. The 'Spoorzone Den Bosch' project reinforced these insights: students emphasized that clear communication and effective collaboration are essential when working with real stakeholders on complex sustainability projects (Lamers et al., 2025; Condeh et al., 2025).

Conclusion

The student projects clearly reflect the CIMO logic:

- Intervention: practice-oriented teaching and supervision, followed by Participatory Action Research of the students.
- Mechanism: a rich learning environment, as offered by researchers, supports students in their learning-by-doing processes and impact in practice.

- Outcome: students gain a deep understanding of actual energy community phenomena, practical recommendations, and tangible progress for energy communities.

Together, these projects underline that students' perceptions truly matter. Students' experiences contributed to developing their research and professional skills and underlined the need to analyse and align different perspectives to achieve shared results. Their ability to step back, ask new questions, and connect diverse groups offers perspectives that established actors often overlook. This exemplifies Avans' future ambitions: developing new education for sustainability that integrates research with education.

The Avans organisation can deploy the talents of students to support energy communities within their quest for decentralised, democratic, renewable energy. Students, through practice-oriented education, are proving to be curious, knowledgeable and willing partners in this process. This aligns directly with SEED's mission: shaping the future of energy education by linking classrooms with communities, and students with systems change.

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Sustainability education requires inter- and transdisciplinary approaches that integrate environmental, economic, technical, and social perspectives to address complex societal challenges. This article presents the bachelor's and master's programmes in Sustainable Development and Applied Sustainability at Bochum University of Applied Sciences, which combine disciplinary specialisations with transdisciplinary project-based learning involving external stakeholders. Drawing on more than a decade of experience, the article reflects on lessons learnt in designing collaborative learning environments, developing integrative competencies, and linking theory with practice. It also discusses institutional and pedagogical factors that support inter- and transdisciplinary education and outlines possible pathways for future programme development and societal impact.

Transdisciplinarity In Action: Empowering Students To Co-Create Sustainable Futures

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Introduction

Sustainable development requires combining environmental, economic, technical, and social approaches to find integrative solutions. Consequently, sustainability science is inherently transdisciplinary, combining knowledge, approaches and methods from a variety of different fields in order to address complex challenges.

However, higher education institutions are typically organised along disciplinary lines, creating specific challenges for sustainability education. Such structures can make it challenging to establish and maintain interdisciplinary and transdisciplinary learning environments, as administrative and legal frameworks often impose limitations. Therefore, the question of how and when to institutionalise transdisciplinarity is closely linked to academic culture and organisational timing. As Vilsmaier (2021) notes, the debate surrounding this issue tends to focus on two opposing viewpoints. While some argue that a solid disciplinary foundation is necessary before engaging in inter- and transdisciplinary work, others emphasise the importance of early familiarity with these approaches in order to avoid disciplinary narrowness.

Bochum University of Applied Sciences is addressing these challenges through its organisational and curricular design. In 2013, it became one of the first universities of applied sciences in Germany to establish a bachelor's programme in Sustainable Development. The programme was designed from the outset to be both inter- and transdisciplinary, while at the same time providing foundational knowledge from a wide range of disciplines.

In 2017, consecutive and non-consecutive master's programmes were introduced. While the consecutive programme in Sustainable Development is intended for bachelor's graduates who wish to continue studying in this field, the non-consecutive programme in Applied Sustainability is open to graduates from all academic backgrounds. It enables them to incorporate a sustainability perspective into the knowledge from their original discipline.

This article outlines how these programmes foster inter- and transdisciplinarity through thematic specialisations and project studies. It also discusses challenges and success factors and reflects on possible directions for future development.

Inter- and transdisciplinarity in higher education

Interdisciplinarity involves integrating the perspectives, theories and methods of different disciplines to address complex problems. Transdisciplinarity goes one step further: in a narrow definition, it means creating a unity of knowledge (Mittelstraß 2011). In a broader sense, it extends cooperation beyond academia to include practitioners, interest groups and citizens. This enables robust, actionable knowledge. (Lang et al. 2012, Lawrence et al. 2022). In our programmes, transdisciplinarity is therefore understood as a structured and criteria-based collaboration in which academic and non-academic actors jointly define problems, co-produce knowledge and develop solutions that are directly applicable in practice.

These approaches are key to sustainability education, enabling students to address complex real-world problems beyond disciplinary boundaries. Through inter- and transdisciplinary learning, they develop systems thinking and an understanding of complex interdependencies, the ability to integrate technical, economic and social perspectives, strong communication and collaboration skills across disciplines and institutions, and participatory competencies for co-creating solutions with societal stakeholders.

Our inter- and transdisciplinary study programmes

The bachelor's and master's programmes in Sustainable Development and Applied Sustainability have a unique organisational design. Rather than establishing a dedicated 'Department of Sustainability', the university adopted a matrix structure that connects five faculties and the central institute for key competency development. This model requires coordination and mutual understanding across disciplines with distinct traditions, yet it has become a strong driver of institutional change. Today, sustainability is recognised as a shared responsibility across all faculties.

Approximately half of the curriculum of the bachelor's programme is transdisciplinary, integrating multiple perspectives and involving external partners. Some of these courses are co-taught by members from different faculties and guest lectures from practitioners are common. The remaining part consists of disciplinary specialisations. The master's programmes are fully transdisciplinary from the outset.

Graduates are often employed in strategic interface roles connecting business, public administration and civil society, where holistic problem-solving, communication and collaboration skills are particularly valued.

Specialisations

The bachelor's programme currently offers three specialisations:

Construction, land-use, environment

Offered in partnership by the faculties of geodesy and civil and environmental engineering, this specialisation focuses on sustainable infrastructure planning and land management. Within this specialisation, students can focus on areas such as mobility, water management, or climate-adapted urban development.

Engineering

The engineering specialisation focuses on production, energy and digitalisation. Lecturers from the faculties of electrical engineering and computer science, as well as mechanical engineering and mechatronics, provide students with the engineering skills needed to design technologies that reduce resource consumption and save energy.

Business and economics

This specialisation offers insights into the economic and business aspects of the transformative changes in the economy, from production and logistics to socially responsible leadership, economic policy, and energy and environmental economics.

While each specialisation maintains a disciplinary core, they all address sustainability challenges that require an integrated approach.

Project studies: learning through transdisciplinary collaboration

Project-based learning is a key part of the programmes. Bachelor's students work on applied projects in semesters five and six, while master's students do the same in the first two semesters. Each project addresses a real-world sustainability challenge and involves interdisciplinary collaboration, often with external stakeholders such as municipalities, NGOs, and companies. To ensure quality, projects require multidisciplinary teaching teams, authentic real-world problems and designs aimed at long-term impact. These projects are not fictitious challenges created for didactic purposes; they are genuinely transformative projects that contribute to the transition of specific societal sectors. This contribution goes beyond providing recommendations for practice, as it involves joint research and development with practitioners. They enable students to apply their theoretical knowledge, improve their teamwork and negotiation skills, and provide valuable solutions to real-world problems, making them important environments for transdisciplinary learning.

Examples of problem-based learning projects:

ANKE – Autonomous Sustainable Disaster Relief Energy Supply

The goal of the 'ANKE' project is to develop and build an energy supply system that is fully autonomous and as sustainable as possible. This system will enable people in regions without infrastructure, or in areas where infrastructure is unavailable due to disasters, to independently meet their essential needs. Using rainwater and solar energy as inputs, the system is designed to provide drinking water, heating, electricity and propulsion energy (in the form of hydrogen). Future additions (e.g. food supply via vertical farming) are planned.

Students independently develop and build individual modules, including systems for water collection and purification, power generation and storage, and hydrogen conversion. They analyse the safety and sustainability aspects of the individual components, the overall system and its potential applications.

Repair Culture

The Repair Culture project aims at promoting a societal transition away from a "throwaway mentality" and towards more sustainable lifestyles. It not only helps people to acquire the skills needed for repairing by providing the necessary knowledge, but also facilitates the development of a new mindset, that favours and motivates repair instead of replacement. The concept of repair culture thus emphasises sufficiency as an important approach to sustainable development.

A key milestone of the project was the establishment and ongoing support of a local repair café. Students learn about the connections between product lifetimes, resource consumption, recyclability, reparability and sustainable lifestyles, both individual and societal. They engage with repair techniques and explore the most effective ways to share knowledge, skills and motivation, identifying suitable methods, contexts and formats for doing so.

Lessons learnt

Over a decade of experience with our multi-faculty and project-based learning approach has taught us several things:

Interdisciplinary collaboration must be actively designed. Co-teaching and co-development foster the genuine integration of perspectives.

Transdisciplinary projects facilitate authentic learning. Real-world cooperation improves academic understanding and practical skills.

Integrative competencies are valued in practice. Feedback from alumni/alumnae and partners confirms the relevance of cross-disciplinary and communicative abilities.

However, coordination across faculties remains challenging. Institutional flexibility and supportive frameworks are therefore essential.

Reflection is key to improving quality. Feedback loops between teaching, projects and partners ensure relevance and improvement.

Inter- and transdisciplinary learning therefore emerge as ongoing institutional learning processes that are adaptive, reflective and evolving.

Possible future developments

Building on these lessons, several possible areas for further development of our study programmes can be envisaged.

Deepening thematic integration: Broader, challenge-oriented study profiles could connect technical, economic, social and health perspectives.

Expanding authentic learning environments: Larger, cross-faculty projects could strengthen collaboration and real-world impact further.

Enhancing institutional support: Flexible timetabling, shared teaching formats and digital tools could facilitate cooperation.

Strengthening stakeholder engagement: Long-term partnerships with local stakeholders could link learning and societal transformation more closely.

Connecting learning and societal impact: Future developments may emphasise the university's role as a living laboratory for sustainable transformation.

In this sense, transdisciplinarity is both a pedagogical approach and an institutional journey, continuously evolving to meet the complex demands of a sustainable future.

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The CAS Photovoltaics at HSLU integrates a concise transdisciplinary element into its established technical programme. Through a module on coloured photovoltaic modules, participants explore how design and aesthetics can support public acceptance. Working with industry partners, they design and follow the production of their own modules, linking theory and practice. This shows how small educational adjustments can connect engineering, innovation, and the design perspective of renewable energy.

Colouring Energy Education: A Transdisciplinary Approach In The Continuing Education Programme On Photovoltaics

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Introduction

The energy sector is changing fast. Engineers, architects, and other professionals need more than technical knowledge, they need a broader understanding of design, sustainability, and social acceptance. The Certificate of Advanced Studies (CAS) in Photovoltaics at Lucerne University of Applied Sciences and Arts (HSLU) combines applied research, creative design, and hands-on work with industry. The focus is not only on how to plan photovoltaic (PV) systems, but how to integrate them meaningfully into buildings and communities.

Programme context

In Switzerland, continuing education is an essential part of professional life. HSLU offers a wide portfolio of continuing education programmes that respond directly to the needs of industry and society. These courses are shaped by a strong link between applied research and practical relevance. In the field of renewable energy, this connection ensures that new technologies and findings are transferred rapidly into professional training.

The CAS Photovoltaics is a good example of how lifelong learning can actively contribute to the national energy transition. This CAS has been running successfully for more than ten years, each year with around 15 to 25 participants. Most participants are building engineers, but there are also newcomers from other fields, who want to understand solar energy for their own projects. In the Swiss context, large solar power plants play a minor role; instead, building-integrated PV is central, where public acceptance is paramount. Many façade or roof installations face objections from neighbours or heritage offices. This is where colour and design can make a difference.

Research and development

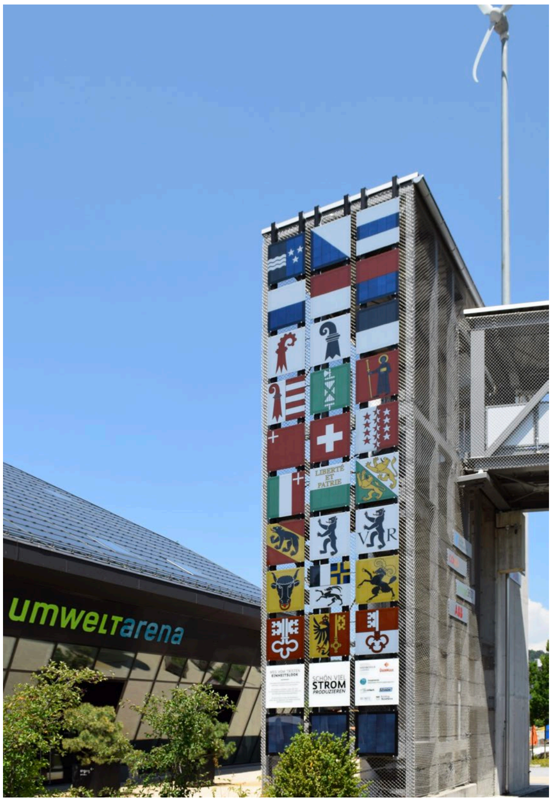
Since 2014, HSLU has been conducting applied research on coloured photovoltaic modules, focusing on adapting digital ceramic printing on glass for solar applications. This method, well established in architectural glass production, allows the printing of durable coloured surfaces using ceramic pigments that are fused into the glass during tempering. The advantage is that existing PV manufacturing processes remain unchanged while allowing full control over the visual appearance of the module.

Early research correlated the transparency of printing inks with the resulting electrical performance and visual characteristics, leading to a patent filings. In collaboration with the glass manufacturer Glas Trösch, a Colour-Efficiency-Model was developed, enabling balanced colour designs that maintain consistent electrical output.

The collaboration between academia and industry not only led to technical innovations but also created a valuable exchange platform. Research outcomes are directly discussed with students and industry partners, allowing feedback loops that improve both education and technology.

The first demonstration project was realised in 2016 at the Umweltarena in Spreitenbach, Switzerland, where a full-scale façade installation showcased the potential of coloured PV modules for architecture.

Figure 1. The "Swissness" PV façade at the Umweltarena Spreitenbach. Every glass panel is a solar module carrying a cantonal coat of arms, forming a colourful mosaic.



Source: Stephen Wittkopf.

This research now forms the scientific foundation for the educational activities within the CAS PV.

Innovation through transdisciplinarity

The integration of coloured PV modules into the CAS Photovoltaics introduces colour and design into an otherwise technically oriented programme. This transdisciplinary addition enables participants to experience the intersection of engineering, creativity, and public acceptance. They are encouraged to design their own coloured PV modules, combining design sketches, colour selection, and performance considerations.

Each participant can follow the complete manufacturing process — from the first hand sketch of the design, through the preparation of a print file with optimised, performance-equivalent colours, to the digital printing on glass, the lamination of that glass into a PV module, and finally the electrical testing and installation. In this way, abstract research becomes a tangible experience. Participants learn how colour influences both visual perception and energy yield, discovering first-hand the trade-offs and opportunities of coloured solar design.

This experimental learning format gives professionals a strong sense of ownership in innovation and invites reflection on how technology can respond to human and cultural factors, not only to efficiency. Through discussions and shared experiences, they explore how aesthetics can foster broader acceptance of renewable energy.

Industry collaboration

The module is delivered in close collaboration with two industrial partners: Glas Trösch and 3S Swiss Solar Solutions. Participants visit both facilities to observe each production step. At Glas Trösch, they see how digital designs are translated into printed glass panels, and later at 3S, they follow the lamination and assembly into functioning PV modules.

The hands-on experience links academic learning with industrial reality. Each participant receives their self-designed module at the end of the course, a small but impactful element that represents both technical understanding and personal creativity. Through these activities, the CAS PV fosters industry engagement.

Figure 2. One participant proudly stands next to the coloured PV module she designed, just released from the production line.

Source: Stephen Wittkopf.

Reflections and impact

Feedback from participants reflects the diversity of professional backgrounds and motivations. Engineers and energy planners value the connection to real-world applications and industry processes. Architects and designers appreciate the creative possibilities and the chance to link aesthetics with sustainability. Many participants describe the experience of designing and receiving their own PV module as highly motivating — a concrete takeaway that reinforces their engagement with renewable energy. Based on participant feedback, the coloured PV content has been adjusted over the years to about 20 percent of the total course workload, ensuring a balanced integration within the technical framework of the CAS PV. Attempts to offer the topic as a stand-alone short course were less successful, confirming that its greatest value lies in combination with the broader PV topics.

Conclusion

The CAS Photovoltaics shows that small curricular adjustments can enhance continuing education in sustainable energy. Integrating design, research, and industry collaboration makes learning more tangible. It also creates a learning environment that reflects the complexity of real-world innovation. At the same time, the approach also has its limits. The coloured PV module represents only a small fraction of the overall course, and its impact depends strongly on participant background and interest. Not every engineer feels comfortable with design topics, and not every architect is drawn to electrical performance. However, we believe that this mix of perspectives is what makes the experience valuable.

Acknowledgements

The author thanks the CAS PV program director and industry partners Glas Trösch and 3S Swiss Solar Solutions for their collaboration, as well as Swiss funding agencies for supporting research on coloured photovoltaic technologies.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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The energy transition will only succeed if organizations invest in human capital as much as in technology. This article examines the organizational challenges of training and reskilling in a fast-changing technological and regulatory environment. Drawing on recent European projects in the port sector, it illustrates how skill needs can be identified both from a forward-looking and role-specific perspective. The central insight is that targeted training strategies are a critical enabler of sustainable transformation.

Detecting Training Needs: A Critical Step For A Successful Energy Transition

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Introduction

The energy transition requires not only technological innovation but also a workforce capable of adapting and leading change. Identifying training needs in this fast-evolving context is therefore a critical challenge.

Many organizations, particularly SMEs, struggle with this. The path is fraught with uncertainty: which technologies will dominate? How will regulations evolve? Investing in training without a clear roadmap can seem risky. However, as recent research in the European port sector demonstrates, a methodological approach to identifying skills gaps can turn uncertainty into a strategic advantage.

The port sector, a critical node in global trade, is at the epicentre of this transformation, facing immense pressure to decarbonize. This article explores how training needs can be identified, drawing lessons from two recent European projects. The analysis combines qualitative and quantitative data using surveys, interviews, and workshops. Data were analysed through descriptive statistics and thematic categorisation, enabling a robust interpretation of skill gaps. While focused on European port communities, the results are transferable to other transport and logistics sectors with similar operational and regulatory dynamics

A Dual-Pronged Methodology: Horizon-Scanning and Role-Specific Analysis

The studies reviewed show that a comprehensive skills assessment requires a dual approach: one strategy to anticipate future needs and another to address current, role-specific gaps. The initiatives in which Fundación Valenciaport has participated are complementary, each addressing one side of this challenge and together providing a more complete picture. The results presented here stem from two case studies which, when combined, illustrate how long-term foresight can be bridged with immediate operational needs.

Case Study 1: BLUEPORTS – Blue Careers in Net Zero Emissions Ports

The BluePorts initiative (funded by European Commission by EMFAF Project Grants) seeks to strengthen the skills and capacities of the port ecosystem's workforce, aligning them with the green transition goals set by the European Green Deal and the Sustainable Blue Economy Strategy.

Box 1. Case Study 1: BLUEPORTS.

- **Objective:** Identify skill needs related to environmental protection, energy transition and alternative fuels, digitalisation and automation, circular economy practices, and leadership.
- **Methodology:** A multi-faceted approach was applied, combining a **quantitative survey** of 145 participants across four countries (Georgia, Greece, Italy, and Spain) with **stakeholder workshops** and **in-depth interviews**. Quantitative data were processed using descriptive statistics, while qualitative inputs were synthesised through thematic analysis.
- **Key results:** Specialized training is currently acquired reactively—on the job and in response to new technologies. To build resilience, training must become anticipatory. Priority areas for 2030, such as alternative fuels and circular economy practices, were identified,

providing a strategic roadmap for educational institutions and companies.

- **Message:** Skills identification must be forward-looking.
- **Transferability:** The methodological approach can be adopted in other port ecosystems seeking to align workforce development with long-term decarbonization strategies.

Case Study 2: NeXTraIn.PortS – Skills and Competences on Energy Transition and Digitalization

The NeXTraIn.PortS project (EU funded through EACEA Erasmus+ programme) explores current competencies, skills, and training needs of workers in the port sector concerning the energy and digital transition. While BLUEPORTS focused on long-term trends, NeXTraIn.PortS addresses immediate operational needs.

Box 2. Case Study 2: NeXTraIn.PortS.

- **Objective:** Capture the current status of companies within the port community regarding training needs related to green skills and digital transformation.
- **Methodology:** A survey of 120 participants in Spain, Italy, Greece, benchmarked against the Port of Rotterdam. Data analysis combined descriptive statistics with profile-specific comparisons.
- **Key results:** A one-size-fits-all training program is ineffective. Profile-specific training programs are required, with modular courses tailored to each professional category. Continuous and innovative learning methods are recommended. Strengthening industry–academia collaboration is essential to ensure that curricula reflect real operational needs and to attract and retain young talent.
- **Message:** Skills identification must be differentiated by roles and profiles.
- **Transferability:** This approach is applicable to other logistics-intensive sectors where diverse operational profiles demand tailored training pathways.

A practical framework for action

The evidence from these projects provides a replicable model for any company or sector navigating the energy transition. Taken together, the results highlight the importance of combining a forward-looking perspective with role-specific training design:

- **BLUEPORTS** emphasized the need to anticipate future skills, identifying 2030 priorities such as alternative fuels and circular economy practices.
- **NeXTraIn.PortS** demonstrated that closing today's critical gaps requires modular, profile-specific programs and closer collaboration between industry and academia.

The results converge in pointing to three general approaches to guide future training programs:

- **Combine macro and micro perspectives:** Use surveys, workshops, and interviews to gather both broad trends (the "what's coming") and precise, role-specific data (the "what we need now").
- **Adopt a dual timeline:** Develop training that is both anticipatory (preparing for the skills of 2030) and immediate (closing today's critical gaps).
- **Move beyond generics:** Reject one-size-fits-all solutions. Design modular, profile-specific training that aligns with the daily realities of different professional roles.

Conclusion

Investing in human capital is not a cost but an essential enabler of the transition. This investment must be strategic, beginning with a clear and methodological understanding of the skills that organizations lack. By systematically detecting these needs—through a blend of horizon-scanning and granular analysis—companies can empower their workforce not only to adapt to change but also to lead it.

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Education with hands-on impact: This project highlights how a German and a Malagasy higher education institution, together with their spin-offs, collaborate to implement sustainable energy solutions and promote social participation at the local level. Through the joint establishment of a pellet factory and the development of efficient cookstoves, students acquire technical expertise, intercultural teamwork, and a sense of empowerment – especially among women in rural communities. The cooperation exemplifies how practical educational approaches, and local engagement can drive the transition to clean cooking and advance international knowledge exchange in line with the Sustainable Development Goals.

Cooking Up Learning: Clean-Cooking Education And Global Collaboration Between Germany And Madagascar

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Introduction

The energy transition calls for new educational models that are practice-oriented and culturally grounded in local contexts, enabling learners to acquire locally relevant competencies (Manteaw et al., 2025). Furthermore, student leadership and community collaboration can enable students to take charge in sustainability projects, making the projects impactful and aligned with local priorities (Uzorka et al., 2024).

This paper explores an educational collaboration between Madagascar and Germany which integrates energy engineering education through a partnership between former-student-led organisations and international university exchanges for students and faculty. At the local level, students engage in energy projects involving technical development as well as participatory workshops emphasising women's roles and their contribution to transferring knowledge. In addition, the collaboration aims to promote entrepreneurial motivation of Malagasy students.

By linking community engagement in clean cooking with global collaboration and learning, this model offers a transferable framework for sustainable energy education aligned with the sustainable development goals (SDGs), in particular addressing SDGs 3, 4 and 7 (Clean Cooking Alliance, 2015).

Use case: The pellet factory

In Madagascar, only 1.6% of the population has access to clean cooking facilities (IEA, IRENA, UNSD, World Bank, WHO, 2025), while most people still cook using polluting fuels such as wood, charcoal or (crop) waste. Besides health risks due to emissions, the dependency on firewood lead to severe deforestation and eroded soils. Also, it increases the effects of poverty, poor infrastructure, and low levels of education, especially in rural areas (Bliss et al., 2017).

In Madagascar, two organisations collaborate with students to improve the situation:
The non-profit organisation AJPER, founded in 2013 by students from the University of Fianarantsoa, Madagascar, initiated travels to villages and communities to improve people's living conditions. This includes the use of alternative cookstove designs as well as of alternative fuels, e. g. Miscanthus grass or peanut shell pellets.
In 2021, a student from the University of Applied Sciences in Duesseldorf founded the non-profit company BioPellets Energy with partners in 2021. In a joint effort by the two NGOs, an energy self-sufficient pilot pellet factory, consisting of a hammer mill, pellet press and workshop installed in two containers, was put into operation in southwestern Madagascar in 2024, as shown in Figure 1.

Figure 4. Pilot factory with energy supply (left), mill and pellet press (right) near Sakaraha, Madagascar.

The energy supply builds on a 20 kWp photovoltaic system and a 12 kWh battery storage system and currently produces around 200 kg pellets of Miscanthus grass and peanut shells per day. Another pellet factory, powered by 30 kWp of solar direct drive, is being installed in the fourth quarter of 2025.

Besides the technical challenges of the design of an island off-grid system or the construction of the pellet factory, this project focuses on sustainable energy education in a broad sense. The intention is to ensure that a circular system including supply chain and the use of the by-product biochar as soil amendment is managed responsibly at the local level.

Knowledge transfer should take place directly in the communities around the pellet factory. Now that the proof of concept has been established, it is being transferred to a local educational setting for sustainable energy to enable widespread application.

Educational design – engaging teaching approach

This infrastructure provides the two organisations and the Universities of Fianaranstoa and Applied Sciences Duesseldorf with opportunities to collaborate on student projects, research for development and upscaling, and promote learning through teaching. AJPER students themselves act as trainers, sharing knowledge and consolidating participatory methodologies.

The pellets and their use in suitable stoves create a project-based environment that promotes intercultural, intergenerational and global learning, with a particular focus on empowering women.

Joint involvement of students

Since 2023, AJPER students on site have been supported by at least two German students through a joint programme per year. German students spend three months in Germany familiarising themselves with the subject matter and establishing contact with AJPER. Then, they join Malagasy students on site to learn community engagement and social entrepreneurship methodologies. These projects supported by the ASA Academia scholarship, focusing on various subjects, e.g. biomass supply chains or the establishment of an 'Entrepreneurship Centre' at the University of Fianarantsoa, enable understanding international teamwork.

To stimulate interest in global challenges and clean cooking already in the first semester, students at the University of Applied Sciences Duesseldorf can participate in the 'Energy project' described in Text Box 1.

In addition, since 2025, the partnership between the universities has also offered Malagasy students a study abroad semester in Duesseldorf, Germany, where they can gain experience in courses on the energy transition.

Given limited resources and higher job prospects for students with practical experience, Malagasy students benefit most from applying theoretical knowledge in rural communities through AJPER, gaining community engagement skills and bridging urban-rural, generational and cultural differences – soft skills rarely taught at university.

Box 1. From Sparks to Skills: A Hands-On First-Year Student Project as a Gateway to Engineering Competence

Clean cooking innovation is not just a Malagasy focus: German students at the University of Applied Sciences Duesseldorf gain core engineering skills – combustion, materials, performance and design – by building and testing affordable, energy-saving cookstoves. Stove efficiency competitions motivate teamwork and hands-on learning.

International and professional development pathways for teachers

The structured ERASMUS+ exchange for teaching staff, for example a one-week programme in June 2025 on 'Perspectives on Sustainability and Diversity and Their Impact on International Mobility', promotes international cooperation and teacher professional development. It also enhances intercultural understanding, joint teaching and curriculum integration, thereby enriching both education systems.

Community engagement and women-centred workshops

Participatory workshops near the pilot pellet factory involve rural communities, with a focus on women as the main users of the stoves. The workshops are designed by AJPER and run in four stages, as shown in Figure 2.

Two representatives from AJPER travel to each workshop, accompanied by at least five other students from the University of Fianarantsoa and, in some cases, German students. They train at least 20 women in the communities in sustainable cooking and provide them with illustrated information flyers so that they can pass on their knowledge to neighbouring communities and families.

Malagasy students are launching awareness-raising campaigns in schools and rural areas about the impact of deforestation and indoor open-fire cooking. Then they empower communities to build and maintain their own stoves, combining education with social impact and entrepreneurship (see Figure 3).

After evaluation, regular users receive a pyrolysis insert for the stoves, replacing wood with pellets (see Figure 4). Women are taught how to fill and light the stoves.

In the last step, users are guided to operate the ventilation system for clean cooking, producing biochar as a residual fertiliser.

To minimise the dropout rate, a receipt system for tracking pellet usage and biochar production will be developed and implemented in 2026 to determine the current success rate, increase effectiveness, and identify potential improvements at each step.

Figure 2. Four-stage training programme for clean cooking in rural communities, leading from awareness raising to the optimised use of pyrolysis stoves.

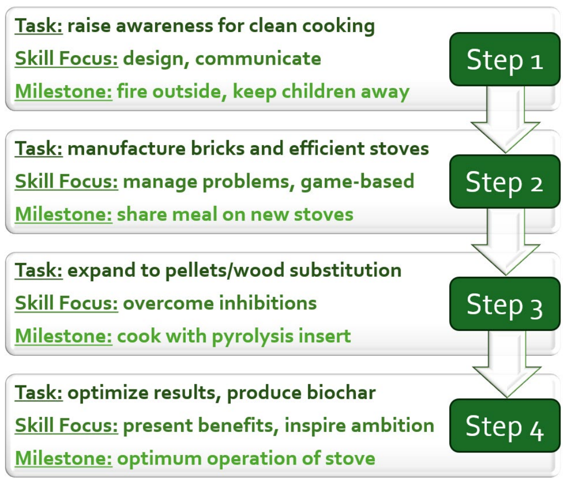
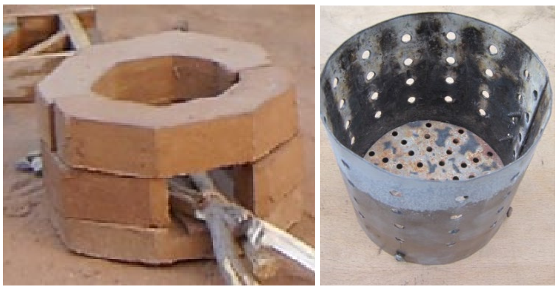


Figure 3. Production of shaped bricks for efficient stoves.

Figure 4. Wood-saving stove and pellet pyrolysis insert.



Three workshops covering steps 1-4 have been completed in three villages around the pellet factory, and steps 1-2 have also been conducted in at least twelve municipalities around Fianarantsoa. These initiatives not only improve living conditions but also empower women and local producers in the field of sustainable energy transition and agriculture.

Challenges and lessons learned

The broad range of tasks is addressed in both countries through research projects and theses, reflecting a shared commitment to ongoing scientific and practical progress. For example, this involves the further development of a cookstove test rig, the optimisation of the on-site pellet factory, and the implementation of an energy system model.

Resource constraints, securing scholarship funding and cultural adaptation continue to be challenges, while the French language barrier limits extensive joint teaching. Frequent student and staff turnover in Madagascar makes maintaining a broad network of personal contacts essential.

Conclusion

The student-founded non-profit spin-off BioPellets Energy enables students in Germany as well as in Madagascar to participate hands-on in designing and testing efficient cookstoves and sustainable fuels in different environments. Together with AJPER's participatory approach, a scalable model for sustainable cooking in rural communities has emerged that links education with socio-economic impact.

This collaboration between Madagascar and Germany shows how challenges in clean cooking create a rich context for practical skills, equity and socially relevant education. Mobility and community partnerships help translate technical knowledge into real-world applications, offering a promising model for integration into mainstream energy education.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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The Dutch housing stock faces an urgent need for renovation, driven by aging buildings and sustainability targets, while labour remains scarce and budgets are limited. This article presents the Plug-and-Play Demonstrator, a rooftop test setup that mimics 1960s apartment facades to explore innovative, affordable renovation strategies. By incorporating design-based learning (DBL), the demonstrator encourages collaboration among students, educators, and industry partners. It functions as both a practical testing environment and a dynamic educational platform for shaping future renovation and energy transition practices.

The Plug-And-Play Demonstrator: A Design-Based Learning Approach For Energy Education

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Introduction

The Netherlands is undergoing a profound energy transition in which reducing household energy demand has become essential for meeting climate targets and ensuring long-term energy security. This shift is driven by the need to reduce CO_2 emissions from space heating, still largely dependent on fossil fuels, and by the structural decline in domestic natural gas production, which has increased reliance on imported gas (CBS, 2024). A central framework for achieving such reductions is the Trias Energetica, which posits a hierarchical approach to energy use: first, minimise demand through efficiency; second, supply the remaining demand with renewable energy; and third, use fossil sources only when no alternative is available (Rijksdienst voor Ondernemend Nederland, 2015). In line with this principle, the Dutch energy transition prioritises renovation of the existing housing stock, as improving the thermal envelope and upgrading building services are among the most effective strategies to structurally lower household energy use (Hoogervorst, 2024; Rijksdienst voor Ondernemend Nederland, 2015). Measures such as insulating roofs, facades, and floors, replacing single glazing, and installing more efficient ventilation and heating systems directly reduce heat losses and thereby the annual gas and electricity consumption of dwellings.

The Dutch government estimates that 1.5 million homes will need to be renovated by 2030 (Dutch Central Government, s.d.). However, the renovation task is complicated by the fact that the construction industry in the Netherlands is currently experiencing a significant shortage of personnel (Economic Institute for Construction, 2023). Additionally, a significant portion of the housing stock comprises social housing, for which housing associations must undertake renovations on a limited budget. The solution must therefore lie in cost-effective, sustainable renovations that require minimal labour and remain affordable. This presents a compelling challenge for the industry and our future practitioners, our students.

To familiarise students with this challenge, we developed a demonstrator setup that enables them to gain hands-on experience with real solutions as part of the EU-funded ARV-project (NTNU, s.d.). The so-called Plug-and-Play Demonstrator simulates a facade of apartment complexes typical of those built in the 1960s in the Netherlands, as shown in Figure 1.

Figure 5. Typical apartment complex in Utrecht, The Netherlands.

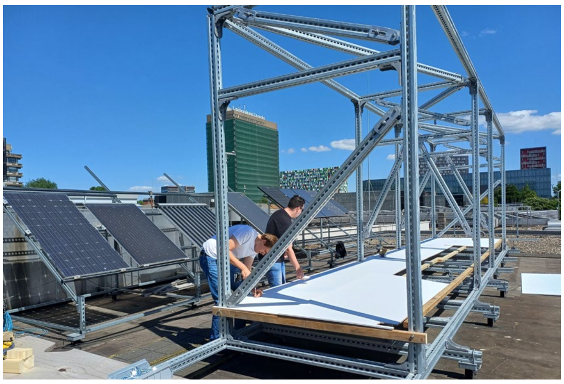
In this article, we examine the demonstrator's design. Then, we explore how we teach our students to handle the complex renovation and energy transition tasks through design-based learning.

Design of the Plug-and-Play Demonstrator

The Plug-and-Play Demonstrator is situated on the testing ground on the roof of one of the university buildings (Figure 2). This testing area is used for energy education and research. Although the demonstrator mimics the building physics of the facades built in the 1960s, it was not possible to replicate the facade exactly. For example, we chose to build the supporting structure out of lightweight steel (Figure 3), and constructed the floor, facades, and roof from wood to reduce weight and allow dismantling if needed.

Figure 6. Plug-and-Play Demonstrator located on the university's roof.

Figure 7. Steel structure of the Demonstrator.



Like the 1960s apartment facades and roofs, the demonstrator has poor insulation. Two window frames from a renovated 1960s apartment were installed on the south-facing facade. Inside, an interior wall was built to match the original 320mm thick wall, allowing visitors to see the structure's thickness. If a new facade is installed over the old one, the entire facade's thickness will double, causing the window frame and sill to protrude more. This demonstrates how insulation strategies, such as a new exterior facade, can affect other components, such as window sills.

Design-based learning in education and practice

Design-based learning (DBL) is an educational approach that involves students collaborating in teams on open-ended, hands-on, and multidisciplinary design tasks that mimic real-world engineering practices. Teachers facilitate both knowledge building and creative thinking, while assessments focus on both the process and the results (Gómez Puente et al., 2013). According to Zhang et al. (2021), DBL enhances students' innovation, teamwork, and problem-solving abilities. DBL fosters systems thinking, multidisciplinary collaboration, and sustainability competencies in engineering education (Zhiliang et al., 2020). DBL was chosen because its iterative cycle enables students to work across disciplinary boundaries, such as building physics, electrical engineering, and mechanical systems, which mirrors the interdisciplinary reality of renovation and energy-transition projects. Design decisions in one domain directly constrain or enable solutions in another (Kolodner et al., 2009; van Dooren et al., 2013). This approach improved their understanding of how energy performance, systems integration, and practical feasibility interact in real-world renovation challenges, thereby fostering more authentic problem-solving and system-thinking skills essential for the energy transition (Dym et al., 2005).

We applied DBL in several projects. One team divided the design into off-site constructable elements, while another created a 4D Building Information Model from the 3D design. Based on their input, two students worked with one of the article's authors to design the off-site construction process and took full responsibility for production (Figure 4) and assembly (Figure 5).

Figure 8. Production of the roof element

Figure 9. Assembly of the roof element.

A student team from mechanical engineering, built environment, industrial engineering, and electrical engineering programs designed various components. They developed floor- and wall-heating systems that simulate heat transfer between neighbouring dwellings in apartment buildings to bridge the gap between reality and the test setup. The group created a model that predicts the temperature and humidity of a real apartment based on measurements from the demonstrator.

As student teams engaged with energy education through the demonstrator design challenge, the relationship between students and lecturers, researchers, and industry partners shifted from instruction-led to collaboration-oriented. The Plug-and-Play demonstrator served not only as a learning tool for students but also for the involved actors, fostering multiple moments of co-creation. This cooperative environment strengthened commitment among all and reinforced students' sense of ownership over the outcomes they delivered.

The design challenge of the Plug-and-Play Demonstrator remains ongoing, with new student projects scheduled to extend and refine the installation. Upcoming cohorts will work with temperature and humidity data to develop a digital twin capable of simulating innovative renovation strategies and heating and cooling systems, while parallel groups will design, install, and test these solutions in practice. The demonstrator also offers a platform for evaluating the energy performance and durability of biobased facade panels, as well as for improving processes, for instance, reducing engineering effort in prefabricated facade production or assessing and optimising labour productivity for emerging systems. Building on this momentum, the design-based learning approach will continue once the demonstrator is operational. The demonstrator can also support educational materials for first- and second-year students, enabling them to observe and analyse how multiple disciplines interact in a realistic built environment.

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The purpose of this expert article is to present a scalable, hands-on electric vehicle (EV) education model that has successfully engaged more than 200 learners across multiple age groups and settings. As the global shift toward clean transportation accelerates, educators need accessible, scientifically rigorous approaches that help students understand EV technology, sustainability, and renewable energy. This article highlights a sequence of activities from simple combustion and CO_2 demonstrations to full EV go-kart construction that teachers can adopt regardless of budget, prior experience, or classroom resources. By combining project-based learning with real-world engineering practices, the program demonstrates an effective way to inspire curiosity, environmental awareness, and STEM engagement.

Teaching Tomorrow: EV Education For All

Author	Expertise
Arbin Thapaliya	Arbin Thapaliya is the chair and associate professor of physics in the department of chemistry and physics at Franklin College, Indiana, USA. He specializes in project-based, hands-on learning that connects physics, engineering, and sustainability. His work focuses on electric vehicle and solar energy education to engage students across all levels while promoting engineering and sustainable learning.

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Introduction

The global transition toward electric vehicles (EV) and clean energy systems is accelerating, prompting educators to equip students across all levels with foundational knowledge and skills (Hiskens et al., 2011; Hayes, 2020). Beyond technical knowledge, EV and sustainability education also seeks to cultivate environmental awareness, problem-solving abilities, and curiosity about the interplay between energy systems and the environment.

This article highlights a range of hands-on activities and semester-long projects that teachers can integrate into their classrooms or adapt to any schedule while maintaining scientific rigor to teach the basic principles of EV technology and sustainability. The motivation for this work lies in the opportunity to engage students meaningfully with sustainability concepts, making complex scientific ideas accessible to learners regardless of prior science or math background.

Background

Research in science and engineering education shows students learn best when actively engaged. Project-based learning has emerged as a particularly effective pedagogical approach, fostering real-world application, student motivation, and interdisciplinary learning as it deepens understanding, increases retention, and promotes critical thinking (Auliyan et al., 2025). Programs centred around building solar cars, wind turbines, or small EVs show that complex STEM topics become approachable when students can see, touch, and test the technology themselves (Hayes, 2020). Initiatives for younger learners highlight how accessible projects inspire early interest (Dökme & Hancıoğlu, 2025; Perry, 2024). Meanwhile, University-level capstone projects demonstrate that vehicle prototyping fosters interdisciplinary learning that blends physics, electrical engineering, and mechanical design (*EvGrandPrix - Purdue University*, 2024). Many existing programs require significant funding, space, or technical knowledge, creating barriers for broader adoption (Ravi et al., 2024). A flexible and scalable model is needed.

Method

Our instructional approach is built to help students understand concepts incrementally, progressing from foundational scientific principles to fully applied EV projects through hands-on demonstrations, modular activities, and iterative project design. Students begin with combustion and CO_2 demonstrations, exploring the essential components of internal combustion engine by launching an ethanol rocket and generating CO_2 to visualize environmental impacts. This foundation then leads to a thermal expansion activity using water-filled and air-filled balloons, illustrating how oceans absorb heat and how this contributes to rising sea levels. Electricity and magnetism concepts follow through Faraday's Law demonstrations, dynamo flashlights, and basic electromagnetism experiments that prepare students for understanding EV motors. Students then build simple electric motors to observe the Lorentz force in action and engage with battery fundamentals through a lemon battery experiment that connects chemical energy to electrical current. Renewable energy demonstrations including wind turbines, solar panels, solar-powered cars, and solar ovens allow learners to explore energy conversion and the role of renewable resources in sustainable transportation. These activities culminate into EV prototype and go-kart construction, where students design and assemble functional electric vehicles using motors, batteries, chassis materials, and electronic speed controllers.

The program has engaged over 200 students from various age groups through a broad range of initiatives, including summer camps (CampGRIZ) for middle-school students, undergraduate physics labs, an immersive three-week long January term course, Earth Day outreach events at the local libraries, and teacher-training workshops, all of which featured activities ranging from hands-on demonstrations to building and riding electric go-karts.

Figure 1. Students from diverse age groups and educational levels from middle and high school to college actively participating in our EV and solar technology program.

Key Evaluations

We performed evaluation of student understanding using concept checks, review of student work, and exit surveys from lab courses, camps, and immersive programs. Students showed improvement on core topics, including electric motor principles, energy conversion, combustion, electricity and magnetism, and renewable energy. Exit surveys for CampGRIZ indicated high engagement with approximately 90% of participants rating the activities as "very engaging." Teacher training workshop and public demonstrations extended the program's impact. Participating teachers also rated the training program very strongly and reported plans to implement at least two hands-on EV activities in their classrooms the following academic year.

The program's success also led to the installation of a solar charging table at the college, believed to be the first of its kind at an Indiana higher-education institution, increasing visibility and demonstrating the real-world impact of sustainable engineering education.

Iterative project design, modular activities, and flexible hands-on experiments contribute to the program's adaptability. Instructional materials are continuously refined, allowing new cohorts of students and educators to engage with improved resources. The inclusion of immersive, applied projects particularly building and riding electric go-karts offers a memorable, engaging experience that reinforces conceptual learning and fosters enthusiasm for STEM and sustainability topics.

Challenges include balancing scientific rigor with accessibility, managing resources for hands-on projects, and ensuring that concepts are digestible for students with limited prior exposure to science or mathematics. However, the program demonstrates that these challenges can be mitigated through structured learning sequences, scaffolded activities, and engaging, interactive experiences.

Conclusion

This program represents a scalable and effective model for teaching complex STEM topics through simple hands-on learning. In a short period, it has impacted over 200 students, reached the community, and trained K–12 educators. By integrating scientific principles with immersive projects including building electric go-karts, the program fosters curiosity, problem-solving skills, and understanding of EV technology and sustainability. Students and educators' feedback consistently highlights the program's effectiveness. Participants at CampGRIZ, the immersive course, and teacher training workshops reported strong engagement, curiosity, and improved understanding of EV and sustainability concepts. Public outreach events further extend this impact, illustrating the program's potential to engage the broader community in meaningful STEM and environmental education. Its success provides a model for other institutions seeking to implement impactful EV education initiatives.

The author is willing to provide the instructional materials upon request from any interested reader.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Conference on Sustainable Energy Education – SEED 2026
Utrecht, The Netherlands, 2026

The School of Energy at the British Columbia Institute of Technology (BCIT) educates trades people, technicians, technologists and engineers for work in the energy sector and the wider industrial sector in the Province of British Columbia (BC), Canada. We see the future of energy education in providing students with meaningful experiential learning opportunities. In this article, we are highlighting three types of examples where we have successfully implemented this: innovation driven by student projects, simulation-based training, and industry-aligned education. The examples showcase how multidisciplinary initiatives – spanning electrical, mechanical, chemical engineering, and cybersecurity domains – equip learners with the skills and mindset needed for the sustainable energy transition.

Experiential Learning In Industrial Environments Through Immersive Laboratories And Projects

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Andrea Frisque	Dr. Andrea Frisque is a mechanical engineer specializing in energy systems design, computer algorithms and simulation. At BCIT's School of Energy, she leads innovation in modern energy systems, digital transformation and advanced manufacturing while fostering interdisciplinary collaboration. She holds a Dipl.-Ing. In mechanical engineering a doctorate in physics (Dr. rer. nat.) at RWTH Aachen University.
Jeanie Chan	Jeanie Chan is a mechanical engineer with over nine years of experience in high-performance building design. She leads program development and builds partnerships to align education with industry needs. She holds a BASc from the University of British Columbia and an MASc in mechanical engineering from the University of Toronto.
Sanja Boskovic	Dr. Boskovic is an academic leader with over 20 years of experience in engineering and post-secondary education. She has led programs in energy, aerospace and industrial trades, led multidisciplinary teams and driven curriculum innovation. With dual PhDs in mechanical engineering and educational technology, her work focuses on power engineering, sustainable education models and industry partnerships.
Viktoriia Kovalova	Dr. Kovalova has more than 20 years of experience in academia and the electrical engineering industry. She specializes in high-power systems, renewable energy, and smart grids, and contributes to IEEE and EGBC. She holds a PhD in Electrical Engineering from Pryazovskyi State Technical University.

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Introduction

The School of Energy (SoE) at the British Columbia Institute of Technology (BCIT) educates trades people, technicians, technologists and engineers for work in the energy sector and the wider industrial sector in the Province of British Columbia (BC), Canada. Traditionally, BC has a strong oil and gas sector at the same time as a very low carbon grid with electricity mostly generated from large hydro dams. Recently, a large Liquified Natural Gas Terminal has started operations in Kitimat, BC, liquifying and shipping natural gas from the neighbouring Province of Alberta. The SoE's training is integrated into our communities and industries, adapting our programs in response to community needs.

Sustainable Energy Education in this context means to prepare graduates for both types of workplaces, fossil fuel based as well as renewable, sustainable energy work places. It also means to equip graduates to drive the energy transition forward independent of which stage of industry they might find themselves in.

The future of energy education needs to be

- Inclusive of a wider range of students, making energy literacy accessible to all communities and everyone, removing limitations resulting from stereotypical demographics.
- Able to attract and retain students into the energy field by offering a welcoming and comfortable learning space, and helping to create comfortable workplaces increasing retention.
- Equipping students with both, hands-on and engineering design skills. The whole value chain needs to be supported with skilled labour and personnel to succeed.

This expert article presents a collection of multidisciplinary initiatives that merge sustainable energy innovation, applied learning, and inclusive education. It highlights how emerging technologies, simulation-based training, and industry partnerships are transforming energy education and workforce development. These examples reflect BCIT's School of Energy's commitment to responsive, community-based learning and regenerative education models.

Student Projects Driving Innovation

Electrifying a Legacy: The Ind-E project

One of the most ambitious multidisciplinary capstone initiatives at BCIT's School of Energy is the Indy Electric (Ind-E) Conversion project. This ongoing effort aims to retrofit a vintage IndyCar with a fully electric drivetrain, engaging students from the Bachelor of Engineering in Electrical and Mechanical Engineering programs in a collaborative challenge that blends technical innovation with sustainability. The project addresses key engineering domains, including control systems, power management, and mechanical integration.

The electrical engineering teams focused on two core areas: Controls and Power. The Controls group developed a modular and safe system to operate the vehicle, implementing Field Oriented Control (FOC) algorithms and establishing communication protocols via

CAN bus and UART. The Power group designed a robust energy management system, emphasizing safety and modularity through detailed wiring diagrams and schematics to support future development and maintenance.

Mechanical engineering students contributed significantly to the physical integration of the electrical systems. Their work included designing custom motor mounts, battery enclosures, and modifying the chassis to accommodate new components while ensuring structural integrity, thermal stability, and safe operation.

Figure 1. A team of BCIT engineering students with Ind-E.

Source: Rapid3D (2025)

The project also benefited from external collaboration, notably with Rapid3D, which provided high-precision 3D scanning services. This enabled the creation of a digital twin of the IndyCar chassis, allowing students to validate designs and test-fit components virtually before fabrication.

Designed to evolve over multiple academic years, the Ind-E project allows each cohort to build on the work of the previous one. This continuity fosters long-term innovation and provides students with a real-world engineering experience that mirrors industry product development cycles. It exemplifies how BCIT's SoE prepares learners to lead in the sustainable energy transition through applied, multidisciplinary education.

Innovative Approach to Lithium-Ion Battery Recycling

The capstone project introduces a novel method for addressing the environmental impact of lithium-ion battery (LIB) waste. By utilizing supercritical CO_2 ($scCO_2$), the process achieves two key outcomes:

- Efficient recovery of critical metals (lithium, cobalt, nickel)
- Productive use of captured CO_2 emissions as a solvent in the extraction process

This dual-purpose approach not only enhances the sustainability of battery recycling but also contributes to climate change mitigation by reducing emissions and preventing soil and groundwater contamination. The project supports a circular economy by reintegrating valuable materials into the supply chain.

Supervised by Dr. Ali Al Jibouri, P.Eng., from BCIT's Chemical and Environmental Technology Program, the initiative aligns with national sustainability goals and empowers youth leadership in clean technology.

Simulation-Based Training

Simulating the Future: Power Engineering

This initiative integrates Kongsberg's digital simulation tools (i.e., K-Sim Connect) into BCIT's Power Engineering curriculum. In British Columbia, Power Engineers operate, maintain, and manage industrial plants that use equipment such as boilers and refrigeration units. In every Canadian province and territory, only certified power engineers are permitted to operate such equipment.

Simulations of such plants and the equipment enhance student understanding of complex energy systems and operational scenarios, preparing them for real-world challenges in the energy sector.

This approach offers several pedagogical advantages that strengthen technical education in engineering disciplines:

- Enables safe interaction with complex systems without real-world risks. Particularly relevant here is the possibility to experiment with systems such as power plants and observe the changes in the impact on the environment without actually causing harm.
- Builds teamwork, communication, and decision-making skills.
- Easily updated to reflect current technologies and industry standards (Brinson, 2015). This allows for student assignments to be aligned with the most recent sustainable technology.

Cybersecurity in Action: Immersive Learning in the INC Lab

While the simulation of regular operations allows to find the most sustainable operating scenarios, keeping operations safe from cyber attacks reduces the risk of major failure with potentially catastrophic impacts on people and the environment. The Industrial Network Cybersecurity (INC) Lab is a purpose-built facility designed to meet the growing demand for professionals capable of securing operational technology systems in critical infrastructure. The INC Lab recreates industrial environments, including process control systems with boilers, valves, and instrumentation, and integrates cybersecurity scenarios through game-based learning. Students work collaboratively to operate a simulated factory while responding to real-time cyber threat simulations. This immersive format cultivates both technical expertise and essential soft skills such as communication, adaptability, and systems thinking.

The lab's pedagogical design aligns with global research on active learning in engineering education. Freeman et al. (2014) found that students in active learning environments perform significantly better in STEM disciplines compared to those in traditional lecture-based settings.

Figure 2. The Industrial Network Cybersecurity Lab.

Source: BCIT (2021)

The INC Lab also illustrates the importance of industry collaboration in vocational education. Its development was shaped by input from energy and technology sector stakeholders, ensuring that training scenarios reflect authentic operational challenges and standards. This model is supported by Vuoriainen et al. (2025), who emphasize that partnerships between higher education institutions and industry enhance curriculum relevance, student engagement, and workforce preparedness.

Building Skills Through Industry-Aligned Education

Indigenous Inclusion and LNG Industry Collaboration

Major resource projects in Canada require meaningful participation by Indigenous communities where the projects are located. The SoE provides an inclusive education model where training programs are directly delivered in the community through collaboration with the Indigenous communities. One example is the Woodfibre LNG Power Engineering 4th Class Program, completed in 2025. It included a readiness program to enable participants for success, and Part A and B certification pathways, co-designed with industry to address skills gaps and promote Indigenous participation in the energy workforce. Power Engineering certification is required to operate LNG plants.

These efforts reflect BCIT's commitment to responsive curricula, community engagement, and regional development, positioning the region as a living lab for sustainable energy education.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Living Labs are vibrant, open innovation ecosystems where research and development take place in real-world settings instead of isolated laboratory environments. Through a structured co-creation process, they position citizens and end-users at the heart of innovation, ensuring that emerging solutions are both cutting-edge and deeply aligned with real-life needs. In the energy sector, Living Labs play a crucial role in accelerating the transition toward sustainable, efficient, and user-driven energy systems. They enable testing and validation of technologies such as smart grids, renewable integration, and energy efficiency measures in real-life contexts, fostering collaboration between industry, academia, policymakers, and communities to drive the clean energy transition.

Living Labs In The Energy Education Sector: Bridging Academia, Industry, And Communities

Author	Expertise
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Athina Krestou	Assistant Professor in the Mechanical Engineering Department of the University of Western Macedonia, Greece. Her work focuses on bridging academic research with practical applications that support sustainable energy transitions.
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Introduction

The need for innovation has increased as a result of the global transition to sustainable energy systems. Although it has been the mainstay for acquiring information and skills, traditional education frequently finds it difficult to keep up with the energy sector's rapid change. It is essential to close the gap between theoretical knowledge and real-world application.

A potent strategy for tackling this issue is the emergence of Living Labs, which are cooperative settings where communities, business, and academia jointly develop solutions in real-world settings. In order to ensure that students gain practical, relevant experience while promoting local and regional energy transitions, this article examines how Living Labs can support an integrative, region-as-campus paradigm in energy education.

The Energy Transition Requires More Than Just Traditional Education

Modern energy systems are intricate, linked, and always changing. Conventional educational methods, which are usually discipline-specific and classroom-based, frequently lack the flexibility to address the quickly changing energy challenges of the real world. Although graduates may depart with solid theoretical underpinnings, they frequently lack experience to the socio-technical realities of energy transitions and interdisciplinary problem-solving (Campos & Gonzales, 2023).

Key limitations include:

Static Curricula

As energy technologies, laws, and market conditions evolve, the material covered in static courses may quickly become outdated.

Theoretical Focus

Few chances to interact with stakeholders from other industries or actual difficulties.

Siloed Learning

A lack of coordination across the social sciences, engineering, economics, and policy.

Absence of Regional Context

Traditional programs could ignore the special opportunities, constraints, and resources of certain areas.

Figure 1. Facing just transition.

Source: https://www.istockphoto.com/photos/clean-energy-transition.

The shift to sustainable energy necessitates locally specific solutions that take into account social, economic, and environmental factors; this calls for experiential, strongly place-based, and cooperative learning strategies.

Conceptual Framework

What is a living lab?

Living Labs should:

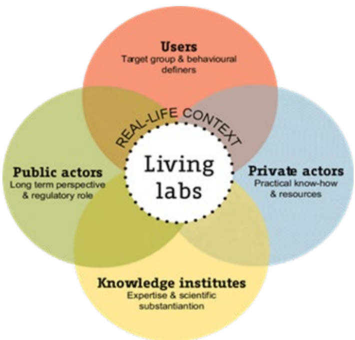
- Identify local energy challenges and opportunities.

- Co-design and implement solutions (e.g., smart grid experiments, renewable installations, behaviour-change interventions).
- Collect and analyse data, promoting iterative learning.

"Living Labs are open innovation ecosystems in real-life environments based on a systematic user co-creation approach that integrates research and innovation activities in communities and/or multi-stakeholder environments, placing citizens and/or end-users at the centre of the innovation process."

Living Labs are characterized by i) User-centred innovation promoting the direct involvement of end-users and communities, ii) Multi-stakeholder collaboration thus crossing traditional sectoral boundaries, iii) Co-creation including iterative cycles of solution generation, prototyping, and assessment and iv) Real-world context, meaning that experimentation takes place in actual settings, not just simulations or labs (Compagnucci et al., 2021).

Figure 2. Schematic representation of Living labs.



Source: European Network of Living Labs (ENoLL). What is a Living Lab? https://enoll.org/living-labs/.

Region as Campus: Integrating Living Labs into Energy Education

An entire territory or even region is transformed into a dynamic learning environment via the "region as campus" model. Universities can serve as anchor institutions supporting sustainable development by integrating Living Labs into local environments (McCrory et. Al., 2020). Important elements consist of:

Local – regional Stakeholder Engagement

Successful Living Labs require active & continuous participation from a wide range of stakeholders including key decision makers (Campos & Gonzales, 2023):

- Academia: provides inputs from students and researchers and guarantees scientific quality.
- Industry: contributes technology, entrepreneurial viewpoints - feeds, and real-world experience.
- Municipalities and local communities: provide special knowledge of local requirements, legal frameworks, and implementation assistance.
- Students: not only as passive learners but also participating in the design and implementation process.

Curriculum Integration

Living Lab activities can be included into projects, theses, and courses. This could consist of (Compagnucci et al., 2021):

- Difficult tasks carried out in association with regional energy suppliers.

- Compiling and evaluating data on campus renewable energy systems or local energy consumption.
- Multidisciplinary teams addressing regional energy challenges while honing soft skills like cooperation and communication.

Innovation and Impact

Living Labs with a regional focus directly benefit community groups:

- Quicker adoption of cutting-edge technologies.
- Well-informed choices about urban planning and local strategies .
- Increased public acceptance of innovative solutions and improved energy literacy.

Participating students gain flexibility and professional preparedness in addition to a stronger sense of purpose and belonging.

Case Example - The SMART Living Lab at the University of Western Macedonia, Greece

Box 1. UoWM living lab (Source: A Campus Open to Experimentation - https://livinglab.ece.uowm.gr/).

The Living Lab is based at the student dormitories of the University of Western Macedonia in Kozani, Greece. Since 2018, it has transformed the campus into a real-life experimental facility for energy research and education. The main dormitory building (4,212 m², 190 single rooms, 800 m² of glazed openings) serves as a realistic testbed where students, researchers, faculty, and industry partners co-develop and test innovative energy solutions.

Key features of the SMART Living Lab:

The lab integrates two rooftop PV systems (~35 kWp), high-voltage battery storage (>30 kWh), and a dual EV charging station (up to 22 kW). A dense sensor network—including meteorological sensors, thermal meters, power-quality analysers, and over 200 smart plugs—supports detailed monitoring of building performance and user behaviour.

Real-time data collection and visualization: A custom DAQ/SCADA platform feeds an online database with more than 1,200 energy and air-quality metrics. Students and researchers access live and historical data for projects, theses, and hands-on learning activities.

Curriculum integration: Students from engineering, environmental science, and business take part in interdisciplinary projects—such as smart grid simulations, energy forecasting, and demand-side management—making them active co-creators rather than passive recipients.

Community engagement: The lab supports the just transition in a region traditionally reliant on lignite by piloting sustainable solutions and informing public policy.

Through such Living Labs, students gain valuable skills in advanced energy technologies, data analysis, and collaborative innovation, preparing them to contribute effectively to the ongoing energy transition.

Challenges and Future Directions

Obstacles to integrating Living Labs include overseeing intricate, multi-stakeholder partnerships, matching project schedules and academic calendars to current events, making sure that involvement lasts beyond trial initiatives. Clear governance frameworks, continuous communication channels, and systems for recognizing student efforts are among solutions. Future trends suggest further embedding sustainability as an operational and pedagogical paradigm, international collaboration amongst Living Labs, and deeper digital integration (IoT, AI-driven analysis) (Compagnucci et al., 2021).

Conclusion

The shift to sustainable energy systems is a social and educational necessity. Conventional classroom methods are no longer adequate. Higher education can play a revolutionary role by embracing Living Labs and embracing a region-as-campus attitude. This will bridge academics, industry, and community and provide the knowledge, collaborations, and experiences that the next generation will need to fuel the energy transition.

Acknowledgements

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Hydrogen is emerging as a key element of Europe's clean energy transition, creating an urgent need for specialised skills across the hydrogen value chain. The GreenSkillsforH2 project addressed this challenge by developing a comprehensive blueprint for upskilling and reskilling, implementing targeted training programmes in transition regions such as Western Macedonia, Greece. Building on this foundation, the H2VE project advances the approach through Centres of Vocational Excellence (CoVEs), focusing on Hydrogen Valleys and regional skills ecosystems. This article focused on showing how these initiatives, together, strengthen Europe's hydrogen skills infrastructure and bridge the gap between education, research, and industry.

Strengthening The European Hydrogen Skills Ecosystem: The Evolution From Greenskillsforh2 To H2VE

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Introduction

The global energy landscape is transforming as countries accelerate climate action and strengthen energy security through cleaner sources. Low-emission hydrogen (H2) plays a key role in decarbonising hard-to-abate sectors and supporting the EU's 2050 strategy, which foresees H2 meeting 24% of total energy demand, reducing emissions by 15%, and generating €820 billion in revenue (International Energy Agency, 2023).

Achieving these targets requires a skilled workforce to enable large-scale H2 production and resilient regional ecosystems. Green H2 could create around 1 million jobs by 2030 and 5.4 million by 2050 in the EU, about 10,300 per €1 billion invested (Fuel Cells and Hydrogen 2 Joint Undertaking, 2019). Yet, current training programmes still fall short of meeting this demand (European Hydrogen Skills Strategy, Green Skills for Hydrogen Project, 2023).

Initially, the Green Skills for Hydrogen (GreenSkillsforH2) Erasmus+ project designed and implemented a sustainable European H2 Skills Strategy to meet the short-, medium-, and long-term needs of the evolving H2 Value Chain. Moreover, it provided a blueprint for upskilling and reskilling opportunities, creating new employment pathways, and establishing a comprehensive Hydrogen Skills Agenda. Throughout the project, in the first phase, the development, testing, and rollout of urgent Vocational and Educational Training (VET) programmes on H2 were conducted in energy transition regions in four European countries, including Greece, to empower the workforce, establishing the blueprint for the subsequent more specialised pilot trainings in the second phase. The pilot training programmes were developed and tested by selected VET providers and higher education institutions to address the skills required for emerging roles in the H2 sector. They were implemented across different target groups in nine partner countries, including Greece.

The Hydrogen Valley Vocational Excellence Hub (H2VE) Erasmus+ project focuses on developing skills ecosystems for Hydrogen Valleys and addresses labour market needs in the hydrogen sector. It establishes six CoVEs across Europe and Africa, creating a network linking secondary, vocational, and higher education with lifelong learning. Through collaboration and learning, it promotes vocational excellence, supports the EU's green and digital transitions, and strengthens Europe's leadership in H2 technologies.

This expert article aims to present the trainings organised in the Region of Western Macedonia (RWM), Greece, during the implementation of GreenSkillsforH2, which eventually led to their acceleration through the H2VE project, specialising these educational activities to address the skills needs of Hydrogen Valleys, while also interconnecting the European skills landscape with the emerging African skills ecosystem.

Training programmes in Western Macedonia within Green Skills for Hydrogen project

Upskilling and reskilling training programmes in the hydrogen sector support the global transition to sustainable energy solutions. While H2 emerges as a clean and versatile energy carrier, demand for skilled professionals grows as well. Hence, these educational initiatives are designed to equip the workforce with skills needed to bridge the skills gap and apply hydrogen technologies through new training modules and curricula.

Specifically, regarding the Greek landscape, RWM has produced over 75% of Greece's energy since 1955, mainly from lignite (Ziouzios et al., 2021), being the country's main energy hub. With lignite phased out under EU decarbonisation policies, the region must adopt CO_2-free technologies and pursue new sustainable development pathways. Therefore, as a transition region, RWM should foster operational knowledge of these technologies within both the existing and future workforce. In this context, during GreenSkillsforH2, 3 urgent trainings (Fig. 1) and 2 pilot trainings (Fig. 2) were organised in RWM for students, engineers, and technicians affected by the energy transition, implemented by CluBE and Advent Technologies in cooperation with the University of Western Macedonia (UoWM). These programmes provided rapid knowledge and skills for employment in the hydrogen value chain, showcasing an innovative dimension through the combination of cross-sector collaboration, interactive learning tools, and practical demonstrations that connected theory with real-world hydrogen applications.

Urgent & Pilot trainings

Masterclass: "One - Day Hydrogen"

The Masterclass: "One-Day Hydrogen" targeted stakeholders, policymakers, engineers, innovators, researchers, and energy producers. The training, gathering 70 participants, covered the full hydrogen value chain, highlighting hydrogen's role in the energy transition of RMW. Participants explored hydrogen production, transport, storage, and end uses, while gaining insight into the technological, economic, regulatory, and safety aspects essential for achieving a carbon-neutral economy by 2050.

Hydrogen Summer ScH2ool

The "Hydrogen Summer ScH2ool" followed the Masterclass as a more specialised training for undergraduate and postgraduate students, featuring 78 participants. It covered H_2 technologies, electrolyzers and fuel cells, H_2 safety. It also included a workshop on creating an H_2 start-up company and a round table on developing a Hydrogen Valley in RWM, while two study visits complemented the training, one at the Laboratory of Alternative Fuels and Environmental Catalysis (LAFEC) at the UoWM and another at the facilities of CERTH/CPERI in Thessaloniki.

Engineering our Future: Developing Hydrogen Skills

The "Engineering our Future: Developing Hydrogen Skills" training was organised in cooperation with the Technical Chamber of Greece/Department of Western Macedonia for engineers from various departments. It gathered 36 attendees and addressed H_2 technologies, uses, properties, and safety in heat and power applications. Advent Technologies also presented its HT-PEM fuel cell systems.

Figure 1. Urgent Trainings in Western Macedonia, Greece.

Source: Picture 1 was created from photographs taken during the urgent trainings in Western Macedonia, 2023

2nd Hydrogen Summer ScH$_2$ool

The 2nd Hydrogen Summer ScH2ool built on the success of the first edition, gathering 63 participants, including engineering students, researchers, and PhD candidates from across Europe. Topics included H2 production, storage, transport, and end-use applications, electrolyser and fuel cell technologies, H2 safety, distribution and mobility, H2 economics, and EU policy frameworks and funding. A pilot training by Advent Technologies focused on HT-PEM fuel cells with a live demonstration, while an interactive session introduced the Hydrogen Game, an interactive learning tool, developed within GreenSkillsforH2, that uses icons and boards to facilitate learning and discussion on the H2 value chain in classrooms and workshops. The programme concluded with a study visit to the industrial facilities of the Hellenic Gas Transmission System Operator S.A. (DESFA) in Nea Mesimvria, Thessaloniki, providing practical insight into hydrogen infrastructure operations.

3rd Hydrogen Summer ScH$_2$ool

Organised as an annual event, the 3rd Hydrogen Summer ScH2ool, co-organized this year in the framework of the i-STENTORE project, gathered 46 participants from across Europe, including students, PhD candidates, researchers, and professionals from the energy and hydrogen sectors. The programme offered lectures, demonstrations, workshops, and study visits covering the whole H2 value chain, electrolyser and fuel cell technologies, H2 refuelling stations, mobility and industrial integration. A workshop with H2 related companies complemented the sessions, and a live demonstration of a H2-powered vehicle linked theory with practice. Study visits were organised to LAFEC at UoWM and HORIZON S.A.'s facilities.

These innovative sessions featured more than sixty speakers from Greek universities, industry representatives, along with researchers, start-up companies and European H2 associations from the hydrogen sector across Europe. More than 200 participants attended the aforementioned trainings in total in RWM, meeting the project's declared KPIs. During the trainings, participant lists were distributed to monitor the participants' backgrounds, and evaluation forms to collect their feedback in order to improve future activities. The feedback indicated a high level of satisfaction, with participants valuing the industrial perspective, interactive elements, and the overall innovative character of the trainings.

Figure 2. Pilot Trainings in Western Macedonia, Greece.

Source: Figure 2 was created from photographs taken during the pilot trainings in Western Macedonia, 2025.

Integrating GreenSkillsforH2 and H2VE: Expanding H2 skills towards Hydrogen Valleys

In order to further accelerate the aforementioned practices and increase their impact, the GreenSkillsforH2 blueprint and training framework will be expanded accordingly and operationalised through the H2VE project. Building on the achievements of GreenSkillsforH2, the H2VE project will implement more scalable and advanced training activities within CoVEs to support the development of Hydrogen Valleys across Europe. While GreenSkillsforH2 established the training programmes and the general blueprint covering the whole H2 value chain, H2VE focuses on specific, targeted, technical, and practical educational activities directly linked to the establishment of Hydrogen Valleys reflecting the sector's evolving needs.

More specifically, the H2VE project aims to further strengthen the regional skills ecosystems by fostering a symbiotic relationship that accelerates both technological progress and workforce development. Including RWM, each CoVE in partner countries will act as a hub, equipping learners, educators, and professionals with essential skills and co-creating training strategies aligned with local priorities. Moreover, by uniting education providers, research organisations, industry, and regional actors, H2VE will deliver adaptive training reflecting technological, economic, and social needs of every region, starting from the Summer ScH2ool in RWM. Consequently, building on the practices of GreenSkillsforH2, this evolution focuses on five pillars, namely expanding target groups to include technicians and broader learners, promoting lifelong learning through workshops and mentoring, customising curricula through participant feedback, reinforcing industry collaboration to match labour market needs and improving accessibility through hybrid formats and digital platforms for community and knowledge exchange. For this purpose, H2VE will deploy an e-learning platform with digital tools and a database of materials to support knowledge sharing and continuous learning, ensuring the scalability and long-term sustainability of the H2 skills framework initiated by GreenSkillsforH2 while expanding knowledge through remote training.

Future Perspective

Building on the success and experience of the aforementioned activities implemented under GreenSkillsforH2 in RWM, the H2VE project will adopt and expand this methodology into a comprehensive framework, enhancing regional skills ecosystems and aligning education with Hydrogen Valley development across Europe and Africa.

Acknowledgements

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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This article presents the SEED PV Summer School, a blended international training that combined theory and hands-on learning in solar photovoltaics. The programme brought together VET and UAS students, teachers and industry partners from five SEED regions. Feedback confirmed that collaboration and experiential learning were key to building relevant solar skills. The experience provides a transferable model for future summer schools within SEED and beyond.

Hands-On Excellence In Solar Education: Lessons Learned From The SEED PV Summer School

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Introduction

The PV Summer School was implemented and funded as part of the SEED – Centres of Vocational Excellence in Sustainable Energy project to explore new ways of developing renewable-energy competences through collaboration between vocational and higher education institutions and industry partners. The initiative aimed to create a practical model for international cooperation that connects education with real-world applications in the fast-evolving solar energy sector. Designed as an international learning experience, it brought together participants from SEED regions across Europe, providing opportunities for intercultural collaboration and peer learning (Lakkala et al., 2018).

Skills needs and rationale

The solar photovoltaic sector is the world's fastest-growing renewable energy industry, employing over 7.1 million people globally in 2023 (IRENA & ILO, 2024). Rapid expansion, especially in Asia and Europe, has created a strong demand for skilled professionals. In most education systems, vocational programmes emphasise hands-on installation skills, whereas higher education focuses on theoretical design and analysis. The PV Summer School was created to bridge this gap by giving vocational students deeper theoretical insight and UAS students more practical experience, helping both groups gain a comprehensive understanding of photovoltaic systems and their real-world applications.

Purpose of the PV Summer School

The PV Summer School helped participants understand how photovoltaic systems are designed, built, and simulated through hands-on experiments, laboratory sessions, and site visits. It fostered interdisciplinary collaboration by bringing together VET and UAS students and teachers from four countries and encouraged interest in further energy-related studies and careers. The programme also piloted new regional cooperation between Turku UAS, Raseko, and Solar Finland, supporting the development of mixed-learning methods for future training.

Design and implementation

Blended learning structure

Table 1. Structure of the PV Summer School.

Phase	Duration	Main Content	Format
Online preparation	4 weeks	PV fundamentals, basic design and simulations	Online (live + self-study)
On-site Day 1	1 day	Utility-scale system design; simulations, construction site visit	Classroom + field
Days 2–3	2 days	PV module manufacturing / PV installations (parallel groups)	Hands-on
Day 4	1 day	PV in Africa workshop, project management, sauna	Workshop + social
Day 5	1 day	Quality, lab measurements, data and IoT	Laboratory

Source: Author.

The PV Summer School combined a four-week online preparation phase with an intensive on-site week in Turku. The online component established a shared theoretical foundation, while the on-site days focused on utility-scale design, PV module manufacturing, installation work, an international workshop by Green Power Brains, and laboratory sessions on PV quality assurance and data monitoring.

Participants and partnership

The PV Summer School brought together around 30 participants from six different organisations representing SEED regions across Europe. The Summer School itself was free for participants, while travel and accommodation were arranged individually and covered through Erasmus mobility grants or personal funding. The group included vocational and higher education students as well as teachers, creating a diverse learning environment that encouraged collaboration across educational levels and national contexts. This approach reflects current developments in European VET, where learning increasingly takes place across multiple sites and educational levels (Cedefop, 2022).

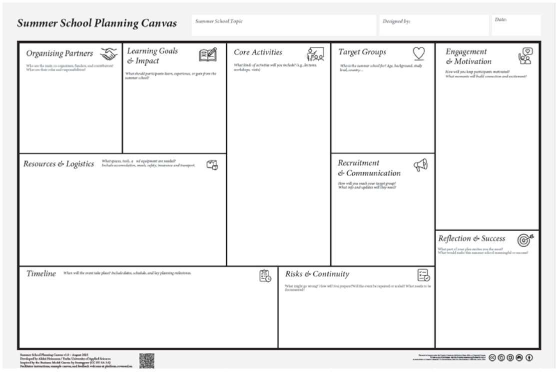
The mixed groups enabled vocational students to deepen their understanding of design and simulation, while UAS students developed their practical installation and testing skills. Teachers participated as mentors and co-learners, strengthening pedagogical cooperation within the SEED network.

The programme was jointly implemented by Turku University of Applied Sciences (TUAS), Raseko Vocational College, and Solar Finland Ltd, whose collaboration formed the foundation of the initiative. TUAS coordinated the academic and logistical arrangements, Raseko contributed pedagogical expertise in vocational training, and Solar Finland provided access to industrial facilities, real production environments, and professional know-how. This combination of educational and industrial perspectives ensured that the learning experience was both authentic and directly relevant to the renewable energy sector.

Design tool: the Summer School Planning Canvas

During implementation it became clear that planning a blended and international programme of this scale would have benefited from a more structured design methodology. To address this need and to make the model easier to replicate, the *Summer School Planning Canvas* was developed after the pilot as a practical tool for coordinating goals, partner roles, and learning methods in future editions (Heinonen, 2025). The tool is available on the SEED Platform, where educators can adapt it and exchange ideas on planning impactful blended learning experiences in sustainable energy education.

Figure 1. The Summer School Planning Canvas developed after the pilot to support the design of future blended learning programmes within SEED.



Source: Heinonen (2025).

Participant experience and feedback

As this was the first summer school of its kind, feedback was collected to support the further development of future editions. While participants shared many positive impressions during the event, an anonymous survey was conducted afterward to also identify areas for improvement.

Feedback collection

A feedback form was sent to all 29 participants of the summer school. The form was prepared as anonymous Webropol survey consisting of background information (country, age, role, previous experience), 14 quantitative questions on learning and content and collaboration and organisation, and four open-ended questions.

Figure 2. Participants manufacturing a PV module at the Solar Finland factory, illustrating the hands-on learning approach.

Source: Turku University of Applied Sciences.

Quantitative results

A total of ten participants responded to the feedback survey, representing VET students, UAS students, teachers, and other participants from Germany, the Netherlands, and Spain. Overall satisfaction with the PV Summer School was very high (average score 5.0), and all evaluated areas received strong ratings.

Participants reported improved understanding of solar PV systems (4.4), exceptionally strong support from teachers and company experts (5.0), and high value in international teamwork (4.8) and VET–UAS collaboration (4.9). The combination of theory and hands-on activities received the highest rating (4.9), and site visits and workshops were also rated very positively (4.8). The online preparation course was seen as moderately helpful (4.1), indicating room for improvement in aligning the online phase more closely with the on-site programme.

Qualitative themes

The open-ended feedback highlights several recurring themes. Participants especially valued the balance between theoretical instruction, practical laboratory sessions, and hands-on work at the Solar Finland factory and installation site. Many described the international and mixed VET–UAS groups as one of the most rewarding aspects, noting that diverse backgrounds enriched discussions and strengthened teamwork.

Key suggestions for improvement focused on time management: participants wished for additional time for reflection, group project work, and final wrap-up discussions. Several respondents recommended providing shared accommodation to enhance group cohesion, and others suggested refining the online course to make its content more engaging and better integrated with the on-site activities. Additional topics, such as emerging PV technologies and more concrete simulation exercises, were also proposed.

Lessons learned and future outlook

Key success factors

Several factors contributed to the success of the PV Summer School. A key strength was the new form of regional cooperation established between the company partner, the vocational school, and the university of applied sciences, which enabled an effective combination of complementary expertise. The Turku region's strong competence in solar photovoltaics and the support provided by the SEED project—both funding and expert resources—created a solid foundation for implementing and evaluating the programme professionally and collaboratively.

Challenges and improvements

Despite the overall success of the PV Summer School, participant feedback identified several areas for improvement. The most frequent comment concerned time management, suggesting that the programme could be adjusted by either extending its duration or narrowing the range of topics to allow more time for reflection and informal exchange. The diversity of skill levels in mixed learning groups also required careful coordination to ensure balanced participation. Some participants proposed shared accommodation to strengthen group cohesion and recommended adding more content on emerging PV technologies. In future editions, the organisers plan to refine the preparatory phase and better integrate the online course with the on-site programme, ensuring a smoother learning progression. A final wrap-up and reflection session will also be introduced to consolidate learning outcomes and participant experiences.

Future directions

Building on the positive experience and feedback, the organisers plan to repeat a similar international PV Summer School, further strengthening cooperation between vocational and higher education institutions and their industry partners. In addition, a new training concept for teachers is being developed, allowing educators from different countries to exchange methods and co-teach within the SEED network. The approach will also be adapted nationally into a blended summer school model in Finland, enabling more students and teachers to benefit from the hands-on and collaborative learning methods that proved successful in this pilot.

By linking theory with real practice and fostering cooperation across education levels, the PV Summer School provided a model for developing the hands-on skills and practical understanding essential to the future solar workforce. The lessons learned form a strong foundation for scaling similar initiatives within SEED and beyond, supporting the long-term goal of building a skilled, adaptable, and collaborative clean-energy workforce.

Acknowledgements

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Conflicts of interest

The author declares no known competing interests.

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CoVE SEED is an EU-funded ERASMUS+ project aiming at developing regional centres of vocational excellence (CoVE) on sustainable energy education. In the project, collaborative design practices (codesign) were employed to engage partners and regional stakeholders in the development of regional strategies, development plans and learning programs. Throughout the project, the partners adopted codesign practices by collaborating with a design researcher from HU University of Applied Sciences Utrecht. This expert article describes how codesign became a practice for the CoVE SEED partners. This article explores how the partners developed design ability and how codesign methods facilitated the development of regional strategies, development plans and learning programs.

Applying Codesign For Developing Educational Ecosystems

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Introduction

CoVE SEED aimed to create regional and transnational learning and collaborative communities on sustainable energy education with various participants, including students, citizens, professionals, lecturers, researchers, and policymakers. Applying codesign practices results in a more inclusive, reciprocal approach in which partners, including learners, contribute to both constructing and delivering responsive learning programs that bridge the gap between school and the workplace (Bouw, Zitter, & De Bruijn, 2021). Through the development of Centres of Vocational Excellence (CoVE), SEED builds strong regional ecosystems in five European regions. It strives to deliver excellent vocational education that engages societal stakeholders and regional partners to develop practical, durable solutions for responsive education in the context of the sustainable energy transition.

Codesign

Codesign is a way to involve stakeholders in the design process. Codesign emphasises inclusive collaboration on societal challenges, such as sustainable energy education. Research with health care professionals showed that design ability develops when professionals are engaged in codesign processes (Godfroij *et al.*, 2024). Design ability can be defined as the interplay between knowledge, skills, and attitude, supported by a well-equipped toolbox and rich case descriptions. This article explores the development of the design ability of SEED partners involved in codesign processes, based on trainer and participant reflections, cross-checked against meeting minutes.

Codesign in CoVE SEED

The five regions forming the CoVE SEED consortium regularly hold regional meetings (within regions) and transnational meetings (between regions). Approximately twice a year, a multi-day face-to-face meeting was hosted by one of the regions to exchange and develop knowledge via workshops and collaborative work.

Lenny van Onselen, a codesign facilitator, trainer, and researcher, was invited to train CoVE SEED partners in codesign methods adapted for CoVE SEED's objectives, including the Empathy map and Sociona's (van Onselen, 2023) and MissionMapping (Kuijper *et al.*, 2024). The partners could later apply these codesign methods within their regional contexts.

Figure 1. The trainer explains the MissionMapping steps.

Source: SEED project.

The participants were introduced to design theory, such as the Design Thinking approach (Brown, 2009) and the Double Diamond model (Design Council, 2025). Furthermore, the participants employed different exploration and definition methods to frame problems, identify needs, and formulate goals and missions in a designerly way. Also, they experimented with codesign principles, design thinking methods, and codesign approaches.

Ultimately, the partners were equipped with codesign methods and had resources to develop themselves as codesign facilitators to co-create innovative learning environments. The participants practised codesign methods to collaborate on a shared design goal. Additionally, they learned that engaging various stakeholders (e.g., governmental and branch organisations) could create a more inclusive and responsive education system.

Figure 2. The finish partners apply MissionMapping with their regional stakeholders.

Source: SEED project.

After the training, codesign methods were applied in each region to develop a regional development plan in collaboration with regional partners (Figure 2). Sometimes, the region adapted a codesign method to fit the regional context. The northern countries often opted for playful, experimental techniques, while the southern countries preferred structured codesign methods aligned with formal practices.

"The partners reviewed the different codesign methods that were presented during the codesign workshop ... They decided to follow the Double Diamond method... Last but not least, they decided to conduct a bibliographic research on different Double Diamond methods to find the most suitable template." (Excerpt from regional meeting minutes)

Applying codesign to create hybrid learning environments

The codesign approach not only connected stakeholders—it empowered them to shape their own regional development plans, fostering ownership and innovation. For example, in the Netherlands, energy education has strong ties to the energy sector; however, the industry is facing ongoing policy changes and intense competition, which challenge teachers to develop curricula that meet the sector's specific requirements. In response, the vocational education institutions within the CoVE SEED project designed modular education in collaboration with the energy sector to enable rapid adaptation to these changes.

An example from Spain is that their VET institutions have a traditional educational approach. The problem is that VET institutions are not intensively collaborating with the energy sector. Codesign methods were used to connect VET institutions with the energy sector, resulting in the development of challenge-based education and micro-credentials.

Developing codesign ability

During the training and codesign workshops that followed, various codesign techniques were applied. Initially, participants displayed a lack of enthusiasm during training, appearing critical and resistant to the exercises. However, this led to an important lesson for us regarding cultural differences and how work and the work context are perceived in other countries. For example, Dutch people tend to be aversive to hierarchy and discuss collaboration over a cup of coffee. Creatively working together with a wide variety of stakeholders using 'funny' techniques does not result in much discomfort. However, forming collaborations is a much more complex process for other CoVE SEED regions, particularly when considering the use of various codesign methods to work together with stakeholders.

Interestingly, the most critical participants later actively implemented codesign methodologies in both international and regional settings (Box 1).

Box 2. How Greek partners adopted codesign.

> One particular insight came from the Greek partners, who explained that they removed the "fun" elements from the methodologies because such aspects did not align with the Greek work culture, where work is often regarded as a serious and formal matter. Nevertheless, they did apply the core of the methodology, such as stakeholder analysis. Their initial critical stance was not a rejection of the approach, but rather a need to tailor it to their context. Interestingly, they later contributed creative and engaging formats for the international consortium workshops, including a poster featuring balloons for idea generation and a MoU building-blocks template.

Codesign helped participants move beyond the boundaries of their own expertise, for instance, in preparing and hosting workshops. Workshop leaders codesigned richer, more interactive sessions with us and refined them iteratively. The transnational meetings provided a safe space for experimentation and the testing of codesign practices. It also helped create coherence between different workshops during transnational meetings by aligning content and formats and building on each other's work. After four years into the project, the impact of the codesign training and other workshops has become evident among the project partners. Their critical stance could have been a sign of learning and finding ways to adapt the codesign methods to their working culture. The continued application of the codesign approach led partners to adopt, adapt, and even develop new methodologies, often consulting us during their development process.

The adoption of codesign approaches often occurs gradually, especially when participants are initially critical or reserved. Over time, enthusiasm emerges, along with adaptations that reflect the partners' specific cultural and professional contexts. The cultural differences that emerged throughout this process were a valuable learning opportunity for us, as the playing field differs from the Dutch ways of working.

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This paper describes the current and future development of our minor Energy Transition. The experiences of the Inholland UAS contributors may be of interest for colleagues in other UAS, and/or invite useful feedback.

Development Of An Education And Research Minor Energy Transition At Inholland UAS

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Introduction

This paper describes how the energy transition both challenges and inspires the continuous development of the education and research at Inholland UAS. The main focus of this paper is the development of an Energy Transition Minor at Inholland University of applied sciences.

Background

The driving force of the development is the need to better equip our students to address societal challenges (van Boekel, 2024 and 2025). Also, there is a shared interest in the topic among both research and educational staff, and an intrinsic motivation to foster this development within the constraints of the existing organisation.

Energy transition, research and educational context

Energy transition is defined here as the process of abolishing fossil resources in favour of renewable resources. The main motivation is climate consequences caused by fossil fuel consumption, although other reasons (autonomy, robustness, and cost) are also relevant. Energy transition is closely related to other necessary transitions, such as the material and food transitions.

From an educational and research perspective, some characteristics of the energy transition will be addressed here:

Symbiosis of research and education: For 25 years now, applied research has been a core task of the universities of applied sciences. At Inholland, the 'knowledge and innovation agenda' will be a vehicle to foster the synergy between research and education. The core of this agenda is a thematic collaboration between research and education. The minor described in this paper is in the focal point of the energy transition collaboration, which consists of masterclasses, excursions, practical assignments, internships, graduation projects, collaborative subsidy projects with external partners, etc. *The minor is an effective instrument for thematic collaboration between research and education.*

Action perspective: Students can perceive energy transition as urgent on the one hand, but also as overwhelming on the other, which may lead to lethargy. *We need to equip our students with ample perspective for their individual contributions.*

Multidisciplinarity: Many technological innovations cannot be covered fully in existing monodisciplinary educational programs. As an example: a wind turbine, in terms of disciplines, is an amalgam of aerodynamics, composites, civil engineering, electrical engineering, cybersecurity, rules and regulations, ecology, etc....and many existing industries had to reinvent the wheel (literally: a gear box in a wind turbine is in many ways different from a gearbox in a car). This means that single disciplines need to adapt to the required technology, and a great deal of system engineering is required to combine disciplines into an optimal innovation. *We need to adapt our education to accommodate multidisciplinary careers in the energy transition.*

Topical connectivity: While the example of a wind turbine refers to a single machine; the energy transition comprises many highly different and interconnected machines, systems and society. The interactions between complex transitions are sometimes difficult to predict. For example, food crops can either be eaten or turned/converted into bio-based fuels; durable materials can cause environmental problems. *The minor introduces a systemic perspective to the students to address multi-stakeholder problems.*

Benefits and challenges in development of the minor

This minor was developed with a number of potential benefits in mind.

Profile of energy transition: The fully developed minor is expected to be a pivotal learning experience, equipping students with tools to actively address the subject providing increased interest for the students' later research and work activities.

Efficiency: As a co-production of research and education, and as a minor that is accessible for students from multiple technical and, in the future, potentially also non-technical disciplines, our minor efficiently combines knowledge, staff hours, and infrastructure. Examples of this infrastructure are our innovation laboratory (Box 1) and energy lab. The minor is both scalable and can be adapted for different target audiences. Furthermore, many activities in the minor can be merged with or offered separately to other target audiences.

There were also challenges while developing the minor, among others:

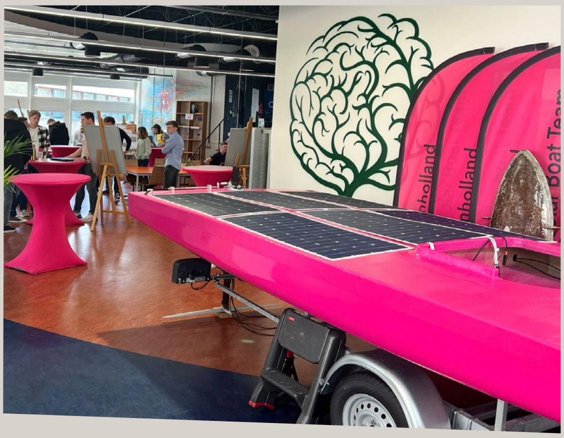
Rhythm and flexibility: The educational program follows the academic year dynamics, while research programs have their own rhythm.

Motivation: The motivation for different stakeholders to participate in either research or education can be different. Students, researchers and teaching staff all have different needs and expectations.

Organisation: In our university, research and education are currently organized along separate lines with separate management views on funding. In the development of the minor, to warrant the breadth and depth of the course content and practical assignments, we worked with colleagues from different departments (initially mechanical engineering, electrical engineering and research) with a mandate from the team leaders involved. To accommodate other educational tracks when scaling up the minor, involvement from other expert staff will be required.

Box 1. Innovation laboratory

The Innovation Lab in Alkmaar is a place where research students and staff meet their educational counterparts to work with external partners from the quadruple helix to turn ideas into prototypes. The main themes are Energy and Material Transition, Robotics, Data Science and AI and the Built Environment.



First editions and lessons learned

For pragmatic reasons, this elective minor was evolved iteratively. The minor started in 2023, and the original context of the minor is a co-production between the engineering educational program and the applied research group 'smart materials for the energy transition'.

Prior to launching the minor, the educational program was set up to include existing courses, such as thermodynamics and computational fluid dynamics, modified with an energy transition twist. For example, the students designed a home heating boiler conversion from natural gas-fed to hydrogen-fed. In addition, dedicated courses were developed on wind energy, sustainable energy technology, and materials for the energy transition.

The one-semester minor was originally divided in a theoretical and a more practical part. In the first edition, it was found that both time constraints (logistics for externally sourced parts) and the candidates work load and energy favoured a more uniform distribution of theory and practice, so in the next edition the full semester was dedicated to designing and building. This required careful timing of the parallel education units, but increased the intrinsic motivation of candidates, teaching and research (support) staff.

In the most recent editions, one of the practical assignments was the design, building and testing of a small wind turbine. In the spirit of the challenging energy transition context, the students actually participated in the International Small Wind Turbine Contest (e.g. Adema, 2025). Such a competitive and international component was very motivating for all participants. It also facilitated deeper and more multidisciplinary involvement from one edition to the next; e.g. the second time the student teams participated, mechanical engineering students endeavoured to design and build their own electrical generator in cooperation with the electrical engineering students.

There are several lessons learned from the first editions that can improve content and participation in future editions as well as minor development at other UAS.

Firstly, the bridge-building nature of the minor in linking research and education, was both facilitated and deepened by the involvement of a research/education driven makerspace called the innovation laboratory (see Box 1). At the Alkmaar location of Inholland UAS, this facility provides ample room for rapid prototyping using standard tools (3D-printing, metal working, laser cutting) and more dedicated facilities (composites workshop and bio-based materials laboratory).

Figure 1 shows the wind turbine created by one of the student teams participating in the International Small Wind Turbine Contest. In subsequent editions, the amount of pre-bought components has progressively made room for a larger contingent of self-made parts.

Figure 1. Small wind turbine in innovation lab.

Source: Author.

Secondly, a related lesson learned is that active participation in a design- and build project is a stronger motivator than expected, and the rich practical contest of this minor will be further expanded in future editions, starting with participating in other contests and including students from vocational programs.

Facts, figures and future developments

Some facts and figures regarding the minor are discussed briefly here.

Table 1 lists the participation in the first editions. The total number of students is listed, as well as the educational programs involved, and type of participation in a practical assignment/contest.

Table 1. Some numbers on the minor Energy Transition.

edition	# of students	Educational programs	Practical, contest
2023	8	ME	HCH
2024	9	ME	WT, ISWTC
2025	10	ME, EE	WT, HG, ISWTC
2026	Expected : 20	ME, EE, IEM, EI, AE	WT, HG, ISWTC, Hydrogen cart

ME(Mechanical Engineering), EE(Electrical Engineering), IEM (Industrial Engineering and Management), EI (Engineering Informatics), AE (Aeronautical Engineering); HCH (Central heating boiler conversion to hydrogen), WT (wind turbine design and build), ISWTC (International Small Wind Turbine Contest), HG (Hydrogen Generator).

For a pilot development, these numbers are sufficient, however for future viability, upscaling and further integration with other educational programs is essential.

Discussion and reflection

In the first editions fewer students applied than expected. This could be caused by student versus teacher idealism and perceived difficulty. Therefore, to improve the number of participants elements of the minor could be promoted in the first-years program of a broader range of educational tracks (Zee, van der, and Zoetmulder, 2025).

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The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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The Dutch heat transition requires a highly context-specific approach. Diverse stakeholders - such as housing corporations, network operators, and residents, must collaborate closely at a neighbourhood level to realise plans. A Dutch study offers insights into professional skills that participants in these complex, local, interdisciplinary collaborative processes may benefit from.

Interdisciplinary Collaboration At A Neighbourhood Level

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Interdisciplinary collaboration at a neighbourhood level

While policy frameworks for the energy transition are established at (inter)national and municipal levels, the local character of the Dutch heat transition requires solutions at a neighbourhood level, considering significant differences in property ownership, infrastructure, available energy resources or financing opportunities. Technology and policy intersect with residents' daily lives, and parties with different interests, goals, organisational cultures and structures must work together. A study following local heat transition processes in Dutch post-war neighbourhoods highlights the specific challenges faced by collaborating professionals at this level.

Similar challenges

For two years, researchers from University of Applied Sciences of Utrecht and Amsterdam and University of Tilburg researched three municipality-led collaborations on the local heat transition, where representatives from local municipalities, energy companies, network operators, residents, and housing corporations worked together to develop and implement heat transition plans in one neighbourhood.

The research was conducted through participatory observation and interviews with participants. The collaborative governance model (Ansell and Gash, 2008), a framework for analysing multi-stakeholder processes in public policy implementation, was used as an analytical framework to interpret their findings. Despite differences across cities and neighbourhoods, the cases showed similar moments in which joint processes stalled or were obstructed. Beyond financial and technical issues, challenges also seemed to arise from how collaborations were structured and enacted. Factors such as a lack of shared understanding, misalignment in expectations, or uncertainties about roles and responsibilities appeared to be influential.

Certain participants succeeded in navigating these challenges more effectively than others, often with simple interventions in collaborative dynamics. In what follows we will identify the specific challenges and provide suggestions on the skills needed to deal with them.

Exchange of insights

First, shared understandings of how heat projects should be implemented were sometimes lacking. Although participating organisations shared the common goal of fossil-free neighbourhoods, their understandings on how this goal could be best achieved often diverged, usually prompted by differences in organisational objectives, interests, and constraints. Those were not always clearly articulated at the outset but only became explicit when concrete obstacles or resistance prompted parties to clarify their positions. Consequently, crucial exchange of insights only took place at a later stage, sometimes delaying the process.

Interdependencies and friction

Secondly, the interdependencies between participants in the sequencing of actions within the joint processes were often unclear. Technical, spatial, financial, policy-related, legal, or organisational dimensions that could be of influence were sometimes self-evident to certain organisations but unknown or unclear to others. This lack of shared understanding led to unforeseen barriers, causing friction or necessitating adjustments in agreed plans.

Coordinating without authority

The shared findings, thirdly, revealed the challenging role of coordinator in the local heat transition assigned to municipalities by the national government. While municipalities depend largely on other stakeholders, they do not hold any formal authority over them (Herreras Martínez et al., 2022). Actions and solutions must therefore be voluntary. This necessitates extensive joint exploration of the needs and constraints of participating stakeholders, to build a collective foundation from which shared decisions can be made. Coordinating this process among stakeholders with substantial differences—such as energy companies and resident cooperatives—proved to be challenging at times.

These challenges were amplified by pressure to accelerate the process, while the uncertainty of the energy transition, in which variables such as local decision-making or legislation are subject to frequent change, required flexibility from all participants. Fostering goodwill, patience, trust, and adaptability sometimes proved to be a challenge for municipal representatives operating within this complex and unpredictable context.

Internal resistance

Fourthly, even when parties reached mutual understanding and agreed on implementation pathways, professionals in all cases frequently encountered resistance within their own organizations, when attempting to translate these agreements into practice. Unexpected legal constraints emerged, staffing proved insufficient, and policy goals or internal planning conflicted with the project's agreed timeline.

Skills for mutual success

In the face of such barriers, solutions often depended on the proactive engagement of specific participants. By inviting others to share their perspectives, asking clarifying questions, taking time to listen and to deeply connect with, for instance, the challenges faced by certain stakeholders, they encouraged dialogue, and contributed to mutual understanding.

Practical interventions initiated by these professionals, such as sharing specific insights to establish a collective knowledge base, or integrating time schedules, helped participants to gain deeper insights in constraints and possibilities. It also helped build a shared understanding and opened up new avenues for collectively endorsed solutions.

This reliance on individual participants with a specific set of skills reveals a potential vulnerability. Interdisciplinary collaboration under the uncertain conditions of a transition requires continuous navigation of ambiguity and the bridging of differences between sectors, organizations, and disciplines. To succeed, more is needed than the coincidental presence of professionals who happen to be skilled in doing so.

We therefore need to better understand which professional competencies—beyond, for example, technical expertise or regulatory literacy—are necessary, and how these can become an integral part of the collective practice of local transition efforts, to reduce dependency on individual actors.

To understand, we turn to the theory of boundary crossing (Akkerman, 2011; Engeström et al., 1995; Wenger, 2000).

Boundary crossing for professional development

The learning theory of boundary crossing focuses on how people learn when they move between different social, cultural, or institutional contexts, called "boundaries." It provides a conceptual framework for identifying useful professional competencies, called boundary crossing skills or competencies (Williams, 2002). Based on this framework, we can identify essential skills for boundary crossing in the heat transition.

Among these are the ability to recognize other participants' interests, incentives and perspectives and the existing boundaries those may create. Subsequently, the ability to translate perspectives, values, or logics helps cross those boundaries. Since a good level of trust is necessary between collaborating partners in the heat transition, skills like openness and interpersonal communication are also important. Reflexivity, needed to identify patterns of interaction and certain routines that might hamper a constructive collaboration, while being able to align interests and incentives or bridge knowledge gaps could help dealing with such patterns.

Our findings show how the success of local heat transition initiatives is partly influenced by the quality of collaboration among stakeholders. This collaborative quality appears to be partially dependent on specific competencies, which are not necessarily present among participants, thereby exposing potential vulnerabilities. Organizing collaborative qualities should therefore be addressed within organizations and educational institutions, with training opportunities. The theory of boundary crossing offers a useful framework for designing training programs that focus on non-domain-specific boundary crossing skills. Investment in such professional development initiatives may prove instrumental in facilitating professionals in their collaborative endeavours for the energy transition.

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In today's rapidly evolving learning landscape, trainers must adapt faster than ever to new technologies, diverse learners, and shifting labour demands. Competence frameworks provide structure, but reflection transforms them into meaningful action. This article explores how self-assessment empowers trainers to connect theory with practice and turn prescribed standards into personal growth paths. By embracing reflective practice, trainers move beyond compliance, while also cultivating agility, confidence, and a culture of continuous improvement.

Strengthening Trainer Competencies Through Continuous Professional Development

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Introduction

Nowadays, trainers must continuously evolve their knowledge, skills, and approaches if they want to stay effective and relevant. In the context of this article, the term "trainer" refers primarily to vocational education and training (VET) practitioners and adult learning facilitators involved in delivering upskilling and reskilling programmes, including those operating in emerging fields such as sustainable energy and digital technologies. Their role has been extended beyond the delivery of knowledge to learning facilitation, development of critical thinking and digital literacy support. Thus, their continuous professional development is essential for delivering high quality education and for responding to learners' expectations.

As the energy transition accelerates, trainers in VET and adult learning increasingly support emerging skill needs related to renewable technologies, efficiency practices, and green digitalisation. Strengthening the skills of trainers becomes a major requirement for ensuring that learners acquire the adaptive, interdisciplinary and future-oriented competencies needed within sustainable energy systems. In this article, the reflection and self-assessment are explored as a means of transforming competence frameworks into active tools for professional growth, since trainers can use reflective practices to recognise strengths, identify learning gaps, and translate new knowledge into improved teaching and facilitation.

Background

Numerous frameworks define what effective trainers should know and be able to do. Some indicative international ones that are seeking to define trainer competencies are listed in the following paragraphs.

Although these frameworks establish valuable benchmarks, they are sometimes perceived as difficult to translate into everyday practice. However, these frameworks are often seen as static checklists rather than dynamic instruments for growth. Many trainers find them complex or disconnected from their daily challenges. What is needed is an enrichment of existing frameworks through tools that encourage reflection and personalisation.

It should be noted that the frameworks presented below each address a different facet of trainer competence, collectively reflecting the cognitive, pedagogical, digital and socio-emotional dimensions of the role. Identifying their shared elements as well as their points of divergence provided a basis for consolidating these perspectives into the competence areas outlined in this article and, subsequently, for shaping the seven axes of the self-assessment tool. This creates a coherent link between international standards, operational competence categories, and the reflective instrument introduced later in the paper.

European Qualifications Framework (EQF)

Provides competence levels standardised system for describing learning outcomes across Europe, covering knowledge, skills, and responsibility at eight qualification levels. It is widely adopted but as it was designed for general educational and vocational contexts, it is not tailored to the specific needs of trainers.

DigCompEdu

This framework identifies six areas of competence, i.e. professional engagement, digital resources, teaching and learning, assessment, empowering learners and facilitating learners' digital competence. It offers a detailed set of digital teaching competencies but requires contextual adaptation to reflect sector-specific practices or national educational standards.

Curriculum globALE

It was developed by UNESCO, DVV International and the International Council for Adult Education. This framework was designed to cover diverse cultural and institutional contexts, but its depth is conceptual rather than operational, leaving implementation to national or institutional bodies .

National Adult Learning Standards

These standards provide useful benchmarks for teaching practices, digital literacy, ethics, etc. Depending on their national/geographic context, they vary in depth, applicability and structured reflection processes.

Essential skills for trainers professional growth

Drawing on the complementary insights of the above frameworks, the competences summarised in Table 1 reflect the recurring cognitive, pedagogical, digital and interpersonal domains that appear across these international standards and form a practical foundation for reflective trainer development. In addition to the interpersonal and self-management dimensions often highlighted in the literature, the competence areas also incorporate cognitive and technical elements derived from the broader qualification and pedagogical frameworks reviewed earlier, recognising that effective trainer performance relies on the integration of both domains. Table 1 presents key categories of trainer competences that support reflective practice and continuous learning.

Table 1. Core Trainer Competences and their Contribution to Effective and Reflective Practice.

Trainer Competence	Benefits
Cognitive and analytical skills	*Evaluation of learning situations, informed decisions, creativity encouragement among learners*
Intrapersonal / Self-Management Skills	*Pressure handling, focus maintenance, performance improvement*
Interpersonal / Communication Skills	*Clear communication, management of group dynamics, inclusive learning environments*
Leadership and Management Skills	*Effective group guidance, inspiration of learners, efficient management of learning processes*
Emotional and Personal Qualities	*Positive classroom climates and ethical, learner-centred practice*
Pedagogical / Facilitation Skills (Trainer-Specific)	*The core of professional training. Long lasting learning outcomes can be achived*

Indicative Sources: Coelho et al. 2022, Galster et al. 2023, Ragusa et al. 2022, Volkova et al. 2020.

Each competence category can be operationalised through reflective prompts used by trainers during or after training sessions.

A widely accepted tripartite model (from scholars and employers) however, groups soft skills into three broad categories:

Social & Communication Skills

These include: listening skills, persuasion and argumentation, networking, negotiating, presentations, sales skills, self-presentation, public speaking, teamwork, focus on results, business letter, customer focus.

Cognitive Skills

This category includes critical thinking, problem-solving, creativity, information management, time management, self-learning, design thinking, creative thinking, time management.

Personal & Emotional Qualities

Emotional intelligence, honesty, flexibility, motivation, optimism, resilience, stress management, planning and goal setting, as well as using feedback, enthusiasm, initiative, perseverance are included in this category. It is therefore obvious that within and across these categories, skills interact dynamically. Effective communication, for instance, depends on emotional intelligence while leadership requires both cognitive decision-making and interpersonal influence.

However, in order to ensure that such competences evolve over time, trainers need structured ways to observe their progress and identify new areas for improvement. Reflection and self-assessment tools provide this bridge by transforming abstract skills into tangible, measurable learning practices.

Development of reflection and self-assessment tool

Professional growth involves not only technical knowledge but also personal and social awareness. Reflection and self-assessment could help trainers recognise how the wide skill areas interact in real practice - encouraging balance between analysis, empathy, and self -discipline.

Building on such examples and existing European frameworks, a Trainer Self-Assessment tool intended to help trainers apply these concepts in a measurable, practice-based way. This tool focuses on seven core areas, namely (i) Pedagogical and Didactic Design, (ii) Learner Engagement and Interaction, (iii) Digital Competence and Innovation, (iv) Assessment and Reflective Feedback, (v) Inclusiveness, Empathy and Ethics, (vi) Subject-Matter Expertise and Continuous Learning, (vii) Resilience and Professional Balance. These seven axes were derived through a consolidation of recurring competence themes identified across the European and international frameworks discussed earlier, namely digital capability, pedagogical design, learner interaction, inclusiveness, reflective assessment, subject-matter expertise and professional resilience. By grouping overlapping areas and distinguishing those that represented unique developmental priorities, the tool integrates both technical and relational dimensions of trainer effectiveness into a coherent structure. This approach ensures that the instrument remains conceptually grounded while also practical for trainers to use in real learning environments.

At this stage, the tool is presented as a conceptual framework designed to translate established competence standards into a structured reflective process for trainers. While it has not yet been formally piloted, its structure has been informed by preliminary discussions and practitioner feedback gathered during training activities within related European projects. Future applications of the tool could include small-scale trials with VET and adult learning trainers, followed by qualitative analysis of its usefulness in identifying development needs and guiding continuous professional learning. Such implementation steps would allow for refining the instrument and assessing its practical impact in diverse training contexts. Together, these axes provide a structured yet flexible lens through which trainers can examine their practice. By engaging with each axis through self-reflection and structured evaluation, trainers are encouraged to identify strengths, recognise development needs, and establish concrete goals for continuous improvement. In practical terms, the seven axes offer trainers a flexible structure that can be adapted to different learning contexts. Practitioners may self-rate their current performance in each area, reflect on concrete situations in which these competences were demonstrated or challenged, and set targeted actions for improvement. The axes can also be used during mentoring discussions, peer-learning sessions or professional development planning, enabling trainers to revisit their progress over time and adjust their goals as their roles and responsibilities evolve. This flexible use supports the dynamic, iterative character of reflective practice that the tool aims to promote.

Conclusion

Competency frameworks remain essential for defining the standards of trainer excellence, yet they reach their full potential only when integrated with reflective, practice-oriented tools such as the Trainer Self-Assessment Tool presented in this article. By regularly evaluating their skills trainers can maintain motivation and ensure their learning remains relevant to evolving professional realities.

Ultimately, such tools cultivate a culture of continuous reflection and professional growth, ensuring that trainers remain adaptable, innovative, and aligned with the evolving demands of education and the labour market. At the same time, when used at institutional and policy level, they can actively inform quality assurance processes, trainer certification frameworks and the design of evidence-informed professional development strategies.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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In this article, we showcase the journey of a solar charging station—designed by students in collaboration with SunCrafter GmbH at Bochum University of Applied Sciences, which has grown into a flagship example of successful scientific project acquisition, regional replication, and hands-on knowledge transfer.

The Solar Charging Station As A Model Example For Effective Teaching And Scientific Knowledge Transfer

Name	**Expertise**
Noman Hanifa	Noman Hanifa works as a Research Associate at the Sustainable Technologies Laboratory at Bochum University of Applied Sciences in Germany. He has an academic and professional background in renewable energy particularly in solar energy, and his research focuses on sustainable solutions for micromobility and neighbourhood energy systems.
Lisa Wendzich	Lisa Wendzich is the co-founder of SunCrafter GmbH, a startup dedicated to off-grid solar solutions. She holds a master's degree in public policy and worked in the energy and sustainability field before moving into entrepreneurship. Her work focuses on renewable energy access, circular and sustainable business approaches, and sustainable mobility. She is also an active speaker advocating climate-friendly solutions.
Semih Severengiz	Semih Severengiz is a Professor and the Head of the Sustainable Technologies Laboratory at Bochum University of Applied Sciences. The laboratory focuses on sustainable mobility, circular economy, life cycle engineering, innovative digital solutions, and decentralized energy systems.

How to cite: Hanifa, N., Wendzich, L., Severengiz, S. (2026). The Solar Charging Station As A Model Example For Effective Teaching And Scientific Knowledge Transfer In: Expert Articles. Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026). Utrecht, the Netherlands, 24-25 March 2026. DOI: https://doi.org/10.48544/1dabb012-c959-45cd-97b4-b4fd449fe9a8.

Introduction

The deployment of light electric vehicles (LEVs) particularly in shared mobility are rapidly expanding across the European cities (Coenegrachts et al., 2024). In the Netherlands, around 42 % of adult are reported to own a LEV (LEVA-EU, 2023). Meanwhile trips made by shared mobility rose up to 640 million (Mecatti, 2025). Yet, the prevailing charging infrastructure for these vehicles by the sharing companies are often unsustainable commonly referred as milk run concept where companies charge the LEVs at their charging premises and re-distribute it to the business area usually with diesel powered vans (Schelte et al., 2021b). Photovoltaic-based charging stations are an attractive alternative as it has a high potential considering the environmental perspective (Schelte et al., 2021a). The installation of such system requires advanced skills, system knowledge and interdisciplinary training. The additional installation of the renewable capacity to meet the EU green deal will boost the demand for the skilled workers and trainees (European Commission, 2025). In this article, we describe how a solar charging station at Bochum University of Applied Sciences gained regional attention by bridging student engagement, scientific knowledge transfer, and sustainable mobility.

"When we first started building the solar charging stations, our goal was to connect decentralized mobility — micromobility — with decentralized clean energy. We wanted renewable energy to become part of everyday life, visible and accessible right on the streets. We also liked for students to get hands-on experience: to learn from the systems, experiment, and improve them. Watching their curiosity and seeing how their ideas have helped shape the stations has been very rewarding."

*— **Bryce Felmingham**, Operations and Product Manager, **SunCrafter***
Lisa Wendzich**, Co-Founder, **SunCrafter

Journey of the Solar Station

Student Project: Bobby Sharing

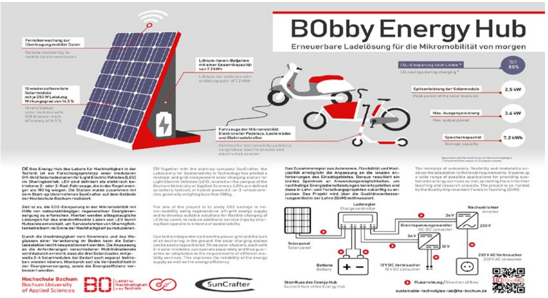
The project was started with the development from the students in the year 2019 in collaboration with the SunCrafter GmBH. A glimpse of the structure implementation is depicted in the figure 1.

Figure 1. Students assembling the solar charging station at the campus of Bochum University of Applied Sciences.

Source: Sustainable Technologies Laboratory, Bochum University of Applied Sciences.

The system has a capacity of 2.5 kW and the battery capacity of 7.2 kWh in total. The technical sketch of the system has been depicted in the figure 2 below. The main use case of the system is to charge the e-scooter. The project became a successful highlight at the Bochum university of applied sciences as a project study which successfully trained students in domain of data collection techniques, lifecycle assessment, business model and technical aspects of such system.

Figure 2. Technical description of the functioning of the solar charging station.



Source: Sustainable Technologies Laboratory, Bochum University of Applied Sciences.

Acquisition of scientific project and development of the living laboratory

The concept successfully acquired about million-euro funding through the sponsor German ministry of education and research in the year 2021. Under the well-known funded project Sustainable City Sustainable Mobility (SciSusMob), the more sophisticated station was put in the city of Essen and Oberhausen. Which was utilized by the sharing company EVO which had registered customer of about 24,000 in the year 2024. The station has a PV capacity of 1.6 kW with the battery capacity of 3.6kWh along with one available charging port depicted in the figure 3.

Figure 3. Solar Station placed at the Essen West Railway Station as part of the Living Lab.

Source: Sustainable Technologies Laboratory, Bochum University of Applied Sciences.

Regional Replication and Good Practice

In the recent years the station remains a highlight during the visits of the students from the other university such as University of applied sciences Utrecht, events such as Girls Day, Expert visits. A most successful regional replication example by the VET students at university of applied sciences Utecht. The inspired students to replicate their own system as depicted in the figure 4. Moreover, the station remains a central pillar for an organized spring school in March 2026 open for the students and teachers from all over EU.

Figure 4. A replication of the Bobby Project being Implemented by the VET student in the Utrecht.

Source: University of Applied Sciences, Utrecht.

Scientific Publications and Writing

The table 1 below refers the area in which scientific publications were carried out, in these publications solar station was the basis. The publications focused on the demanded scientific method i.e. life cycle assessment (LCA) with the goal to improve the business model, technical design modifications under the real conditions.

Table 1. List of the domains in which publications were carried out over the solar station.

Area	Publication
Living Lab Testing and Sustainability Assessment	Hanifa et al., 2025
User Expereince	Mehta et al., 2025
Operational Business Model	Takahashi et al., 2025
Life Cycle Assessment	Schelte et al., 2021a & Schelte et al., 2021b
Technical Design	Lange, 2021

Source : Publication Database: SustainableTechnologies Laboratory.

Student Involvement

To effectively transfer the knowledge from the solar station, Currently the solar station remains an active part of the curriculum in project study course named as 'Sustainable Energy Impact (Hochschule Bochum, n.d.)'. The curriculum revolves around based on the above topic discussed in table 1. The students are directly engaged with the hardware combined with the problem-based learning on the variety of the topics discussed above. Student from the diverse range of program of the Hochschule Bochum such as sustainable development, electrical engineering and energy related background are enrolled into the course. Further a spring school with the focus on the life cycle engineering with the focused training on the off grid solar (Hochschule Bochum, n.d.).

Final Remark

The Solar Station has proven to be an excellent example of effective knowledge transfer. Its impact extends beyond scientific publications, and the acquisition of third-party funded projects. It also plays a vital role in student learning. While hardware remains a key factor in ensuring efficient training and skill development, the transfer of related knowledge often does not fully reach the students. Based on experience with the Solar Station, involving students directly in the development process, organizing dedicated technical sessions, and fostering active cross-regional exchange with companies and research institutions helps to bridge this gap.

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Conflicts of interest

The author declares no conflict of interest.

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Sustainability is not just a technological challenge—it is a complex, multidisciplinary endeavour that demands collaboration across domains. Living labs like the biogas installation at Hogeschool Utrecht offer a unique opportunity to learn by doing, bridging theory and practice.

Biogas As A Catalyst For Multidisciplinary Sustainability Education

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How to cite: Bollemaat, H.Z. (2026). Biogas as a catalyst for Multidisciplinary Sustainability Education. In: Expert Articles. Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026). Utrecht, the Netherlands, 24-25 March 2026. DOI: https://doi.org/10.48544/1dabb012-c959-45cd-97b4-b4fd449fe9a8.

Introduction

In the face of climate change and resource scarcity, universities of applied sciences are increasingly called upon to lead by example in the transition to sustainable energy. Hogeschool Utrecht (HU) has taken a bold step by installing a biodigester on campus, transforming food waste into renewable energy. While the technology itself is impressive (it can produce 5000 m^3 biogas yearly out of 50kg organic waste per day), the true value of this initiative lies in its role as a living lab—a multidisciplinary learning environment where students, educators, and stakeholders collaboratively tackle sustainability challenges. This expert article explains how the biodigester exemplifies themes 2 to 4 of the SEED Conference: Innovative Energy Education, Region as Campus, and Skills for the Sustainable Energy Transition.

Innovative Energy Education

The biogas installation at HU is more than a technical showcase—it is an educational tool embedded in the curriculum. Students from engineering, chemistry, communication, communication and multimedia design, legal studies and social studies engage with the system from different angles. For example, chemistry and engineering students analyse the anaerobic digestion process, while communication students investigate behavioural change and community engagement for the collection of waste streams. Legal students investigate the use of organic waste from other institutes. In the nearby future other educational institutes can contribute too; for example business students will explore circular economy models and cost-benefit analyses. This cross-disciplinary approach reflects the SEED Conference's emphasis on hybrid learning environments and responsive curricula.

The initiators of this project have the ambition to involve all HU institutes, both in education and research, ranging from social to technical studies. Because for every discipline there is something to learn and something to add to this living lab. 8 studies are already involved in the project.

The installation also supports lifelong learning and professional development, because the installation of the biodigester demanded additional skills from the employees of the HU and the legal authorities. By integrating the biogas system into formal and informal learning pathways, HU fosters a culture of continuous learning aligned with the energy transition.

Region as Campus

HU's biogas project exemplifies the concept of 'region as campus' by actively involving local stakeholders. Other institutions at the Utrecht Science Park are involved in a feasibility study to explore the use of biogas in the energy usage of the future. The wish to be an energy autonomous campus is starting to gain support and bio digestion might be a key element in this transition.

> The biogas installation serves as a hub for open innovation, stakeholder engagement, and regional development.

The living lab demonstrates how sustainability challenges can be addressed through place-based learning and community partnerships.

The Utrecht Science Park is also the perfect place to test this concept. All disciplines and expertise needed are within reach. The innovative strength of the campus can be used perfectly in the living lab.

Skills for the Sustainable Energy Transition

The biogas living lab cultivates a wide range of skills essential for the energy transition. Technical skills include system design, energy efficiency, and waste-to-energy conversion. Digital skills are developed through data monitoring and sensor technique. Soft skills such as teamwork, adaptability, and cultural awareness are honed through interdisciplinary collaboration.

Students also gain entrepreneurial skills by developing business models for scaling biogas solutions. Research and design skills are fostered by performing research in a complex (real) situation. Professional development is supported by real-world exposure and boundary-crossing experiences.

Figure 1. Placement of the Biodigester.

Source: Author.

Living Lab Case Study: Installation of the HU Biogas Living lab

> The installation of the biodigester was an excellent example of the hurdles you can encounter in the energy transition.

A new concept, like small scale bio digestion, raised questions within the educational teachers team, in the facility team and at the legal authorities. Questions like: 'Is it safe?'; 'How do we get the organic waste into the machine?'; 'Will we smell it?' were asked. In this process already we decided to work with student projects, because this creates a win-win situation: the problems were solved, the questions were answered and the students learned a lot.

The fact that the Biodigester is a living lab makes it a very appealing project. However, the consequence is that the outcome is unknown: in the coming years we will figure out with students if bio digestion in a complex environment, like a university, is one of the ways to go in the transition to a circular economy.

The projects planned for the future are related to: logistics of organic waste streams, communication about separation, legal questions, social acceptance, purification of biogas, the business case for different applications and so on.

Conclusion

The biogas installation at Hogeschool Utrecht is a compelling example of how sustainability education can transcend disciplinary boundaries. It demonstrates that the energy transition is not solely a technological endeavour but a complex societal challenge requiring integrated solutions. By embracing living labs, educational institutions can prepare students with the skills, mindset, and experience needed to lead the transition.

Acknowledgements

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper

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This paper explores how research-integrated project courses can transform sustainable energy education by immersing students directly in ongoing scientific research. Using the "Sustainable Energy Impact" project seminar as a case study, it demonstrates how interdisciplinary teams tackle real-world challenges in hydrogen and solar technologies, developing both technical expertise and collaborative skills.

Sustainable Energy Impact – An Example Of The Importance Of Project-Based Learning In Energy Education

Name	Expertise
Loredana Tiedke	Loredana Tiedke is a Research Associate at the Sustainable Technologies Laboratory of the University of Applied Sciences Bochum with a background in sustainable development. She is the head of the project study "Sustainable Energy Impact" that is project-based and uses methods such as problem-based learning.
Semih Severengiz	Semih Severengiz is a Professor and the Head of the Sustainable Technologies Laboratory at Bochum University of Applied Sciences. The laboratory focuses on sustainable mobility, circular economy, life cycle engineering, innovative digital solutions, and decentralized energy systems.

How to cite: Tiedke, L., Severengiz, S. (2026). Sustainable Energy Impact – An Example of the Importance of Project-Based Learning in Energy Education. In: Expert Articles. Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026). Utrecht, the Netherlands, 24-25 March 2026. DOI: https://doi.org/10.48544/1dabb012-c959-45cd-97b4-b4fd449fe9a8.

Introduction

Using the "Sustainable Energy Impact" project seminar as a case study, this paper examines how interdisciplinary student teams engage with real-world challenges in hydrogen and solar technologies within an active research environment. The seminar structure enables students to work on authentic research questions, contributing to ongoing laboratory activities while developing technical expertise, problem-solving abilities, and collaborative skills.

The findings indicate increased student motivation, a stronger integration of theory and practice, and tangible contributions to research processes. By systematically linking teaching and research, the format illustrates how project-based learning can serve as an effective pedagogical approach for preparing students to navigate the complexity, uncertainty, and interdisciplinary nature of the energy transition.

Research-Integrated and Project-Based Learning in Energy Education

The global transition towards sustainable energy systems requires technological innovation as well as new approaches to higher education. While traditional lecture-based formats are effective for delivering foundational knowledge, they often fall short in preparing students for the complexity, interdisciplinarity, and uncertainty inherent in real-world challenges of the energy sector (Hajri, 2024).

In response, project-based learning (PjBL) has emerged as a powerful alternative. PjBL is an educational approach that situates learning in the context of extended, collaborative tasks with real-world relevance, emphasizing student autonomy, iteration, and the coordination of multiple skill sets (Blumenfeld et al., 1991). Within this broader framework, research-integrated learning represents a particularly impactful method. Through this approach students are directly involved in ongoing research activities, enabling them to contribute to authentic scientific research through data collection, conceptual models, or dissemination efforts that feed into larger research agendas (Guerra & Rodriguez-Mesa, 2021). This participation allows students to develop domain knowledge and collaborative skills while gaining first-hand insight into the dynamics of innovation and uncertainty (Krajcik & Shin, 2014).

This model can be distinguished from other student-cantered approaches. Problem-Based Learning (PBL), for example, is based on student-led inquiry into complex problems (Barrows & Tamblyn, 1980). Project-based learning extends this principle by grounding the inquiry in genuine scientific work, moving beyond analysis to active contribution (Brundiers & Wiek, 2010).

In the context of sustainable energy education, technological advancements are deeply intertwined with societal transformations. As such, a combination of learning and research is especially critical within this area (Guerra & Rodriguez-Mesa, 2021). The development of hydrogen infrastructures, solar integration strategies, or sector coupling models requires interdisciplinary coordination and iterative experimentation. Research-oriented project-based learning allows students to experience the ambiguity of these processes while contributing to tangible outcomes, thus aligning with the core principles of sustainable energy education that stress learner agency, collaboration, and systems thinking (Ariza & Olatunde-Aiyedun, 2023).

This paper examines the potential of such research-based project courses, using the "Sustainable Energy Impact" project seminar at the Bochum University of Applied Sciences as an illustrative example. The seminar is accessible to a wide range of students from diverse disciplines and allows them to participate in active research projects on hydrogen and solar technologies.

Implementing Research-Based Project Learning

The "Sustainable Energy Impact" project seminar was conceived as a research-integrated, interdisciplinary project course situated within the Sustainable Technologies Laboratory at the Bochum University of Applied Sciences. To facilitate interdisciplinary work, students from nearly all university departments are allowed to participate in the project seminar. Within the seminar the students are organized into small teams of two to four people and assigned to research topics within the research field of sustainable energy.

At the beginning of each semester new research tasks are chosen in line with the current research projects of the Sustainable Technologies Laboratory. Examples of recent topics include the conceptualization of decentralized mini-grids, life cycle assessments of electrolyzers as well as the development of training materials for training in the energy sector.

Students are provided with one of these research tasks, but do not receive any further sub-tasks. They are expected to independently define their own work packages and methodological steps in order to address the task.

Supervision is provided through a facilitative rather than directive model. Researchers of the Sustainable Technologies Laboratory act as resource persons, offering technical feedback and access to data or modelling tools where needed. This structure mirrors professional research settings in which responsibilities are negotiated within teams and progress is assessed iteratively.

Assessment in the seminar encompasses both processual and outcome-related criteria. A key criterion is whether the chosen methods are appropriate and adequate for addressing the research question. Furthermore, it is evaluated to what extent the research question has been answered and with which level of rigor and clarity. In many cases, student outcomes have been integrated into the research projects the tasks originated from, further reinforcing the authenticity of their contributions.

Educational and Institutional Impact

According to our internal evaluation, the project seminar has produced several notable educational benefits. Firstly, students report a stronger connection between theoretical knowledge and practical application, as disciplinary concepts are mobilized to address concrete research questions. Secondly, the authentic context appears to increase motivation and persistence, particularly when students perceive their work as contributing to broader research goals. Thirdly, interdisciplinary collaboration emerges organically rather than being imposed artificially, since the students have different educational and knowledge backgrounds.

Institutionally, the format strengthens the link between teaching and research by positioning students as active participants rather than passive recipients. Researchers benefit from additional perspectives and exploratory analyses, while teaching agendas become more closely aligned with the laboratory's strategic focus areas.

Nevertheless, several challenges remain. Research-integrated project formats require substantial facilitation effort and may conflict with standardized assessment structures. Not all students are immediately comfortable with the ambiguity of open-ended tasks, and ensuring equitable participation within teams necessitates careful monitoring. These constraints suggest that such formats are most effective when embedded within supportive institutional frameworks.

Impact of Project-Based Learning in Instructors

Furthermore, project-based learning not only benefits students but also reshapes the role and professional practice of instructors in substantial ways. Rather than acting primarily as transmitters of knowledge, instructors adopt a facilitative role that emphasizes guiding students through inquiry, supporting methodological decision-making and assisting with collaborative problem-solving. This shift often results in deeper engagement and greater teaching satisfaction (Ariza & Olatunde-Aiyedun, 2023), as instructors become more closely involved in students' intellectual processes and development. Because project-based learning aligns closely with authentic research contexts, instructors are able to integrate their own research topics directly into the coursework. Students frequently contribute exploratory analyses, data collection, or new conceptual insights that can enrich or advance ongoing research, creating a mutually beneficial interaction between teaching and research (Guerra & Rodriguez-Mesa, 2021).

At the same time, the demands of open-ended project work expand the pedagogical repertoire of instructors, who must refine their mentoring strategies and facilitate interdisciplinary teamwork. These practices contribute to the development of innovative and research-integrated teaching competencies (Mohedo & Bújez, 2014).

Moreover, with regard to interdisciplinarity, the same applies to teachers as it does to students: the interdisciplinary nature of many project-based formats encourages a stronger collaboration among instructors from different disciplines, potentially leading to new research partnerships or broader institutional initiatives.

In summary, project-based learning brings numerous advantages for instructors. It allows for a deeper integration of research and teaching, more meaningful interactions with students, enhancement of pedagogical skills and strengthening of interdisciplinary cooperations.

Conclusion

Research-integrated project-based learning represents a valuable model for sustainable energy education. By involving students directly in ongoing research processes and projects, it enables the acquisition of domain knowledge, methodological skills, and collaborative competencies within authentic contexts. The example of the "Sustainable Energy Impact" project seminar illustrates how such formats can be implemented in practice and how they contribute to both educational development and institutional innovation.

While not without challenges, the integration of teaching and research offers a promising pathway for preparing students to engage constructively with the complexities of the energy transition. Rather than learning about sustainability from a distance, students learn by participating in its advancement.

Acknowledgements

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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This article presents a structured educational approach for training undergraduate engineering students in designing self-sufficient energy island systems. It demonstrates how the integration of specialized simulation software enables optimization of renewable energy concepts which apply for specific island case studies. The methodology equips students with technical, digital, and collaborative skills which are indispensable for advancing sustainable energy transitions on islands. By sharing results and best practices, this work aims to inspire replication of the approach in other academic and professional settings in Europe and around the world.

Educational Strategies And Methodologies For Developing Self-Sufficient Energy Island Systems

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How to cite: Alexopoulos, S. (2026). Educational Strategies And Methodologies For Developing Self-Sufficient Energy Island Systems. In: Expert Articles. Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026). Utrecht, the Netherlands, 24-25 March 2026. DOI: https://doi.org/10.48544/60ca45ce-09af-40fb-87fa-ce4d174fce7d.

Introduction

The author offers an elective course for undergraduate students of Mechanical Engineering in his university about Energy Communities and self-sufficient island systems. In this course he has a different teaching approach that includes the direct application of a software for the creation of a new energy concept for small islands with less than 1000 habitants from the students. The software tool that is used enables the optimization and creation of energy concepts for chosen islands including different energy systems.

Description of energy education approach

This chapter starts with a short description of the course structure and the transferred skills that are necessary for the energy transition for islands. Then the characteristics of the software tool that was used is analysed and a short overview of the results is given.

Description of course structure

The course is structured around a blended learning model combining lectures, workshops, group projects, guest lectures from industry experts, and field excursions to operational renewable energy sites (Garrison & Vaughan, 2008). Students engage in problem-based learning scenarios where they must analyse existing island energy infrastructures and propose optimised solutions using modern simulation tools.

In the course an overview is given of how to proceed with a new energy concept development for energy islands. Different real examples of energy concepts for island are presented to the students from around Europe.

After the theoretical overview some islands are chosen for a case study.

First, the students work in groups to examine the current state of an island's energy supply and, as far as possible, assess the potential for using renewable energy sources in combination with an energy storage system.

With the TOP Energy software, the current state is modelled first which includes the use of conventional fuel.

By examining the current conditions on the island, the local weather, and the potential for energy generation, and by simulating different system designs, the goal is to determine how far the island can move toward an independent, emissions-free electricity supply in the future.

Assessment methods are aligned with intended learning outcomes through project reports, oral presentations, and technical documentation evaluated against scientific standards.

Skills for the sustainable energy transition of islands

Technical, digital, soft, research and professional development skills are educated. The curriculum at the FH Aachen University of Applied Sciences explicitly targets technical skills such as renewable generation planning, storage optimisation, microgrid design, and efficiency analysis using real-world datasets.

The technical skills include further energy planning, storage with batteries, sustainable energy skills through the energy generation from renewable energy systems (RES) and the understanding of complex energy systems.

Digital competencies are in general developed through hands-on use of data analytics platforms and IoT-enabled monitoring systems integrated into simulation exercises (Zhang et al., 2019).

For the digital skills weather data and electricity demand series have to be analysed by the students of the course and prepared preferable with AI from pdf files. The use of AI is supported in the course and students e.g. in a group generated with AI program code in python in order to read the data and to prepare the input values for the TOP Energy software.

Soft skills include the teamwork in multidisciplinary energy teams and the adaptability to changing energy technologies as different renewable energy systems can be selected.

Soft skills including intercultural communication and stakeholder negotiation is planed to be addressed in future lectures via role-play activities simulating community decision-making processes for island projects.

Entrepreneurial thinking is cultivated by requiring students to develop business models for proposed solutions considering economic viability alongside environmental impact assessments.

Additional research skills taught included: developing energy projects for energy communities, and evaluating the environmental impact of new energy-concept solutions.

The energy knowledge is updated continuously and new inputs and considerations are included in the elective course.

Software tool used

There exist different simulation tools in order to develop innovative energy concepts.

The primary software utilised is TOP Energy®, which enables detailed modelling of hybrid power systems incorporating diverse generation sources such as wind turbines, PV arrays, biomass plants, geothermal units or hydrogen fuel cells.

It has a number of advanced features, which are mentioned in Schwarzkopf (2022):

- the possibility of carrying out economic and ecological evaluation
- the freedom to design and test new ideas
- the integration of solvers that help to find the right economic, ecological and energy optimum

This appropriate software uses demand time series and weather data and can create different energy concepts for any island including different energy systems.

The software TOP Energy has been used in different national and international research projects, therefore experience is available and assistance as well as support is provided by the software developers.

Students learn to configure input parameters based on empirical resource data, such as solar irradiation profiles or wind speed distributions, and interpret output metrics including CO_2 reduction potential.

The tool's scenario analysis feature makes it possible to compare different system configurations under changing demand patterns. However, policy restrictions and the current legal framework are not yet included in the model. These aspects can be integrated in the coming years.

Simulation model development

Simulation model development follows a structured methodology as mentioned in Pfenninger et al. (2014) beginning with system boundary definition informed by local geographic conditions.

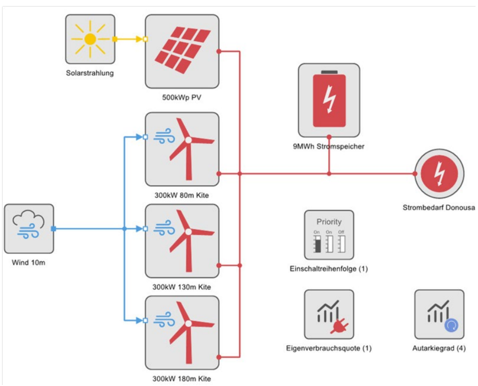
Students apply conservation laws for mass and energy flows when constructing process diagrams representing island microgrids or distributed generation networks.

Validation exercises require comparing simulated performance metrics against case study data obtained from open-access repositories such as OpenEI.

The students in the course applied integrated simulation models in TOP Energy to compare the current energy supply with alternative scenarios, using a novel, data-driven approach suited to small island conditions.

Figure 1 shows a diagram of a new concept for a Greek island that was developed by one group of students during the course.

Figure 1. Diagram of a new concept for a Greek island.



Source: Alexopoulos and Leandro (2025).

As mentioned in Alexopoulos and Mathew (2024) the main difficulty in drawing up an energy plan is that renewable energy production is always linked to storage, as it fluctuates throughout the day and the seasons. An appropriate dimensioning of the storage system had to be considered by the student teams.

The simulation enables the calculation among others of the annual energy yield, of the contribution of different energy suppliers and the saving of carbon dioxide emissions.

Conclusion / Critical Discussion

The implementation of a simulation-based, problem-oriented learning environment in the elective course Energy Communities and Self-sufficient Island Systems demonstrates how innovative pedagogical approaches can effectively foster both technical and transversal competencies required for the sustainable energy transition of islands. The integration of TOP Energy® software into student projects allowed participants to model complex hybrid systems combining different RES and storage technologies under realistic constraints derived from online available datasets. This aligns with findings from Pfenninger et al. (2014), who outlined that early exposure to system modelling enhances students' capacity to evaluate trade-offs between technical feasibility, economic viability, and environmental impact.

A key outcome observed was the ability of students to apply multi-criteria decision-making frameworks when optimising island energy network configurations. Projects frequently balanced high renewable penetration rates with stability requirements through diversification of generation sources. Similar challenges were described by Blechinger et al. (2016) in real-world island electrification contexts.

Critically reflecting on limitations, it is important to notice that while simulation outputs provided robust comparative metrics across scenarios, actual implementation feasibility may be influenced by socio-political factors not fully addressed within the course scope. The future integration of stakeholder engagement exercises or policy analysis modules can therefore further align educational outcomes with real-world deployment challenges as identified by Lund et al. (2015).

The course is already running for three years and the demand for the topic is growing slowly but steadily. The course content will be expanded, updated, and adapted. Particular emphasis will be placed further on current examples of renewable energy communities (RECs), self-sustainable islands in EU and lessons learned.

Acknowledgements

The author would like to thank at this point the TOP Energy team for their assistance and software support.

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Conflicts of interest

The author declares that he has no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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To increase visibility and impact in the green transition, COVE SEED built the SEED Knowledge Sharing Platform. Given the budget and staff constraints typical of publicly funded projects, a lightweight, step-by-step approach was required. This article outlines a low-cost, replicable methodological framework for involving external contributors (complementors) to gradually strengthen the green ecosystem. The core goal is to use actionability and transferability to accelerate experience-based knowledge exchange for educators and practitioners in a fossil-free European Union.

Increasing The Visibility And Impact Of CoVE SEED In Green Transition Through The Design And Use Of The SEED Knowledge Sharing Platform

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Introduction

SEED (Sustainable Energy Education) is a CoVE (Centres of Vocational Excellence) programme that aims to advance innovative VET (Vocational Education and Training). The project's central mission is to build a cross-national collaboration from five regions of the European Union (EU) to work together to phase out fossil fuels and help the EU become a fossil-free area. To enhance the effectiveness of the green transition, COVE SEED requires greater visibility and impact, and this led to the creation of the SEED Knowledge Sharing Platform on its official website.

Creating a digital platform is an effective choice for extending reach and building a reusable knowledge base. The platform could be a practical tool for educators and training providers in renewable energy programmes, especially VET institutions, to access, contribute to, and learn from usable experiences. By sharing useful and practical content, the goal is to attract stakeholders outside SEED, foster a stronger green ecosystem, and enhance COVE SEED's international visibility. The platform also aims to help people in the green transition field find peers and partners more easily, supporting broader cross-regional collaboration.

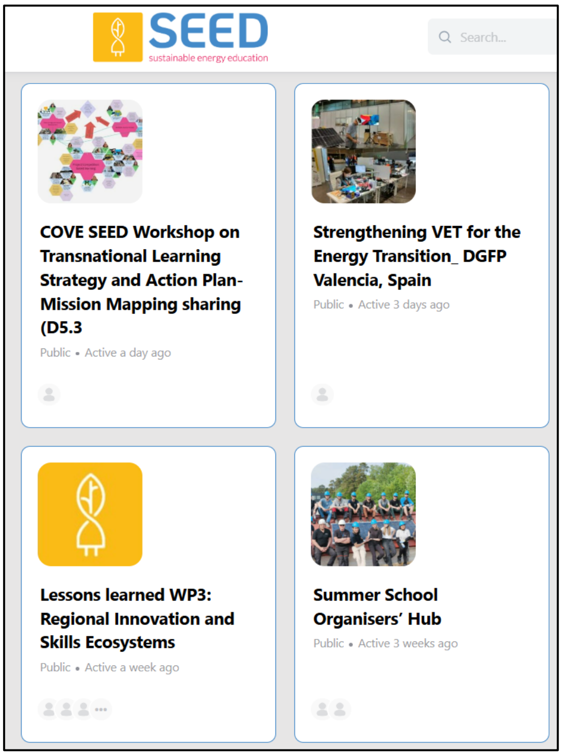
This paper outlines a low-cost, actionable, and replicable design and implementation process to create a self-sustaining and self-reinforcing community platform that addresses the constraints of limited budget and staff, typical of EU-funded projects.

Rationale and Complementors Strategy

Rationale: why a shared platform

Digital platforms and ecosystems can open new paths for internationalisation and scalable knowledge sharing (Nambisan et al., 2019). Each SEED partner operates within distinct regional green transition stages and contexts, making cross-regional knowledge sharing and transfer essential. The first-phase platform design focused on the structured sharing of SEED's internal experience (e.g., Lessons Learned: Regional Learning Strategy) to attract audiences beyond the consortium.

Figure 1. COVE SEED Knowledge Sharing Platform.



Source: https://platform.coveseed.eu/groups/.

Adding the complementor model

However, this initial approach yielded limited external visibility. Performance metrics indicated stagnant user acquisition and no measurable improvement in overall platform engagement (click rates). The platform's weak links to external channels were considered to be attributed to this limitation primarily, with potential audiences spending most time on mainstream social media (e.g., LinkedIn, Facebook).

Faced with resource constraints (limited budget for sustained SEO (Search Engine Optimisation) and labour limitations), the strategy pivoted from sharing SEED's internally generated content to applying the complementor model (External Contributors) to ensure continuous supply and community engagement. Research shows experienced complementors, as external knowledge sources, help trigger innovation and support ecosystem sustainability (Zhou & Inoue, 2025).

While continuing to curate the consortium´s internal content, external knowledge providers were invited. The first round focused strategically on SEED's local stakeholders due to their high relevance and lower communication effort required for their contribution. This targeted outreach involved identifying each stakeholder's industry influence, core interests, and level of involvement in SEED activities to tailor engagement accordingly (Friedman & Miles, 2006).

MVP Design and Implementation

MVP cycle and management

The management process of the platform development was based on the concept of Minimum Viable Product (MVP) cycle —build–measure–learn—so that results could be verified in a short period, allowing the team to learn with minimal effort and iterate quickly (Ries, 2011), which has its roots in the continuous improvement cycle (PDCA: Plan-Do-Check-Act) conceptualised by Shewhart (1939) and popularised by Deming (1986).

Submission template and motivation system

Drawing on previous project management experience, the MVP was designed by Universitat Politècnica de València (UPV) SEED team as a quarterly cycle that completes one operational loop of platform development and follows the four Plan–Do–Check–Act steps. Meanwhile, they also prepared a submission template to standardise the content and ensure easy and fast information transfer. It suggested that a post should include a title, the author´s organisation, a short overview, and main content. A strict format was not enforced in the first rounds to lower the barrier.

A motivation system was established. With the author's consent, SEED could promote high-quality content, such as good practices, through SEED's official social media accounts. Offline, high-quality case studies could also be promoted as premium content at events whenever possible to enhance personal and institutional visibility at the international level.

Evaluation framework

An evaluation framework was designed to measure outputs and guide the platform improvement. The results of the evaluation plan, including the indicators, were reviewed quarterly according to the platform performance. Box 1 shows the different qualitative and quantitative indicators that are retrieved and analysed.

Moreover, greater reusability can strengthen word-of-mouth and referrals, and thus overall visibility. To test "reuse" as a leading signal of stickiness and impact, a quick survey via Google Forms (for registered users) was designed. This low-cost measurement, which tests reusability as a proxy for long-term stickiness, will be introduced in the next MVP cycle once the content baseline is successfully established.

Indicators

Box 1. Quantitative indicators and qualitative indicators used in the SEED Knowledge Sharing Platform.

Quantitative indicators:

1. New users/organizations
2. Posts (internal/external) number
3. Page views (PV)
4. Average engaged time per user
5. Engaged sessions per user

*The indicator of the downloaded data was not included. Due to budget limits, file download numbers could not be tracked and were excluded from the current evaluation.

Qualitative indicators:

1. External (No SEED) feedback through the platform. (Questions/ inquiries, etc.)
2. Internal (SEED partner) feedback through internal communication (Survey, meetings, etc.)
3. Platform´s content management: Whether clearly irrelevant content appears; under limited staffing, assess the feasibility of basic AI pre-checks (e.g., keyword/structure/similarity screening)

Discussion and Transferability

Early external uptake and lessons learned

After the second three-month MVP cycle, the SEED knowledge sharing platform attracted some non-SEED users. For example, after the first MVP cycle, there were 9 posts on the platform, all from SEED core partners. During the second cycle, 3 of 4 new posts came from external local stakeholders, which suggested an early but still limited uptake beyond the consortium core partners. Other quantitative indicators, such as page views and user activity, showed only limited growth. Given the fixed budget and staffing, this outcome was within expectations. To address three main challenges—limited budget and personnel, fragmented digital channels, and low motivation to contribute content—the focus was shifted to activating existing resources and strengthening the link between online and offline activities. A primary lesson learned is that the involvement of external complementors should be prioritized earlier in the process, rather than focusing exclusively on internal content during the initial phase.

Content and channel improvements

- Content: the platform was deliberately designed to make "actionable and transferable" materials its core strength. Practice-oriented resources are expected to include a clear source, concrete steps, and stated limitations, so that different regions can quickly adapt them to local needs. To support this, only low-cost structural adjustments were implemented (for example, highlighting the visibility of key information), and there were no resources available to develop more complex functionality at this stage.

- Channel: the platform was used to reinforce online–offline collaboration: offline events, funded by existing budgets, continue to play the role of building trust and networks, while the online platform serves as a visible and reusable entry point that keeps people and knowledge connected before and after events, such as the SEED conference 2026.

Constraints and transferability

Publicly funded projects typically face short development periods constrained by project duration, small sample sizes, limited indicators and weak possibilities for identifying causal effects. In this context, the study relied on one-off snapshots and proxy indicators as early signals. Under these constraints, the paper focused on a simple, replicable framework that other teams can adapt and turn into shareable experience assets.

Conclusion

The SEED knowledge sharing platform development approach explained in this paper has three practical advantages: (1) it does not depend on sustained SEO spending, which public projects often cannot support; (2) it comes with few content limitations, lowering barriers for external participation; and (3) its evaluation is simple and portable, making cross-region comparison and reuse easier.

Within the real constraints of public projects, the SEED Sharing Platform's "lightweight approach" provides a pragmatic starting point: through small, rapid iterations of content and mechanisms, the platform is gradually built into a channel that connects people, knowledge, and collaboration opportunities, making this channel reusable and portable across regions and contexts—maximizing the impact of stakeholders' outputs across the sector, especially for teachers and trainers in renewable energy VET programmes, who can reuse each other's practice-based materials with low effort.

Acknowledgements

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Special thanks are extended to Dr Alberto Celani, from the ABC-Department of Architecture, Built Environment and Construction Engineering at Politecnico di Milano, Italy, for his professional mentorship and strategic advice on key aspects of sustainable energy and sectoral transition, as well as for his valuable feedback on the design of the SEED platform.

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Innovations often get stranded between concept and implementation, Living Labs serve as vital testing grounds where ideas are translated into real-world impact. At the Celcius House in Amersfoort, students, researchers, companies, and municipalities collaborate to shape the sustainable and healthy Neighbourhoods of tomorrow, directly within the context of those Neighbourhoods. These environments bridge education, research, and practice, enabling experimentation with complex societal challenges. This article shares insights into our methodology for Living Labs; how we organize, learn, and innovate together to turn ambition into lasting transformation.

Thinking Outside The Campus

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Introduction: Celcius House

On business park Hoefkwartier in Amersfoort, which is slowly being converted into a new mixed-use area, the Celcius House stands. This little building which from the outside looks like a simple wooden residential container, is in reality much more advanced.

The house was designed to compete at the international competition for sustainable building: the Solar Decathlon. It was built and designed by students in close collaboration with Dutch companies and serves as a model for circular and modular design and energy efficiency. That close collaboration with businesses and governments has led it to Amersfoort to serve as a University of Applied Sciences Utrecht Living Lab with a mission:

To help making this new Neighbourhood healthier and more sustainable by Problem-based-learning (PBL). In PBL students work together in multidisciplinary teams on complex, real-world issues originating from the needs of the Neighbourhood. These issues often require further definition in order to develop a desirable and viable solution. The role of the lecturer in this process is that of a facilitator.

For the past three years, students and researchers have been working on 28 projects. These issues range from collective energy storage, urban metabolism analysis or new ways to involve nature in area-development.

Because PBL was relatively new to our organization we kept asking ourselves: "*How can our projects align more closely with the Neighbourhood's demands to improve the learning effect for students and increase the impact of our projects for change?"*

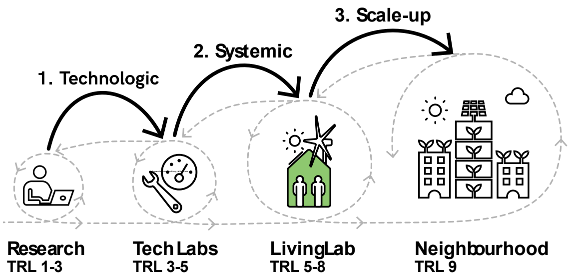
The Living lab as in-between step.

New ideas aren't easy to implement and to scale up for mass use. In our technical labs, we work every day to improve the technical feasibility of a product or to develop new components or products. This usually involves the isolation of technical aspects in order to achieve the necessary depth of understanding. This is where the difference lies between a technical lab and a living lab, such as the Celcius house.

This Living Lab is located in a real Neighbourhood, working on issues of the community and other stakeholders. Building on the studies of our researchers and innovations in the technical labs in order to scale up and leap to real Neighbourhoods.

If we try to implement these technical innovations in our Living Lab Neighbourhood, we face new systemic obstacles such as legislation, politics, financial products, cultural acceptance, or external safety. In order to develop a scalable solution the technical feasibility must be considered alongside its desirability and viability (financial and procedural). This significantly increases the degree of complexity but also the practical impact.

Figure 1. Research, Tech Lab, Living Lab, Neighbourhood.



Source: Zaaijer (2025).

This is precisely what we want for our students: to feel at home with complexity in innovation. This is where they could make a difference later in their lives, making an impact on a sustainable and healthy society.

The problem of momentum

We quickly discovered that planning a project can be frustrating. Businesses, governments, and education all have different timelines when it comes to innovation processes. In the context of education, the main challenge was breaking projects down into shorter subprojects matching the length of teaching blocks, 10 or 20 weeks. The slow start of a student project is another point of concern, as writing an action plan often took half of the project time, leaving our partners in the field wondering when the students will start working on the real issue.

We partially addressed this issue by providing students with the work of previous teams, eliminating the need to start from scratch every time. This also prevents Challenge- and Survey fatigue, whereby our stakeholders are repeatedly questioned.

Not a marathon, but a relay race

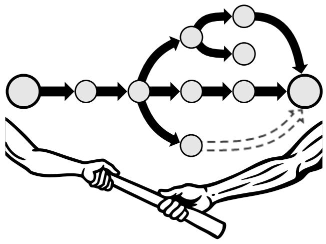
To give a project a flying start and provide clarity for clients and students, we teach students to decompose a problem and sub-problems into a project breakdown structure.

This method of problem decomposition we also incorporated into our own Lab approach,

Instead of working on a single problem in a large process, we treat innovation as a relay race in which multiple sub-issues branch out and connect seamlessly with each other.

Starting with a clear definition of the problem and the end goal, we work with our partners to identify the very first step needed to get closer to that goal and examine why it is not yet possible to take that step: This becomes our first project. In this way, we try to remove obstacle after obstacle, While keeping one eye on the end goal during the process.

Figure 2. Innovation Relay Race.



Source: Zaaijer (2025).

After finishing a project we ask every team to provide recommendations for the next two obstacles to focus on and a reformulation of the main issue. This allows for viewing the issue with renewed perspective and to adjust the trajectory towards the end goal. At the same time, it is a highly effective way for our partners to spread risks, monitor for any deviations from the goal and leaves the door open for incorporating innovations developed in the meantime.

By working on these relay projects, we often encounter barriers from other domains. Because of our own background, issues often starts out as technical, but often the call for a social innovation occurs quickly, but it can also be a policy- ecological- or economic detour, such as a circular revenue model. In that case the main route branches out in a parallel route.

Skills for change

We often see students working with us developing skills that we not typically see in our regular education system. When guiding students in the use of creative thinking techniques for their projects, we were able to see their abilities in Creative- and Critical thinking gradually evolving. Studies on the effect of learning creative skills indicates medium growth in fluency (generating many ideas) and large growth in flexibility (developing different perspectives), and originality (presenting unique ideas) (Dilekçi & Karatayon, 2023). Not only Creative and Critical thinking are fostered in PBL, recent study also sees students building resilience and learning to view failure as part of learning. (Rabello-Mestre et al., 2025)

PBL combined with creative thinking are, according to the World Economic Forum highly relevant for preparing students of a university of applied science for the future job market. Transferable, cognitive skills, such as Analytical Thinking, Creative Thinking, Resilience, Flexibility and Agility are the top skills for future jobs, making this type of education necessary for the future workforce.

Not-knowing is the new Knowing

Other skills we frequently observe and consider important are political sensitivity and dealing with uncertainty or ambiguity. In case of the latter we noticed that a large percentage of students freeze when confronted with uncertainty or ambiguity in a project. We see this especially when not all data is available, the question is unclear or being modified, or when there is no idea yet what the end product should be. All business-as-usual in innovative assignments, but not in education.

In the educational system, we are used to having teachers in the classroom knowing everything there is to know. For innovative problem-based projects the solutions are not yet known, and so a different approach is needed. Coaches must guide students with a mindset of not-knowing with confidence in the process based on their experience.

People who playfully dare to remain in a period of not-knowing and chaos are the ones who will come up with the winning solutions. (John Cleese, 2022)

Students have expressed that this very fundamental mindset of the coaches helps them feel to confident to proceed and even enjoy the journey towards a desired solution.

Next stop, the Future of Labs

In the past years we have started developing a working method that is suited to problem-based learning. We dive deeper into a project by working step-by-step on successive student projects like a relay race, focusing on removing the next barrier. In addition to deepening knowledge, broadening the perspective is also part of our approach. Using the potential of multidisciplinary work by actively looking when a project needs to branch out to other areas to take the next step towards a solution.

The next step for us will come when we fully embrace the notion that Living Labs can play a distinct systemic role in the so-called Valley of Death of innovation (TRL 5-8) and treat it as a vital addition to our Tech Labs.

A promising road to follow, isn't it?

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Conference on Sustainable Energy Education – SEED 2026
Utrecht, The Netherlands, 2026

The transition to a sustainable energy system demands not only technical innovation but also social engagement and collaborative governance. This paper presents a case study from Zoetermeer, a mid-sized city in the Netherlands, where the number of citizen-led energy initiatives grew from four to fourteen over four years. The municipality's approach centred on building trust, stimulating resident engagement, and incorporating real-world learning experiences for students. The findings highlight the importance of soft skills—such as communication, co-creation, and empathy—in sustainable energy education and professional development.

Trust As A Key Success Factor Of Bottom-Up Energy Transition; Lessons From Zoetermeer

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How to cite: Van Rooij, K. M. (2026). Trust As A Key Success Factor Of Bottom-Up Energy Transition; Lessons From Zoetermeer. In: Expert Articles. Proceedings of the Second International Conference on Sustainable Energy Education (SEED 2026). Utrecht, the Netherlands, 24-25 March 2026. DOI: https://doi.org/10.48544/694a4786-f91d-491b-95e1-55274787fdde.

Building trust is not a soft extra—it is the foundation of successful energy transitions. This expert article explores what students can learn from a bottom-up approach to co-create the local energy transition.

Introduction

The energy transition is accelerating across Europe, with the Netherlands committing to completely disconnect residential and commercial buildings from natural gas by 2050. In this context, municipalities have been appointed as the primary coordinators of local energy transition. However, a lack of trust, limited institutional capacity, and growing complexity pose significant barriers to implementation. This paper explores how a collaborative, resident-centred approach can stimulate trust and increase participation in local energy initiatives. The findings highlight the importance of soft skills—such as communication, co-creation, and empathy—in sustainable energy education and professional development.

Methodology

This case study draws on experiences in Zoetermeer from 2021 to 2025. Residents, municipal staff, students, and the local Energy Cooperation DEZo collaborated on neighbourhood pilots. Qualitative data was gathered from municipal reports, student research, and resident feedback. The approach emphasized iterative learning, participatory design and policy experimentation at the neighbourhood level.

Case Study: The 'Sweet Lake City' Experience

In 2021, all Dutch municipalities were required to submit a Local Heat Transition Vision outlining how they planned to phase out natural gas. Zoetermeer (literally translated 'Sweet Lake City') is a New Town; a compact city built largely during the 1960s–1980s housing expansion. It has many residents who bought a typical Dutch row house in the 1970s and are now retired. Even before the local heat-transition study was completed, these 'Passionate Pensionados' began asking questions: Should they invest in a new gas boiler? What would the alternatives cost? Who would bear the financial burden?

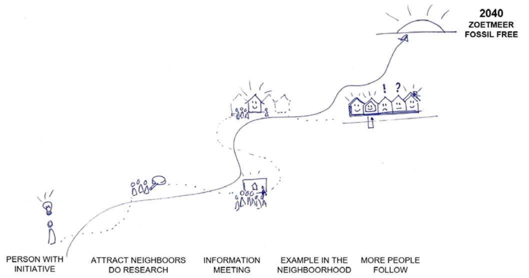
> "By listening you get information that may not *at first sight seem relative to sustainable* construction, but may be crucial for an enthusiastic response to the subject." Anke van Hal 'The Merger of Interest'

Initially, this citizen engagement was perceived as inconvenient. Municipal officials, still navigating internal uncertainties, were not accustomed to such early-stage involvement from residents. The traditional top-down model of municipal governance was no longer sufficient.

A Shift towards co-creation

Rather than postponing engagement until all answers were known, the municipality reversed its approach. The municipality followed the approach suggested by Anke van Hal in The Merger of Interest. Officials invited active residents to participate in exploratory sessions and openly acknowledged the limitations of existing knowledge and capacity. While the municipality could not provide ready-made solutions, it could facilitate local networks, connect stakeholders, and support bottom-up experimentation. This shift marked a transition from directive governance to facilitative co-creation, where residents were empowered to take initiative, and the municipality acted as a partner rather than a planner.

Figure 1. Local roadmap of neighbourhood initiative.



Source: Zoetermeer (2021)

Neighbourhood-Based Experiments

Pilot projects were initiated in several neighbourhoods, each with distinct demographic and housing profiles. In one case, a technically skilled homeowner mobilized fifty neighbours to explore collective heat pump adoption. This resulted in a successful bulk purchase and disconnection of thirty homes from the natural gas grid. In other neighbourhoods, engagement was more difficult, and enthusiasm varied depending on local trust, communication, and prior social cohesion.

After a year of experimentation, an internal evaluation was conducted, led by a university trainee. Key findings indicated that successful initiatives typically included a diverse team of three types of residents:

- Someone with technical expertise (often retired engineers or builders),
- Someone skilled in communication and event organization,
- Someone with financial or administrative knowledge

Development of the 'Joined Forces' Subsidy

Based on the early pilots, the municipality introduced a low-threshold funding mechanism: the '**Joined Forces' Subsidy**. The criteria were simple:

- Each initiative must have three coordinators (reflecting the identified skill set),
- The initiative must target at least twenty similar homes (e.g., in typology and construction year),
- Up to €5,000 could be granted for research, events, expert advice, and outreach materials.

Zoetermeer's uniform housing stock—predominantly terraced homes built in the 1970s—made it feasible to apply technical solutions across clusters of buildings. The local Energy Cooperation *DEZo* played a crucial intermediary role, helping new initiatives access support and mentoring less experienced residents through the process.

Involving Students in Real-World Learning

As the number of resident-led initiatives increased, so did the need for technical and organizational support. Luckily The Hague University of Applied Sciences, contacted the municipality. Could the municipality host a graduation student from engineering and sustainability program?

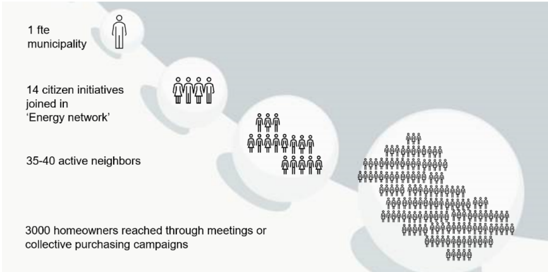
This student started his research; *"What approach can the municipality of Zoetermeer* *adopt to develop a step-by-step plan for the residents of the 1967 drive-in homes in the Palenstein neighbourhood, in order to help them make their homes more sustainable and/or raise their awareness of the energy transition?"* First he started with a lot of desk research. He hesitated to contact the residents. In the first interview with the home owners, he focused on the technical performance of the houses—measuring drafts, identifying moisture problems, and proposing insulation strategies. However, despite delivering detailed reports with recommendations, residents often failed to act. The technical language and complexity were barriers.

Through further engagement, the student realized that homeowners needed clear, digestible information and a step-by-step plan. His final graduation project translated complex renovation advice into practical guidance—a "starter roadmap" tailored to local homeowners. This shift from a purely technical approach to a communication-centred one reflects a broader insight into sustainable energy education: knowledge alone is not enough—empathy, trust, and clarity are essential.

Results and Key Insights

Between 2021 and 2025, the number of active resident-led initiatives in Zoetermeer increased from four to fourteen. With little capacity a snowball effect was created. The neighbourhood initiatives reached a bigger number of households then the municipality alone could have reached. Beyond the numbers, there are several key lessons; Trust is foundational: both interpersonal trust among residents and institutional trust in government enable collaborative action. Diversity drives success: initiatives with varied skill sets (technical, social, financial) were more resilient and effective. Simplicity matters: residents are more likely to act when information is accessible and steps are concrete. Education must evolve: student involvement in real-world projects supports both their development and community outcomes.

Figure 2. Snowball effect in Zoetermeer.



Source: Zoetermeer (2025).

Implications for Sustainable Energy Education

The case of Zoetermeer reveals the essential role of experiential learning, interdisciplinary collaboration, and soft skills in preparing the next generation of energy professionals. While technical expertise remains critical, sustainable energy transitions also require professionals who can:

- Build trust and facilitate dialogue,
- Understand community dynamics,
- Translate complex information into actionable insights.

By integrating these competencies into curricula—and by creating opportunities for students to engage with real communities—education providers can contribute meaningfully to a just and effective energy transition.

Conclusion

The energy transition is not only a technical challenge but a deeply social one. The experience of Zoetermeer demonstrates that when municipalities invest in trust-building, empower local actors, and connect education with practice, they can accelerate the shift toward sustainable energy. The lessons from this mid-sized Dutch city offer valuable insights for policy makers, educators, and energy professionals across Europe.

Acknowledgements

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Prof. dr. ir. Anke van Hal | Nyenrode Faculty

Immerzeel. H.C.M. (2024) Graduation thesis "Step-by-step plans for outdated low-rise homes in Zoetermeer "

Higher education faces the urgent challenge of training students who view sustainability as integral to their professional practice. This article presents the House for Sustainable Education - a practical framework with tools developed through participatory design research at HU University of Applied Sciences Utrecht. The framework enables systematic integration of sustainability across disciplines while honouring the contested nature of sustainability concepts.

A Practical Framework And Toolkit For Sustainable Higher Education

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Joris Gresnigt	Joris Gresnigt is an experienced teacher and researcher within the institute ICT of the Hogeschool Utrecht. For the past 12 years he has been intimately involved in the integration of sustainability within applied science education. Within the ICT bachelor, as a driving member of the project team behind the House for Sustainability and as a member of the HU program for the transition towards sustainable education..
Sam Krouwel	Sam Krouwel is working as teacher & researcher on the integration of sustainability within the technical programs of the Hogeschool Utrecht. For the past decade he has worked in various positions on interdisciplinary and/or sustainable education and currently teaches and advises within programs of the institutes of Life-science & Chemistry and Design & Engineering. As member of the HU program for the transition towards sustainable education he has provided critical review during development and application of the House for Sustainability tool.

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Introduction

Higher education institutions worldwide have committed to embedding the Sustainable Development Goals (SDGs) in their curricula, yet struggle with concrete implementation (Vereniging van Hogescholen, 2019). Reports show that while all Dutch universities of applied sciences address sustainability, integration remains slow (Leren voor Morgen, 2025). Teachers often lack competencies for systematically integrating sustainability principles, and existing curricula offer insufficient space for structural embedding (Wu & Shen, 2016).

This challenge is compounded by conceptual confusion. Sustainability encompasses diverse interpretations (Hopwood et al., 2005), ranging from biophysical and critical to integrative perspectives (Leichenko & O'Brien, 2019). Similarly, sustainable education manifests in different forms. Effective sustainability education requires integrating knowledge traditions that are knowledge-oriented, normative, and pluralistic (Öhman & Östman, 2020).

The transformation to sustainable education requires more than adding content about sustainability - it demands fundamental conversations about values, pedagogy, and the role of education in society.

This article describes the development and evaluation of a practical framework with tools for integrating sustainability in higher professional education. The framework was developed through a co-creative, iterative process across nine institutes with continuous participation from experts and teachers

Theoretical Framework

The concepts of sustainability, sustainable transition, and sustainable education are fundamentally contested in scientific and societal debates (Connelly, 2007). Block and Paredis (2019) emphasize that common misconceptions about transitions obscure the complexity and normative dimensions of sustainability challenges. This contested character requires acknowledging power dynamics, conflicts of interest, and ideological tensions (Avelino et al., 2016).

Within education, emphasis on transformative learning positions students as *change agents* (Warwick, 2016), requiring knowledge, competencies and 'inner' development across cognitive, affective, social, and societal domains (Macintyre, Tilbury & Wals, 2024). Given this diversity, strictly defined concepts are neither possible nor desirable, as interpretation depends on context and discipline (Block & Paredis, 2019). Yet teachers seek guidance and should not reinvent the wheel individually.

Methodology

The project employed design-based research (Aken & Andriessen, 2011) using the Dynamic Innovation Management in Educational Innovation (DIMO) model (Coppoolse, 2020). This model uses a cyclical, energy-driven approach maximizing user involvement through collective decision-making and self-regulating mechanisms. The DIMO model iterates between: 1) stimulating explorations, 2) agreement on visions, 3) dynamics in design practice, and 4) application in other contexts.

Approximately 400 teachers from nine institutes, 150 students, 15 sustainability experts, 30 management members, and 20 directors participated. The project team collected qualitative data during 28 meetings around different prototypes. Data was thematically analysed with inter-researcher and participant checks to validate interpretation (Aken & Andriessen, 2011). During sessions, various prototypes were tested, varying in scope, length, target groups, and interaction mechanisms.

Results

In developing the framework and associated tools, the project team went through three cycles in which both the content and form of the products were further developed based on input from the involved stakeholders, following the different phases of DIMO.

Cycle 1: Exploration

The project team consulted extensively with teachers and experts to create a rich knowledge base. This orientation revealed relevant existing concepts such as Van den Akker's (2003) curricular spider web, and the 'Whole School Approach' (Leren voor Morgen, 2024). Sustainability education experts expressed desire to define sustainable education transformatively: students as change agents in collaboration with others.

The framework contains no strictly demarcated definitions, yet the steering team requested embracing the SDGs. The integral character of the 17 goals based on five P's - people, planet, prosperity, peace, and partnership - offers space for context-specific interpretation. The first iteration was compiled as presentation slides, easily adaptable based on feedback.

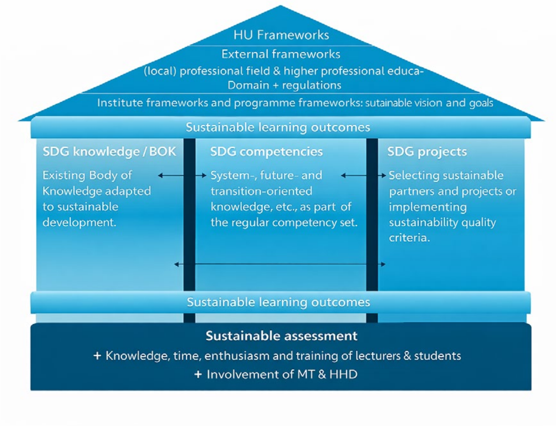


Figure 1: An early Dutch version of the framework.

Cycle 2: Testing Prototypes

This phase involved 28 meetings across nine institutes. Three products emerged: 1) a reflection canvas as conversation starter, 2) a serious game inviting deeper conversation about improvements, and 3) an evaluative questionnaire to monitor development.

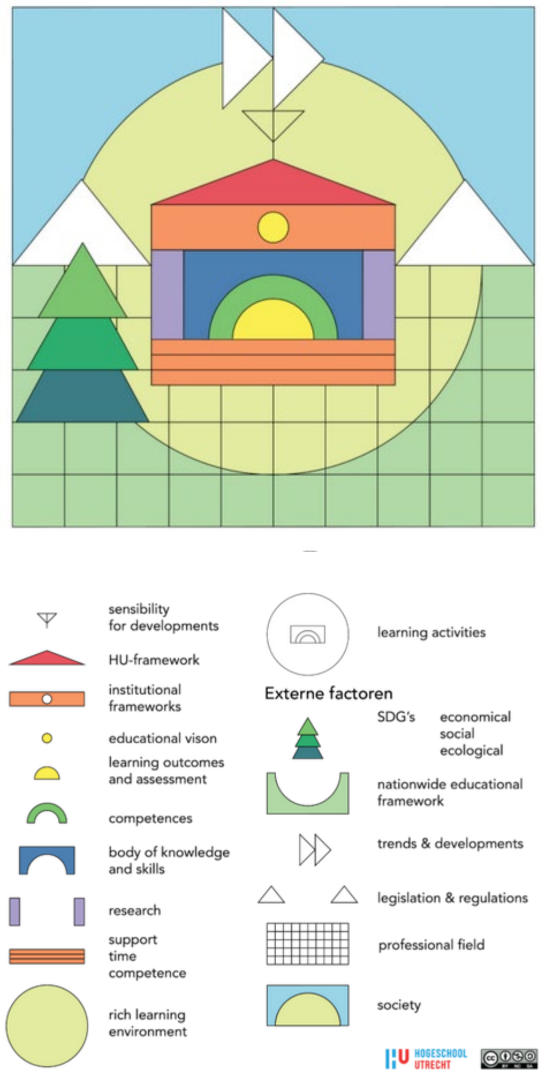
During testing, valuable feedback addressed both content and form. Content feedback included suggestions to make research explicit, replace 'projects' with 'rich learning environments,' adding question cards, examples per component, and add learning outcomes, activities, and assessment following constructive alignment (Biggs, 2003). The classic SDG overview was replaced with the "SDG wedding cake" (Stockholm Resilience Centre, 2016), better representing interconnections with ecology as foundation supporting society and economy. To use SDGs in a specific discipline, examples and questions cards about values and SDGs were added.

Visual design evolved from a traditional house metaphor toward more neutral representations accommodating all relevant environmental components and integrating development levels through colours and letters.

Cycle 3: Realignment

The concluding phase coincided with launching a new institution-wide change team, providing new dynamics. Expert consultation from a change management perspective raised critical questions about centrality of SDGs in the framework.

Figure 2: The final version of the framework.



Though deep adjustments were no longer possible, the SDG's were decentred both in the title and content of the framework. The name for example changed from SDG-house to *House for Sustainable Education*, de-emphasizing SDGs to create space for independent sustainability interpretation.

Discussion

The participatory approach, involving approximately 400 teachers, generated shared ownership and continuous refinement, which supported acceptance and usability of the final tools.

The process confirms that sustainability transition in education requires more than curricular adjustments: it calls for a broader rethinking of pedagogy, educational context organizational structures, and collaboration with the professional field. However, while conceptual ambiguity can create productive space for dialogue, limited time and organizational support foster a preference for quickly usable tools. Potentially foregoing the required dialogue for deeper transformative ambitions. Directive frameworks such as the SDGs may also shortcut essential conversations about meaning, while their number and abstraction still complicate immediate implementation. Even adoption of SDGs demands critical analysis and dialogue about applicability and implementation within specific educational contexts which the framework may facilitate, but does not ensure.

Implications

- Open frameworks with a structured participatory process can be effective to streamline conversation about integrating sustainability in education.
- Use contested concepts as a starting point for dialogue rather than as fixed endpoints.
- Treat SDGs as one possible scaffold; adapt emphasis based on local context and disciplinary values and norms.

Conclusion

Through participatory design across nine institutes, this project developed an integral framework and three complementary instruments that educators can select and adapt to their time and needs. The approach underscores the need to pair practical tools with value-laden conversations about sustainability and education's role. Future work should explore methods that foreground conceptual dialogue at the outset of change processes, support longitudinal tracking of change, and compare contexts across institutions, while centering student experience and development as change agents.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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The paper explores how Centres of Vocational Excellence (CoVEs) can achieve financial and operational sustainability beyond initial EU funding. Using the SECOVE project as a case study, it introduces a Hybrid Funding Matrix that integrates public, private, and commercial income streams. The model promotes a Hub-and-Spoke governance structure to share costly resources efficiently and strengthen collaboration. Ultimately, it argues that sustainable CoVEs must evolve into hybrid enterprises, blending education, innovation, and business to drive Europe's green and digital transitions.

Beyond The Grant: Designing Sustainable Business Models For Centres Of Vocational Excellence

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Introduction

The European Union's transition to a climate-neutral economy is currently obstructed by a severe *"Green Skills Gap"* (Cedefop, 2021) in the energy and construction sectors, which together account for 40% of the continent's energy consumption (European Commission, 2020b). While Centres of Vocational Excellence (CoVEs) have been established to bridge this divide, many face a critical *"Valley of Death"* where innovation ceases once initial public grant funding expires. To ensure long-term impact, VET institutions must transition from a passive *"public utility"* model to a *"hybrid enterprise"* model capable of generating diverse revenue streams. This article analyses the strategic planning of the SECOVE project (Sustainable Energy Centres of Vocational Excellence) to propose a replicable framework for governance and financial sustainability that ensures operational autonomy beyond the grant lifecycle.

The Strategic Imperative: Beyond the Grant

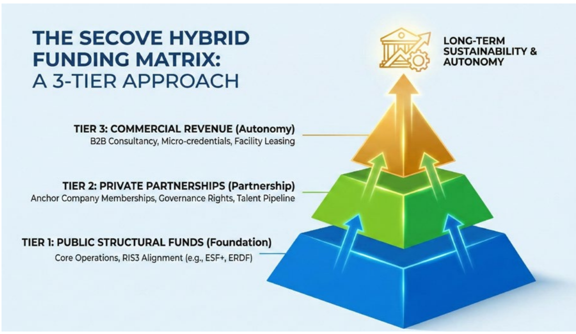
The European Green Deal has fundamentally altered the mandate of Vocational Education and Training (VET) (European Commission, 2019). No longer merely a supplier of labour, VET is now positioned as a driver of regional innovation through the European Skills Agenda (European Commission, 2020a). However, the structural fragility of these initiatives remains a critical barrier. As noted by the European Commission (2018), educational projects frequently suffer from a lack of financial continuity, leading to the fragmentation of knowledge and the obsolescence of infrastructure once EU co-financing concludes.

The SECOVE Strategic Development Plan (SECOVE, 2025), is a transnational initiative operating across Greece, Spain, Italy, Slovakia, and Portugal, that offers a blueprint for overcoming the gap. The project's central premise is that financial sustainability is not an accounting issue, but a governance issue. By analysing the specific economic geographies of these five regions, the project has developed a *"Hybrid Funding Matrix"* that layers public, private, and commercial revenue streams to create a resilient institutional model.

The Hybrid Fundix Matrix

To achieve operational autonomy, a CoVE must diversify its income sources. The SECOVE model proposes a three-tiered revenue architecture designed to withstand economic shocks.

Figure 1. Sustainable COVE Model: Hybrid Funding Governance.



Source: SECOVE Strategic Development Plan (2025).

Tier 1: Structural Alignment (The Public Foundation)

The first tier involves a strategic pivot from *"competitive"* funding *to "structural"* funding. Rather than relying solely on cyclica l

Erasmus+ grants, CoVEs must align their operational objectives with their region's Smart Specialization Strategy (RIS3) (McCann & Ortega-Argilés, 2015).

This alignment takes different forms depending on the regional economy. For example, in the coal-dependent regions of Greece, the SECOVE strategy aligns explicitly with *"Just Transition"* mechanisms (European Commission, 2020c). By positioning the VET centre as an essential vehicle for regional economic restructuring—*specifically for the reskilling of workers displaced by the lignite phase-out*—it unlocks access to long-term Structural Funds (ESF+, ERDF). This ensures that core operations are subsidized by the state not as education costs, but as regional development investments (Kogut-Jaworska & Ociepa-Kicińska, 2023).

"Financial sustainability is not an accounting issue, but a governance issue. By diversifying revenue and sharing resources, CoVEs can survive the 'Valley of Death' and become permanent anchors of innovation".

Tier 2: The *"Club Model"* (The Private Partnership)

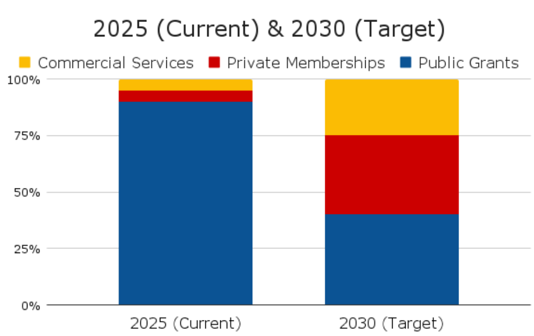
The second tier addresses the private sector's role. While industry partners frequently report skills mismatches, they are often disconnected from the financing of solutions. SECOVE introduces a *"Corporate Membership Scheme"* for Anchor Companies. In this model, firms pay an annual membership fee in exchange for tangible benefits: governance rights via the Local Stakeholder Board, priority access to the talent pipeline, and customized *"train-the-trainer"* programs (SECOVE, 2025).

This approach transforms companies from passive consumers of human capital into active shareholders of the VET ecosystem. As highlighted by the International Labour Organization (2019), such Public-Private Partnerships are most effective when industry contribution is formalized through financial commitment rather than just advisory consultation.

Tier 3: Commercial Diversification (The Market Engine)

The third and most critical tier for autonomy is the generation of unrestricted commercial income. The SECOVE strategy targets a 25% self-funding ratio by 2030 through service diversification. A key component here is the sale of Micro-credentials. As technology cycles shorten, mid-career professionals require rapid, modular upskilling rather than long-form degrees. By offering certified, short-term courses on specific technologies (e.g., Solar Energy Systems), CoVEs can tap into the lifelong learning market extremely important now days. Diversified revenue streams are a key predictor of institutional survival, allowing VET centres to maintain high-quality training standards even during periods of public budget contraction (OECD, 2023).

Figure 2. Projected Revenue Diversification for SECOVE Centres (2025 vs. 2030 Target).



Source: SECOVE Strategic Development Plan (2025).

Governance: The Hub-and-Spoke Architecture

Financial models are only as effective as the operational structures that deploy them. A single VET school typically lacks the scale to justify investment in the capital-intensive technologies required for Industry 4.0 training, such as smart grid testbeds or Building Information Modelling (BIM) labs.

Sharing Resources for Efficiency

To solve this *"thin market"* problem, SECOVE implements a *"Hub-and-Spoke"* architecture. This model concentrates high-cost assets into central *"Centres of Competence"* (Hubs). For instance, the project establishes a Digital Twin Hub in Sardinia. This facility houses expensive simulation software that creates virtual replicas of energy systems.

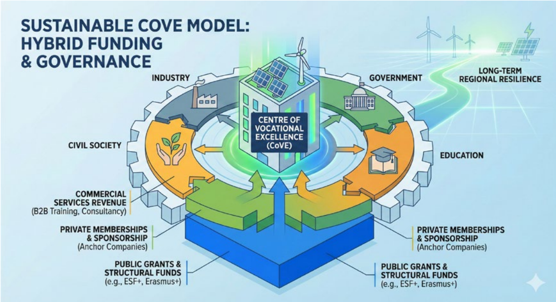
Instead of every school buying this software, local VET providers (Spokes) access the Hub remotely. Students can run simulations on the Digital Twin from their local classrooms, or attend intensive mobility weeks at the Hub. This centralization of expertise reduces the average cost per student while maximizing the utilization rate of expensive infrastructure (ESFRI, 2017). It effectively creates a *"shared service centre"* model for vocational training, where resources are pooled rather than duplicated.

"We must transform VET institutions from passive public utilities into dynamic hybrid enterprises, where industry partners evolve from consumers of talent into active shareholders of the skills ecosystem".

Institutionalizing the Quadruple Helix

Finally, the governance of these hubs is secured through the *"Quadruple Helix"* model (Roman et al., 2020). By establishing Local Stakeholder Boards (LSBs) with binding decision-making power, the project integrates Industry, Government, Education, and Civil Society into the core management structure. This inclusion of civil society is crucial for preventing *"mission drift"*. It ensures that while the CoVE pursues commercial revenue, it remains grounded in its social mission, reinvesting profits into inclusion programs such as the *#MindThe_GAP* initiative for gender balance in STEM.

Figure 3. Sustainable COVE Model: Hybrid Funding Governance.



Source: SECOVE Strategic Development Plan (2025).

Overcoming Implementation Barriers

The SECOVE Strategic Development Plan (SECOVE, 2025) identifies two primary risks: regulatory rigidity and cultural resistance.

First, national VET regulations in Southern Europe are often rigid, limiting the ability of public schools to retain commercial revenue. To mitigate this, SECOVE partners are establishing non-profit foundations or spin-off entities that act as the commercial interface for the public schools, allowing for legal invoicing of B2B services.

Second, there is often cultural resistance within the educational staff regarding *"privatization"*. The project addresses this through an internal incentive structure, where a portion of commercial revenue is allocated directly to departmental R&D budgets, demonstrating to teachers that commercial activity directly funds better equipment and research opportunities.

Conclusion

The transition to a net-zero economy requires VET systems that are as dynamic and resilient as the industries they serve. The analysis of the SECOVE project demonstrates that the *"Valley of Death"* is not an inevitability but a failure of design. By replacing grant-dependency with a Hybrid Funding Matrix and fragmented operations with networked Hub-and-Spoke governance, Centres of Vocational Excellence can transition from temporary projects to permanent, autonomous anchors of the European innovation landscape.

Acknowledgements

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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The global sustainability transition starts with the local introduction of innovative solutions. Living labs in regions have a crucial role to play in testing and applying these innovative solutions in the early stages of the transition. In Utrecht a remarkable Household Lab is developed. It will not only act as a lab to test energy innovations, but also as a learning environment for the professionals of the future.

Transformative Regions For Sustainability; The Utrecht Case

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Urgency

We can only start this story with the urgency of this moment. The Earth is in a bad state. The figures leave little doubt about that. Over the past decade, global greenhouse gas emissions have risen faster than ever recorded (IPCC, 2022) At the same time, biodiversity is declining at a rate not seen before in history (WWF, 2020). These are no isolated incidents, but coherent signals that the natural system we rely on is under severe pressure.

The only thing we can do is to have hope, it gives our lives meaning and orientation; only with hope can we get moving again. The philosopher Byung-Chul Han gives a striking description (Han, 2024):

"Hopeful thinking is not optimistic thinking. Unlike hope, optimism lacks negativity. It knows neither doubt nor despair. Its essence is sheer positivity. Optimism is convinced that things will take a turn for the good. Optimism requires no effort [...]. The existence of hope, by contrast, cannot be taken for granted. It awakens. Frequently, it must be called upon, appealed to".

Are there any hopeful seeds of change somewhere? Yes, of course! A lot of people, whether they are citizen groups, alternative groups, companies or governments, are experimenting with new sustainability solutions that the world of tomorrow needs.

Spaces: regions, campuses, labs

An important aspect of the global transition is the local introduction of innovative solutions. This means that cities and regions have a crucial role to play in testing and applying these innovative solutions in the early stages of the transition.

We argue that university campuses in these regions have a special role. A campus can be seen as a microcosm of the society at large. Everything is present there, but in a simplified form. There is often only one owner of the land. There are sometimes residents, but social life is often not richly developed. On the other hand, knowledge is abundant and a space for experimentation might be relatively easy to create.

Living labs are the places where it happens. Here, innovations are tested in real life, with considerable influence by the users or residents. The labs hold a promise: can the innovations be disseminated more widely, as a contribution to the global sustainability ambition?

The challenge in labs

Experiments with sustainability innovations are taking place in living labs all over the world, like seeds and saplings that blossom everywhere. From a transition perspective, however, all these experiments are only a hopeful seed, and not enough for the transition. In the initial phase of transitions, we are looking for innovations with transformative potential (Ghosh et al., 2021), i.e. innovations that have the potential to initiate a system change.

We think that at least two things are relevant here: the radicality of the innovation and the scalability of that innovation.

By the radicality of the innovation, we mean innovations that "stretch and transform" the existing system. This is in contrast to the so-called incremental innovations that are fitted into the existing system and conformed to It (Smith and Raven, 2012).

The scalability of the innovation is aimed at involving more people (scaling up), spreading the innovation to other places (scaling out) and embedding the innovations in the existing "rules of the game" (scaling deep). Researchers have shown how to increase the chances of scaling up by choosing the right conditions during the experiment. We make a distinction between internal project conditions and context conditions, since the way in which both groups can be improved often differs.

With regard to the internal project conditions, the *technical quality* of the innovation is likely to be essential for future diffusion. The *skills* of those involved also play an important role.

The context conditions are often better in one region than in another, so they are 'localized (van den Heiligenberg, 2022). There are seven of them, and it is more powerful when they are present in combination. It is about the presence of a local or regional *vision*, having a *learning environmen*t, the presence of an environment with a *counterculture* (a group which strives for radical alternatives), the dissemination of knowledge in local, regional and global *networks*, the presence of *local and regional governments*, the presence of *vibrant environments (*such as conferences and festivals), and finally the *culture* in society, such as cultural openness, trust and a shared sustainability ambition.

Case: Household lab

Utrecht University and Utrecht University of Applied Sciences are jointly developing a transdisciplinary Household Lab on the Utrecht campus that focuses on testing innovations in direct interaction with the residents.

We see the building and the household as a self-sufficient resilient micro-society, in which various functions can be tested on a small scale, in relative autonomy and somewhat protected from the outside world (e.g. energy generation, water collection, food production, micro-sharing and borrowing of goods,...).

Testing innovations in the daily life of a household is quite special. We see it as the missing link towards the implementation in regular neighbourhoods (Zaaijer, 2025). We start with three groups of radical innovations:

- Regenerative building innovations that deliver ecosystem services. Consider, for example, the local buffering, cleaning and use of rainwater.
- Technological innovations for construction and installation, including the provision of net congestion services. These can be solutions for the local generation, storage, use and smart feed-in of energy.
- Social innovations with the campus community around circular living: the sharing and borrowing of goods. We are interested in e.g. testing ownership issues.

The interaction between the innovations and the residents will be monitored with a variety of tools. We are planning to use a combination of qualitative and quantitative tools, such as questionnaires, logbooks, sensors, smart watches and tools to measure the actual use of the innovation.

Scalability of the innovations is of key importance. This is why we will involve the future customers of the innovations, such as citizens, area developers, municipalities and housing corporations. Furthermore, we will analyse and improve the project-internal and context conditions for scaling, if possible.

Skills needed

The living labs such as the Household lab are not only test locations for the innovations the world of tomorrow needs. They are also learning environments for the professionals of the future. We focus on two types of professionals. First, we need pioneers, who develop innovations and start experiments themselves, for example at companies but also at governments. Relevant skills are, for example, entrepreneurship, motivation, leadership and perseverance.

The second group of professionals we need are the transition intermediaries. The intermediaries do not themselves participate in a project where innovations are tested, but they do commission them or support them. They work for governments, universities of applied science, NGOs, regional development agencies, and so on. They build bridges between governments and societal partners, and play an important role in experiments and the diffusion of innovations. Intermediaries have a style of 'learning by doing', they act in uncertainty and they work adaptively, i.e. they plan there activities step by step. They need guts, and the ability to deal with barriers and pain.

The approach to transitions on the regional scale and the role of transition intermediaries in this will be further elaborated in a book that will be published in 2026 (van den Heiligenberg, in prep.).

Both groups of professionals do not have it easy. They both have to deal with resistance from the 'regime'. But we desperately need them for a better world.

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This article discusses the development of simulation models in the energy education of tomorrow, in order to gain deeper insight into the functioning of technical installations. The related research focuses on designing a method to simulate complex hydraulic systems and to incorporate these simulations into modern energy education in the form of "Serious Gaming." This study can also contribute to topics such as Digital Twins and gaining digital skills.

Hydraulic Modelling Tool for Education: Drag, Drop, F.l.o.w.

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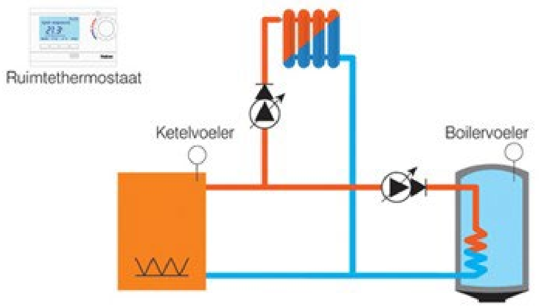
Introduction

In modern society, a substantial proportion of the total global energy demand is attributed to process installations. These installations range from climate control systems designed to ensure comfortable indoor environments to large-scale industrial process plants.

Figure 10 Example of a simple process diagram.



In professional practice, the design of such installations requires a thorough analysis of the functioning of these often highly complex systems by creating and studying so-called process flow diagrams, or Process and Instrumentation Diagrams (P&ID's). An example of a simple P&ID is depicted in figure 1. The central challenge is always: how can one assess whether a design will function as intended prior to the actual construction of the installation? In this context, a hydraulic installation tool could provide significant added value. According to the researcher, no existing tools for hydraulic installation systems sufficiently align with the skillset of bachelor students yet. The purpose of such a tool is to facilitate the design of installations that operate energy-efficiently and perform their intended functions precisely. Moreover, using the tool can be seen as form of serious gaming The main research question was formulated as follows:

What requirements must an educational and practical tool meet in order to provide designers of hydraulic systems with prior insight into the most critical performance characteristics?

SDGs

Education plays a crucial role in advancing the Sustainable Development Goals (SDGs). By introducing younger generations to sustainability at an early stage, the achievement of these goals becomes more feasible. In this regard, engaging the so-called "gamer generation" is essential. By approaching simulations as Serious Gaming, students develop skills such as critical thinking and creativity.

The early implementation of gaming tools in bachelor's-level education enables students to learn how to design efficient and energy-saving installations. This directly contributes to several SDGs, such as Affordable and Clean Energy and Responsible Consumption and Production, by reducing energy consumption and consequently lowering CO_2 emissions. The hydraulic tool can therefore serve both as a professional product and as a learning resource.

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Learning with Simulation Models

Society is experiencing not only the trend of sustainability, but also the trend of digitalization. In modern education, digital competencies are therefore indispensable. Working with simulation models resonates strongly with the learning styles of today's gamer/digital generation. By using a tool for designing sustainable hydraulic installations, younger generations can acquire the skills needed to design future-proof sustainable systems.

Requirements

As highlighted in the main research question, it is essential to define clear requirements for the tool.

Box 1. Tools Requirements.

1. The tool must operate in 2D.
2. The available elements must include at a minimum: a pump, a resistance represented as a two-way valve, and a three-way valve.
3. The system must support a drag-and-drop interface.
4. Users must be able to draw connections (lines) between elements.
5. The tool must implement a snap-to-grid functionality.

Throughout each phase of the project, lessons learned from mistakes have allowed new and improved requirements to be formulated. At the time of writing, the requirements are as stated in box 1.

Serious Gaming

Simulation can be understood as a form of Serious Gaming, in which learning takes place through playful exploration and experimentation within a realistic virtual environment. Rather than focusing solely on knowledge acquisition, simulation-based learning enables individuals and teams to develop insights by interacting with complex and dynamic systems. In this sense, simulating becomes a process of learning by doing and discovering — effectively a form of playful, game-like learning. In terms of design, user experience, and computational capabilities, the program should resemble Every Circuit (2025) and Hysopt (2025).

Target Group

With respect to the target group, the primary focus lies on future engineers trained at the bachelor's level. Nevertheless, the tool can also provide valuable learning opportunities for vocational (MBO) students. In summary: it is developed by and for bachelor students, while remaining highly beneficial for vocational students as well.

Additionally, many bachelor-trained engineers eventually progress into managerial roles, where critical decisions regarding sustainability are made. Further research into broadening the target group is therefore warranted, justifying a research question in this domain.

Parameters

The hydraulic tool relies on various parameters. Within the context of hydraulics, flow rates naturally play an important role. Flow rates in pipes and conduits result in pressure differences; conversely, pressures in conduits generate flow rates. Beyond fluid dynamics, energy transfer emerges as a key parameter. Temperature differences, in combination with flow rates, drive energy transfer.

The tool must be capable of handling these parameters in an integrated manner. A hydraulic situation can be regarded as a complex puzzle. The core consideration is the extent to which the tool itself should calculate all interdependencies (solving the puzzle) versus functioning primarily as a visual aid. One option is to place part of the computational task in the hands of the user. This issue will be further elaborated upon in the chapter Methodology.

Methodology and Findings

The development of the tool was carried out in collaboration with ICT students. In February 2024, the process began with the involvement of graduating student Jonathan Williams (see Table 1). Subsequently, from September 2024 to July 2025, two groups of approximately six students each engaged in the project.

Table 1. Project Development of the tool.

Team	Name	Process time
1	Graduate student	20 weeks
2	INNO 1 group	20 weeks
3	INNO 2 group	20 weeks

Jonathan designed and programmed a system that he called The "Moray Simulator" (see Figure 2). The focus of his assignment was to design and implement a hydraulic process scheme simulator that could replicate, as accurately as possible, the physical relationship between flow rate and pressure. This proved to be a challenging task, as it required the extensive application of quadratic equations.

A substantial part of his work was devoted to determining the so-called equivalent resistance of all series- and parallel-connected resistances. For this purpose, he applied the theoretical framework of LTSpice. The application was developed in Python. In addition to its functional performance, the simulator also featured a visually appealing interface. The project was highly successful, as reflected by the excellent evaluation of his graduation thesis.

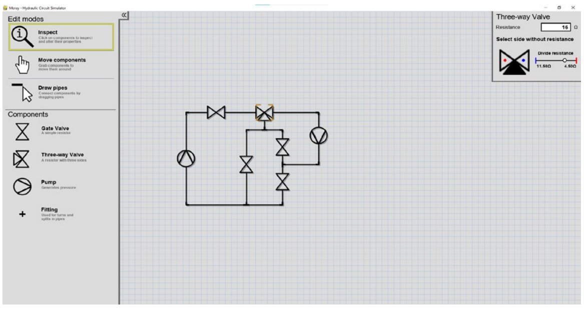


Figure 2: Layout of the Moraysimulator

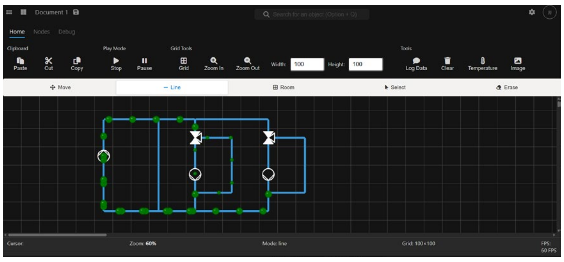
INNO 1 & 2

Following the graduation project, two groups of ICT students joined the initiative as part of the so-called Innovation Project of the HU ICT department. One of the main lessons learned from the graduation project was that the overall "puzzle" could be better approached from a graphical perspective. Consequently, the INNO project placed greater emphasis on graphical design, while the balance between pressures and flows was less central.

In this setup, the system itself was not required to find solutions autonomously. Instead, the user assumed the role of problem-solver and equilibrium-seeker. The primary purpose of the software was to provide visualization of hydraulic processes. When the visualizations were both accurate and aesthetically appealing, solving the puzzle of achieving pressure and temperature balances became an engaging and educational exercise.

In contrast to the work of the graduating student, this program was developed as a web-based application. This time, the programming language used was JavaScript.

Figure 3: The graphical result of INNO 2.



The ICT students placed strong emphasis on modularity, which made the simulator far easier to extend and adapt. For the results of this group, see Figure 3. The program can be tested via the GitHub environment of one of the students. The group also introduced the brand name F.L.O.W. (Fluid Lifecycle Operations Workflow).

Validation and Conclusion

The software developed by the graduate student as well as by the INNO group was validated. The initial findings of the model, tested with mechanical engineering students, yielded cautiously positive insights. At the same time, it became clear that the software is still in an early stage of development. Feedback volume increased rapidly. Among the key issues identified was robustness.

Future Outlook

Building on the lessons learned, it seems logical to further develop the program that operates at a even more global level. A future program would strongly and primarily focus on visualizing the flows, while leaving the task of finding equilibrium between these flows increasingly to the user/engineer. The engineer's attention would then be directed towards ensuring the validity of the continuity equations, which must consistently be satisfied.

In addition, the program must evolve into a stable and robust system. The decision to involve students in the tool's development has provided valuable insights and prototypes, Yet this also has the drawback that the software has, so far, remained at a rather immature stage of development.

Furthermore we must taken time to validation with stakeholders (students, teachers, industry).

A further step for the future would be to link simulation systems with real-life operational data. The visualized flows could then be derived directly from sensors, allowing engineers to compare whether a designed system behaves in reality as it was intended to in theory.

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