D6.9 Training Activities

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Table of Contents

List of Tables

List of Figures

List of Acronyms

Insert here all the acronyms appearing along the deliverable in alphabetical order.

Abbreviation / acronym	Description
CAD	3D Computer-Aided Design
CFD	Computational Fluid Dynamics
CI/CD	Continuous Integration / Continuous Delivery
HyTeG	Hybrid Tetrahedral Grids
HPC	High Performance Computing
IP	Internet Protocol
LBM	lattice Boltzmann method
MRT	Multiple-relaxation-time collision operators in the lattice Boltzmann method

MTW	Material Transport in Water
NCC	National competence centres
NGOs	Non-Governmental Organizations
PETSc	Portable, Extensible Toolkit for Scientific Computation, is an open-source software package for the parallel numerical solution of scientific applications
PU	Public
QCG	Quality of Computing is Guaranteed
RES	The Renewable Energy Sources
SRT	Single-relaxation-time collision operators in the lattice Boltzmann method
TRT	Two-relaxation-time collision operators in the lattice Boltzmann method
Tx.y	Task number y belonging to WP x
UAP	The Urban Air Project
UB	The Urban Building Model
US	Use Case
WF	Wildfires
WPx	Work Package number

Executive Summary

This report presents a comprehensive overview of the HiDALGO2 project's training activities and progress from months 17 to 30, marking a decisive shift from foundational planning toward active, applied delivery. Building upon the initial roadmap and training catalogue developed in the previous report D6.8 [1], the recent period emphasized hands-on, domain-specific training aligned with pilot use cases addressing global challenges such as wildfire management, urban air quality, building energy simulation, and material transport in water.

Key highlights include diverse training formats - ranging from workshops and hackathons to webinars and university courses - that effectively bridged the skills gap between HPC experts and domain scientists. Training content was strategically aligned with exascale computing requirements and leveraged collaboration with European National Competence Centres (NCCs) and the CASTIEL2 initiative, thereby reinforcing synergies within the broader European HPC ecosystem.

Significant training events, such as the International Hackathon on Fire-Atmosphere Modeling, CI/CD and Containerization Sprint, and urban wind comfort webinars, demonstrated HiDALGO2's commitment to delivering practical, multi-disciplinary learning experiences rooted in real-world applications. Participant feedback indicated strong engagement and appreciation for interactive, hands-on formats, though recommendations for improved documentation and extended modular training were noted.

The project's Moodle-based platform continued to evolve, expanding its offerings with advanced modules on wildfire risk management, containerization for HPC, and browser-based CFD visualization, supporting accessible, flexible, and on-demand learning. Collaborative training delivery enhanced impact and outreach, although gaps remain in advanced technical areas such as immersive visualization and PETSc scalability, with upcoming sessions planned to address these.

Overall, HiDALGO2's training program has successfully transitioned into a mature phase focused on operational integration, practical skill transfer, and fostering cross-domain collaborations. These efforts position the project to contribute significantly to the European HPC training landscape, promoting sustainability, resilience, and innovation across multiple domains.

1 Introduction

1.1 Purpose of the document

This document outlines the strategic direction and key objectives of the training initiatives within HiDALGO2. Its primary goal is to consolidate and disseminate knowledge, best practices, and resources relevant to applying High-Performance Computing (HPC) to address Global Challenges. In alignment with the overarching vision of HiDALGO2, the training programme is designed to bridge the identified skills gap, particularly by equipping stakeholders with practical expertise in the scaling, optimization, and integration of computational frameworks into real-world problem domains.

The document reports the achievements on the task for creating a comprehensive and evolving catalogue of state-of-the-art methodologies, tools, and frameworks across the project's core domains, with a specific focus on the new pilot areas introduced in HiDALGO2. These include:

- The Urban Air Project (UAP),
- The Urban Building Model (UB),
- The Renewable Energy Sources (RES),
- Wildfires (WF),
- Material Transport in Water (MTW).

To facilitate this effort, a dedicated working group was established in T6.3, composed of domain experts, HPC practitioners, and educators, to curate and expand upon existing training materials from HiDALGO and extend them toward Exascale readiness and novel application domains.

Training initiatives are targeted at a diverse set of user groups, including:

- **Starting users:** researchers and professionals new to HPC and AI, needing foundational training for effective engagement with advanced computing infrastructures.
- **Super-users:** experienced analysts and engineers who require deep dives into domain-specific workflows, performance tuning, and optimization techniques.
- **Policy makers:** Decision-makers who depend on computational insights for environmental regulation, urban planning, and sustainable development strategies.
- **NGOs and operational stakeholders:** end-users applying scientific modelling and data for on-the-ground decision support in areas such as wildfire response, air pollution monitoring, and water resource management.

In this way, HiDALGO2's training strategy supports its broader mission: to connect communities, empower end-users, and promote collaborative development by

fostering knowledge exchange between Global Challenges scientists and HPC experts. These efforts are directly aligned with REQ-TRA-001 [2] and ensure that all training activities are both practically relevant and technically robust.

The deliverable coincides with the achievement of all pilot use cases (for a more detailed pilot description, see D5.3 [3]) running successfully on internal resources, all main HiDALGO2 web services up and running, as well as the first steps of the pilot code and component integrations underway.

Therefore, specialized training sessions pertaining to flagship codes or associated tools should be delivered, facilitated either by experts within the HiDALGO2 team or through collaborative efforts with the Interest Groups. By incorporating these dual strategies, HiDALGO2 aims to offer comprehensive and tailored training experiences that not only address immediate needs but also contribute to the long-term proficiency and success of the participants.

1.2 Scope and context within HiDALGO2

This deliverable advances HiDALGO2's mission by transforming technical progress in areas like model coupling and Exascale readiness into practical, research-driven training. It builds on HiDALGO's efforts, expanding training content, fostering community engagement, and supporting long-term impact through collaboration with NCCs and CoEs. By aligning with both project goals and broader European HPC initiatives, it ensures sustained knowledge transfer and outreach.

1.3 Structure of the document

HiDALGO2's training services are described in the following chapters:

Chapter 1 frames the context of the document in the project, summarizes the objectives of this document and briefly describes its main contents.

Chapter 2 contains a progress overview since previous report.

Chapter 3 describes training activities delivered in the reporting period.

Chapter 4 describes actual training implementation in M17-30.

Chapter 5 summarises and concludes this deliverable while giving an outlook on future objectives and challenges by drafting a roadmap which includes specific goals, tasks, responsibilities, and deadlines. In addition, it contains the HiDALGO2 plan to evaluate our training activities.

2 Progress overview since previous report

Since the last reporting period, HiDALGO2's training activities have made a decisive transition from foundational planning to hands-on implementation. Building on the initial roadmap and training catalogue established in the first year, the focus during months 17–30 shifted toward delivering applied, domain-specific content tailored to the real-world needs of the pilot use cases. This period was marked by an expansion in training formats, strategic alignment with EuroHPC initiatives, and a targeted effort to bridge the skills gap between HPC experts and domain scientists addressing Global Challenges. The following subsections provide a detailed account of this evolution and the concrete steps taken to deepen impact across stakeholder communities.

2.1 Recap of the previous period training roadmap and catalogue

In first 30 months the HiDALGO2 project, the training activities were primarily focused on laying a solid foundation and defining a roadmap to address both domain-specific and cross-cutting competencies in HPC. This roadmap was structured across two major phases:

- **Quarters 1-2** prioritized foundational training through modules on:
  - High-Performance Data Analytics (HPDA): introductory content and hands-on data analysis techniques.
  - Artificial Intelligence (AI): core AI methodologies with applications in global challenges.
  - Visualization Techniques (VIS): basic visualization workflows and data preparation.
  - Data in HPC (DAT): introductory content on data management challenges in HPC.
- **Quarters 3-4** extended into domain-specific applications:
  - VIS and Uncertainty Quantification & Ensemble Methods (UQEM) tailored to pilot domains (UB, UAP, RES, WF).
  - Participation in scientific conferences and workshops for knowledge exchange.
  - Exploratory topics under the “Others” (OTH) umbrella for niche or emerging areas.

This roadmap was complemented by the creation of a training catalogue D6.8 [1], offering a baseline for future content development, aligned with the needs of the pilot domains and the evolving HPC landscape.

2.2 Transition from planning to delivery

M17-30 marked a clear shift from training planning to implementation and outreach. During this period (May 2024 onward), a variety of formats were deployed to engage stakeholders, including courses, workshops, hackathons, and community engagement at high-visibility events. While some activities occurred shortly before M17, they are included here due to their relevance in demonstrating the transition to active training and outreach:

- January 17-19 2024: The HiPEAC 2024 conference showcased HiDALGO2 through a dedicated show reel, significantly boosting visibility.
- March 19 2024: The EuroHPC Summit 2024 featured HiDALGO2's deployment strategy for flagship codes, emphasizing readiness for EuroHPC systems.
- March 28 2024: A lecture course on Building Energy Modeling and Scientific Visualization was delivered at the University of Strasbourg. It blended simulation theory, CAD-based model generation, and GPU-powered light transport simulation, demonstrating real-world HiDALGO2 applications.

These events highlighted the project's agility in transitioning from a roadmap phase to active training delivery, engaging both technical experts and domain scientists.

2.3 Alignment with exascale and pilot requirements

The M17-30 training content was significantly extended to align with the technical challenges of Exascale computing and the specific demands of HiDALGO2's pilot use cases. The emphasis was placed on:

- Advanced simulation workflows (e.g., light transport in visualization, building energy simulation).
- Integration of Exascale-ready tools like FabSim3, EasySurrogate, and QCG Pilot Job Manager, showcased through collaborative training events.
- Strategic alignment with partner NCCs (e.g., Germany, Spain, France) and CASTIEL2.

The Strasbourg lecture course (March 28, 2024), for instance, tackled the transition from building-level modelling to city-scale simulation, a requirement for scaling pilot activities toward Exascale platforms.

2.4 Addressing the skills gap

Throughout M17-30, the HiDALGO2 training program actively targeted the skills gap between HPC experts and scientists tackling Global Challenges, by:

- Fostering interdisciplinary training environments where technical HPC capabilities were taught in the context of real-world problem-solving (e.g., energy efficiency, air quality, fire-atmosphere modelling).
- Introducing user-friendly tools like mUQSA that lower the barrier for non-experts to perform UQ tasks efficiently on HPC systems.
    - By showcasing mUQSA's GUI, the event significantly lowered the technical threshold for UQ tasks among non-HPC experts.
- Promoting co-learning and mentorship models through hackathons, where participants received direct support from tool developers and advanced users.
    - During the International Hackathon on Fire-Atmosphere Modeling (December 2024, with NCC Spain) participants received direct support from tool developers and simulation experts, applying real-time models to emergency scenarios.
    - The CI/CD & Containerization Sprint (March 2025, with NCC Czechia under CASTIEL2) focused on practical skills for software packaging, benchmarking, and HPC workflow automation — essential competencies for reproducible scientific computing.

In doing so, the training strategy evolved from theory-driven capacity building to applied, context-specific knowledge transfer, better equipping stakeholders to integrate HPC into their workflows effectively.

3 Training activities delivered in the reporting period

This chapter reviews the HiDALGO2's training roadmap for M23-30 introduced in D6.8 [1], which aimed to outline the next objectives and necessary steps and addresses REQ-TRA-004 and REQ-HPII-016 [3].

Table 1. Planned HiDALGO2 training roadmap for M23-M30

Month	Training activities
M23-M30: Domain-Specific Training	**UAP application for the Urban Airflow and Air Quality modelling:** The participants will learn numerical algorithms for the simulation of the urban windfield and the air pollution, model reduction, and data assimilation to create a digital twin of the thermal processes of a solid body, • Implement the numerical algorithms in C/C++ and make their parallelization with OpenMP for CPU nodes and CUDA for NVIDIA GPUs. • Optimize the GPU-code, develop a visualizer based on OpenGL, compile and execute their codes on EuroHPC machines. • Learn and test advanced HPC codes of the HiDALGO2 for urban windfield computations and visualization, the REDSIM and CFDR. • Apply the digital twin for urban airflow and air quality computations under scientifically relevant conditions. • Apply a framework for urban airflow and air quality computations under industrially relevant conditions. **Advanced Techniques for UB:** Parametric models with reduced basis methods. Data assimilation and parameter estimation using ensemble methods. Mastering methods for determining the energy consumption of building equipment. Mastering methods and tools for designing and optimizing the building envelope. Dynamic Thermal Simulation • Compare different insulation solutions and estimate the risk of overheating a building in summer. • Observe the influence of the building's orientation on energy needs.

Month	Training activities
	• Evaluate the impact of external insulation on heating needs and summer comfort. • Compute heating needs to resize equipment. Dynamic Energy Simulation • Choose the heating mode (heat pump, gas boiler, etc.), • Compute air conditioning consumption, • Evaluate the impact of different types of ventilation on heating consumption, • Observe whether there is any consumption drift considering building occupancy and operation, • Estimate future building operation costs. Indoor Air Quality Meteorology and Data Processing Solar masks **Basic Features in RES:** Introduction to EULAG model. Setting up test cases, physical parameters, etc. Domain preparation for simulation. Damages prediction or windfarms/PV energy production: setting up the case. Global weather prediction input data: manual input, automatic coupling. RES execution using runner on local machines and HPC clusters. Post-processing of results with 3rd party tools. **Basic Features in MTW:** Learn fundamental principles of fluid dynamics. Understand the basics of Navier-Stokes equations. Familiarize yourself with lattice Boltzmann methods (LBM) and their advantages over traditional methods. Study the basics of particle simulation for sediment transport. Study the architecture and capabilities of waLBerla and HyTeG frameworks [14]. Learn to set up simulations using waLBerla for lattice Boltzmann method-based fluid dynamics. Gain proficiency in using HyTeG for heat simulation and species transport. **Organization of several hackathons**: HPC modelling in urban areas using OpenFOAM/fireFOAM and other similar CFD solutions.

Month	Training activities
	Hackathon on ensemble simulation in HPC for use in AI engines towards enhancing predictive capabilities and decision-making processes in urban planning, environmental management, and disaster response through the integration of advanced computational methods and AI techniques.

3.1 Summary of trainings delivered

Between M17 and 30 of the HiDALGO2 project, a significant portfolio of training activities was delivered, building on the foundational roadmap established in D6.8 [1]. These trainings targeted key technical competencies - ranging from atmospheric modelling and containerization to urban simulation and CI/CD workflows - and involved collaborative efforts with NCCs and CASTIEL2 partners.

The following major trainings were conducted:

- A hands-on workshop on Uncertainty Quantification, co-organized with SEAVEA and CIRCE, was held in June 5-7 2024. It introduced participants to advanced tools such as EasyVVUQ, MUSCLE3, and the mUQSA GUI for sensitivity analysis and surrogate modelling in multiscale HPC applications.
- The AGCA workshop focused on Global Challenges and sustainability, underlining HPC's interdisciplinary role in shaping a more resilient future (September 8-11 2024).
- International Hackathon on Fire-Atmosphere Modeling (December 2024, in collaboration with NCC Spain)
    - A hands-on event exploring simulation and operational modelling for wildfire emergency response.
- CI/CD and Containerization Sprint (March 24-26, 2025, with NCC Czechia under CASTIEL2)
    - A technically intensive course on HPC code packaging, benchmarking, and workflow automation.
- Urban Wind Comfort Webinar (May 26, 2025, with ENCCS and CASTIEL2)
    - A stakeholder-focused event using HiDALGO2's UAP solution for high-resolution simulations in Stockholm, Sweden.

In addition to these completed activities, two trainings are confirmed for delivery in October 2025:

- "Fire Damage, Reconstruction, and Urban Air Pollution" (October 2, 2025, with NCC France)

- "From Building to City Energy" (October 13, 2025, with NCC Czechia and the KAROLINA team)

3.2 Participation metrics

Quantitative Feedback Summary: Enjoyment & Productivity (rated out of 10), see Figure 1:

- Enjoyment Average: ~8.4
- Productivity Average: ~7.6

Participants generally enjoyed the training but were slightly less productive, suggesting room to optimize time or task clarity.

Majority rated hands-on exercises as "Adequate", but some indicated "Too few", see Figure 2.

What Participants Liked: High appreciation for interactive components, including:

- Developer availability
- Hands-on guidance
- Idea exchange opportunities

Recommendations for Future Trainings:

- Enhance Technical Materials Access: Create a centralized portal for slides, recordings, and instructions.
- Improve Documentation: Focus on improving the clarity of hands-on exercise guides.
- Extend or Modularize the Training: Consider breaking sessions into thematic tracks or offering longer sessions.
- Boost Interactivity: Include structured brainstorming/discussion breaks and Q&A rounds.

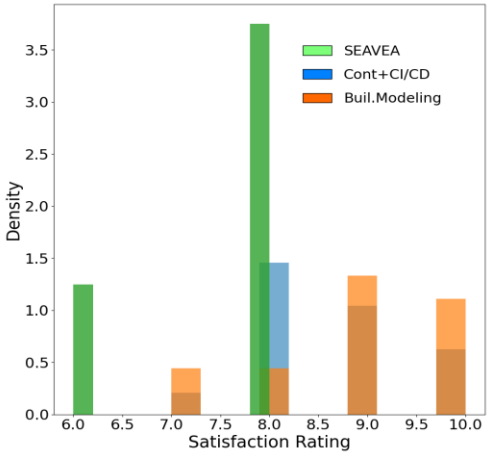

Figure 1. The overall satisfaction with the training courses as evaluated by the participants

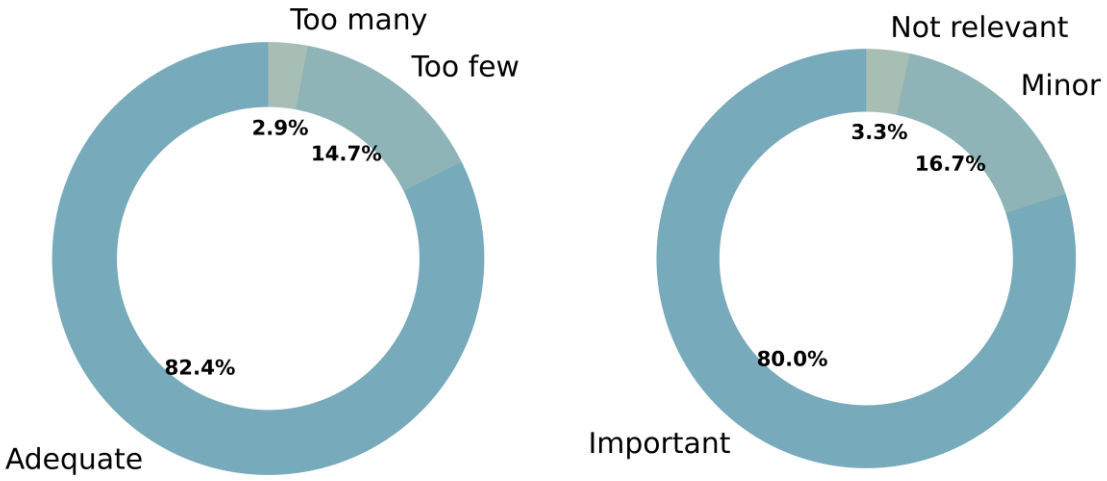

Figure 2. Pie chart distributions illustrating the perceived quality of the hands-on exercises (left), the rated importance of the delivered trainings (right).

Gender Distribution: Males participants: 74.1%, while female participants: 25.9%.

Professional Titles: A significant portion (~66.4%) of participants did not declare a professional title. Few participants held academic or professional titles such as Dr, Ph.D., or Dr.-Ing., indicating a mixed-level audience in terms of academic seniority.

Organizational Distribution: The events attracted attendees from a broad range of institutions, both academic and industrial. Repeated participation from certain universities suggests strong institutional interest and engagement, see Figure 3.

We might need to encourage participants to provide full professional details, which helps better tailor training content and track impact. High engagement from certain institutions suggests potential long-term partnerships or targeted support, Table 2. In addition, we should offer both introductory and advanced content to match mixed professional backgrounds.

Table 2. Fractional representation of organizational participation in HiDALGO2 training sessions.

Organization	Fractional representation of organizational participation
Meteogrid S.L.	7.8%
Brunel University London	6.9%
VSB - Technical University of Ostrava	6.0%
University of Stuttgart	6.0%
University of Strasbourg	4.3%

Organization	Fractional representation of organizational participation
Szechenyi Istvan University	2.6%
Poznan Supercomputing and Networking Center	2.6%
Barcelona Supercomputing Center	2.6%
EuroCC National Competence Center Sweden (ENCCS)	2.6%
Brno University of Technology	1.7%
University of National and World Economy	1.7%
IICT-BAS	1.7%
SJSU-WIRC (Wildfire Interdisciplinary Research Center)	1.7%
University of Coimbra	1.7%
EVIDEN	1.7%
Valencian Environmental Management (VAERSA)	1.7%
SICOS BW	1.7%
ACC Cyfronet AGH	1.7%
Other	43.1%

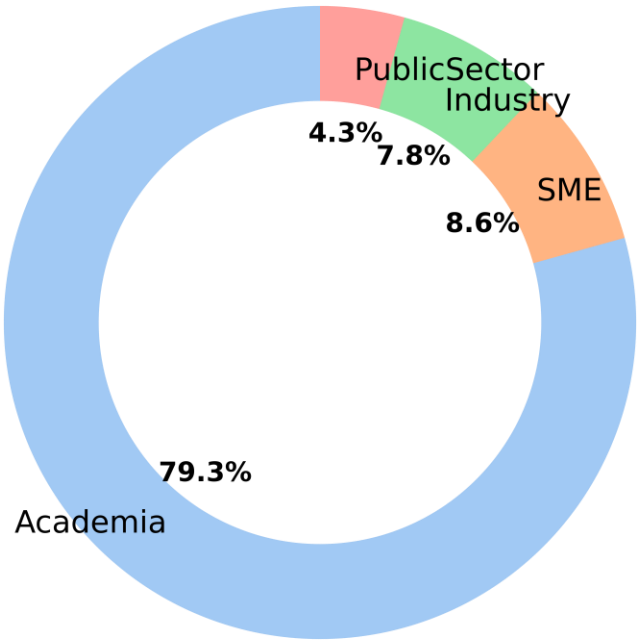

Figure 3. Distributions of participants by institutional sector.

3.3 Highlights from key events and collaborations

As part of HiDALGO2's commitment to capacity building and cross-sector collaboration, HiDALGO2 has organized and supported a series of targeted training events and hackathons across Europe. These activities, often in partnership with NCCs and CASTIEL2, aim to empower researchers, developers, and end-users with advanced skills in HPC, modelling, simulation, and data integration. Below is an overview of key recent and upcoming initiatives designed to foster innovation and operational excellence in urban building modelling, urban air quality, fire, and energy domains.

International Hackathon on Atmosphere and Fire-Atmosphere modelling using HPC (in collaboration with CESGA, NCC Spain). In December 2024, HiDALGO2 and CESGA, NCC Spain organized a three-day hackathon on atmospheric and wildfire simulation. Topics covered included LES-based smoke modelling, coupling of crown fire models, and integration of real-time data assimilation. Researchers, developers, and civil protection agencies worked alongside HPC experts to optimize codes and explore operational applications for emergency management.

The event was aimed at researchers, developers, and end-users of atmospheric modelling and wildfire simulation, at any stage of their professional or academic careers, as well as personnel involved in or interested in wildfire emergency management and preventive planning.

Containerization, CI/CD and Benchmarking Solutions for HPC (in collaboration with NCC Czechia and CASTIEL2). Conducted in March 2025, this sprint provided end-to-end training on containerizing scientific applications, automating deployment pipelines, and benchmarking on EuroHPC machines like KAROLINA. Attendees learned to apply tools like Docker, GitLab CI, reframe-hpc, and more in a hands-on environment - directly benefiting HiDALGO2's Urban Building Model pilot.

Through a mix of lectures and hands-on workshops, participants gained insights into managing HPC environments - integrating job schedulers, environment modules, and efficient data handling techniques - to optimise and maintain their own computational workflows.

This training aimed to equip you with practical skills for large-scale simulations.

High-resolution urban wind comfort computation for the entire Stockholm City - Use Case with SLB Analys. In May 2025, a collaborative webinar with ENCCS and CASTIEL2 and SLB-analys demonstrated UAP's high-resolution urban wind simulations for Stockholm. Compute wind speed at each point of the city under various weather conditions. Real-world use cases were presented, focusing on public safety, simulation scalability, and advanced web visualization tools capable of handling terabyte-scale output. The wind-comfort information, in particular when applied to

several planned building scenarios, can be used effectively by the city planners to optimize next constructions.

Student Workshop on AI and HPC Applications by HiDALGO2 and CASTIEL2. In May 26-30 2025, we brought together students involved in AI and HPC projects to exchange their experiences and generate new collaborations. During the workshop, students from the HiDALGO2 partners NTUA (National Technical University of Athens) and SZE (Széchenyi István University) presented the results of their AI projects in the field of healthcare, aerospace, HPC technologies, and transportation.

4 Training roadmap implementation

In M17-30, HiDALGO2 has advanced the delivery of its training roadmap through a structured blend of domain-specific sessions, hands-on workshops, and collaborative events with National Competence Centres (NCCs) and CASTIEL2. Building on planned priorities such as advanced modelling, workflow optimization, and cross-domain integration, the project has successfully delivered impactful training in key areas including wildfire simulation and urban air modelling. Collaborative formats - particularly with NCC Czechia, Sweden, and France - have amplified the reach and effectiveness of these sessions. While significant progress has been made, certain advanced technical components (e.g., immersive visualization and PETSc-based scalability) remain under development. The program's focus on real-world use cases, skill transfer, and multi-stakeholder engagement ensures that upcoming trainings continue to align with HiDALGO2's holistic simulation objectives and the broader European HPC training ecosystem.

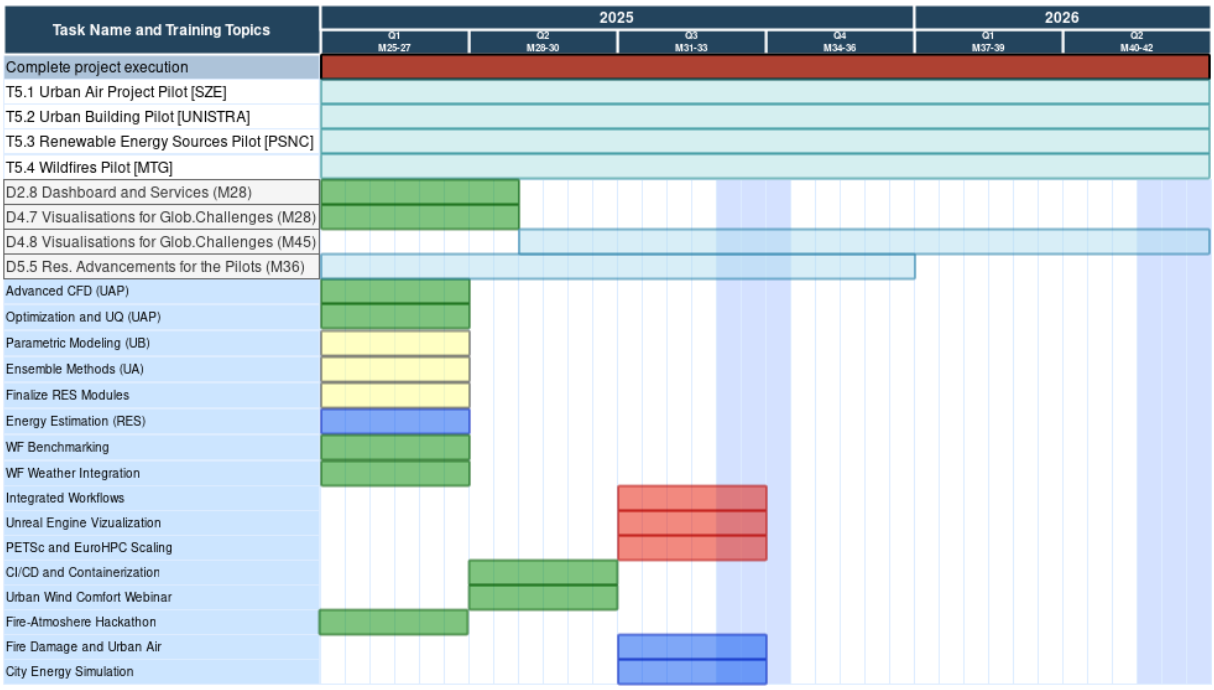

Figure 4. HiDALGO2 training roadmap: Planned vs. Delivered Activities (M17-30). (green bars) – activities that were fully delivered; (yellow) – partial delivery or progress made, but not complete; (red) – activities that were planned but not delivered; (blue) - upcoming/planned activities confirmed for later in M31-48.

4.1 Overview of planned and delivered activities

Planned Activities (M17-30 Roadmap) see D6.8 [1]:

Quarter 1-2: Advanced Techniques and Domain-Specific Training

- Urban Air Project (UAP):
  - Advanced CFD with turbulence modelling
  - Integration of optimization & uncertainty quantification
- Urban Building Model (UB):
  - Parametric modelling via Dymola (Modelica), Feel++
  - Ensemble methods for parameter estimation
- Renewable Energy Sources (RES):
  - Finalization of wind and solar modules
  - Integration of energy production estimation tools
- Wildfires (WF):
  - Benchmark fire-atmosphere interaction models
  - Incorporate real-world weather data

Quarter 3-4: Integration and Optimization

- Integrated workflows: UAP, UB, RES, WF combined simulations
- Advanced Visualization:
  - Use of Unreal Engine
  - VR-ready vector field representations
- Optimization and Scalability:
  - PETSc integration
  - Workflow optimization on EuroHPC
- Collaboration & Training:
  - Workshops, conferences, cross-domain sessions

Progress: The training program is well-aligned with the roadmap's core themes. Wildfire and UAP-related activities are strongly represented, with cross-organizational collaboration.

As shown in Table 3, the delivery of planned training activities has progressed unevenly across themes, with strong collaboration reported in NCC-related efforts, while some domain-specific modules were not covered.

Table 3. Planned vs. Delivered training activities in M17-30

Planned Training Activities	Delivered Status
Advanced modelling (UAP, WF)	Delivered via Hackathon and Urban Wind Comfort Webinar
Parametric modelling (UB)	Pending or partially addressed – No direct UB/Dymola training reported yet
Renewable energy modules (RES)	To be covered in October session (planned)
Workflow automation and containerization	Addressed in CI/CD "Training Sprint"
Integrated & immersive visualization	Not addressed explicitly yet (e.g., Unreal Engine/VR integration training missing)

Planned Training Activities	Delivered Status
PETSc optimization & EuroHPC readiness	Not reported as covered yet
Cross-domain simulation integration	Emerging (Fall 2025 trainings suggest a step toward this)
Collaboration with NCCs, CASTIEL2	Strong collaboration across all reported events
Scientific communication, community links	Participating in wider training ecosystem, e.g., stakeholder webinar and joint NCC events

4.2 Synergies with CASTIEL2, EuroCC2 and CoEs

HiDALGO2 has established meaningful collaborative activities with the European National Competence Centres (NCCs), under the umbrella of CASTIEL2 and EuroCC2, which is in-line with the REQ-TRA-001 [2]. Examples include:

- CI/CD and Containerization Sprint (March 2025): Delivered in collaboration with NCC Czechia under CASTIEL2, highlighting hands-on skill-building in modern software engineering for HPC.
- Urban Wind Comfort Webinar (May 2025): Co-delivered with ENCCS (EuroCC Sweden), bringing simulation outputs to external stakeholders and cities.
- Planned Trainings in October 2025:
  - One with NCC France focused on cross-domain impact: fire damage and pollution.
  - One with NCC Czechia (and the KAROLINA EuroHPC team) focused on urban energy systems.

These activities showcase joint content creation, shared delivery, and skill-transfer aligned with CASTIEL2/EuroCC2's goals of strengthening national and regional HPC expertise. In addition, these collaborations facilitate knowledge exchange and ensure alignment of training initiatives with broader European HPC goals. Such cooperation expands our reach across Europe, particularly to industry stakeholders.

While not explicitly stated, the overlap in domains (e.g., CFD, energy simulation, containerization, visualization) indicates indirect synergies with other CoEs, such as:

EXCELLERAT P2 (focused on Engineering and CFD), EoCoE (Energy), and ChEESE (Earth system modelling and natural hazards).

The Hackathon on Fire-Atmosphere Modeling and wildfire benchmarking aligns well with CoEs like ChEESE, which also address natural disasters. This implies that HiDALGO2 is positioned to build deeper CoE-to-CoE collaborations, especially in technical areas like optimization, uncertainty quantification, and code scalability.

4.3 Lessons learned and shortcomings observed

Collaborative delivery increases training impact. Joint events with NCCs (e.g., Czechia, France, Sweden) enhanced outreach, visibility, and quality of training sessions. CASTIEL2 collaborations enabled specialized trainings (e.g., CI/CD, urban simulation) that combined domain expertise and national HPC competence.

Use-Case-Driven trainings engage stakeholders more effectively. Trainings rooted to real use cases (e.g., UAP in Stockholm, wildfire response, urban energy) provided practical context and higher participant interest.

Smaller, focused trainings are effective. Events like the CI/CD training sprint and urban wind webinar showed that compact, hands-on sessions with a focused audience can be more effective than broader, general-purpose trainings.

Cross-disciplinary themes attract broader participation. Themes like sustainability, climate resilience, and urban planning cut across multiple domains and partner interests, helping bring in a wider set of stakeholders.

Shortcomings: Some planned M17-30 technical trainings (e.g., integration of Unreal Engine for immersive visualization, or full UAP-UB-RES-WF integrated workflows) have not yet been delivered. While NCC collaboration is strong, there's limited evidence of direct training co-design or co-delivery with other CoEs (e.g., EXCELLERAT [4], ChEESE [5], EoCoE [6]).

UB and WF received significant training focus, while RES, UAP and MWF domains appear underrepresented in the delivered activities to date. Some advanced technical areas (e.g., Dymola in UB [7], PETSc scaling [8], Unreal-based visualization) haven’t been explicitly addressed yet.

5 Training content development and platform integration

5.1 Evolution of Moodle-based material

The HiDALGO2 Moodle platform [9] continues to evolve as a central hub for delivering advanced, multidisciplinary training in high-performance computing, AI for societal challenges, and environmental risk analysis. As a robust and flexible open-source learning management system, Moodle remains instrumental in fulfilling REQ-TRA-003 [2] by supporting diverse learning needs across Europe and beyond.

Expansion of Core Training Themes

In addition to foundational topics - such as High-Performance Data Analytics (HPDA), Artificial Intelligence (AI), and Visualization Techniques (VIS) - the platform has expanded to accommodate emerging domains and cross-disciplinary challenges.

Newly Added Modules: Wildfire Risk Management

A key development is the integration of an extensive Wildfire Risk Management training series, designed to promote awareness, preparedness, and resilience in the face of escalating climate-driven wildfire threats. These modules adopt a holistic, citizen-inclusive, and data-driven approach:

- **Wildfire Risk Assessment:** Introduces methodologies to assess fire potential, incorporating vulnerability, impact, and socio-ecological dimensions, with a focus on WUI (Wildland-Urban Interface) areas and citizen science participation.
- **Wildfire Risk Reduction:** Focuses on actionable strategies to reduce ignition sources (especially human-caused), build community resilience, and improve stakeholder training, leveraging lessons learned from past events.
- **Wildfire Risk Adaptation:** Equips learners to develop future-oriented adaptation plans using fire regime scenarios, integrating climate change drivers and remote-sensing data for high-risk regions.
- **Natural Fire Ignition Modelling:** Presents a cutting-edge model for predicting lightning-induced wildfires using ECMWF's lightning parameterization and LiDAR-derived canopy metrics, aligned with satellite observation data.
- **Fuel Modelling & Propagation Potential:** Explores fuel type classification, parameterization via GEDI LiDAR, and dynamic wildfire propagation mapping, essential for real-time decision-making and risk mitigation.

Advanced Technical Modules. The Moodle platform includes in-depth technical content targeting software engineers, researchers, and students working in HPC and digital twin environments:

- **Introduction to Containers for HPC:** A comprehensive module covering Docker, Apptainer (Singularity), container registries, CI/CD pipelines, and containerized software deployment in HPC environments—essential for reproducible research and scalable applications.
- **Computational Fluid Dynamics (CFD) Visualization:** Introduces a browser-based CFD visualization tool using WebAssembly (WASM), SDL2, and OpenGL

ES 2.0. This tool enhances interactivity and accessibility of simulation results, providing learners with a near-real-time, immersive learning experience without the need for pre-processing.

Ongoing Access and Flexibility. To support diverse schedules and global participation, HiDALGO2 continues to offer its training content through on-demand online modules and live webinars. Moodle ensures seamless access to all course materials and facilitates interaction among learners and instructors.

The Dashboard further enhances user experience by integrating access to:

- HPC support services via the Zammad ticketing system
- Public project documentation via the HiDALGO2 Wiki [10][11]

Toward Operational Integration. Looking forward, one of the project's critical objectives is to operationalize simulation use cases across EuroHPC JU sites, such as LUMI in Finland. This effort, successfully piloted by SZE through the Urban Air Pollution (UAP) scenario, will soon scale to include all HiDALGO2 applications, extending the platform's practical impact across domains.

6 Roadmap and outlook

Building on the successful transition to active training delivery during M17-M30, the HiDALGO2 training strategy will enter its final phase with a focus on advanced techniques, integrated workflows, and cross-domain optimization. This phase spans M31-M48 and is structured into two thematic periods: M31-M38, which emphasizes deep technical skill-building and domain-specific advancements, and M39-M48, which targets integration, validation, and scalability across pilot use cases, see Table 4.

M31-M38: Advanced Techniques and Collaborative Skill Building

This period will focus on in-depth technical training that addresses the increasing complexity and specificity of each pilot domain. Key initiatives include:

- **Urban Air Project (UAP):** Training will cover advanced turbulence modelling, optimization techniques, and uncertainty quantification, supported by a technical focus on geometric multigrid methods.
- **Urban Building Model (UB):** Participants will explore advanced parametric modelling using Dymola (Modelica) and Feel++ [12], alongside ensemble methods for parameter estimation and data assimilation workflows.
- **Renewable Energy Sources (RES):** Training modules will enable users to build and run wind and PV models, generate energy production profiles using AI, and apply ensemble processing techniques for damage assessment.
- **Material Transport in Water (MTW):** Modules will explore advanced collision models in LBM (e.g., SRT, TRT, MRT), fluid-solid coupling with waLBerla [13], and matrix-free finite element simulations using HyTeG, with a strong emphasis on subsystem integration and communication routines.
- **Wildfires (WF):** A comprehensive program will be introduced for ensemble-based landscape sensitivity analysis. This includes the planning, execution, and analysis of large-scale ensemble simulations, along with the operational use of AI tools for identifying real-world analogies and generating burn and smoke probability maps. These efforts will culminate in immersive visual training using advanced 3D and VR environments for dynamic factor sensitivity analysis.

These specialized modules will serve dual purposes: (1) deepening technical capacity within each domain and (2) fostering collaboration and knowledge exchange through shared tools and methodological approaches.

M39-M48: Integration, Optimization, and Community Engagement

The final project period will shift focus toward integrated training and holistic simulation workflows. Training content will emphasize cross-pilot collaboration and the convergence of simulation strategies into unified, scalable models.

- **Integrated Simulations:** Participants will learn to combine components from UAP, UB, RES, WF, and MTW domains into joint simulation workflows, incorporating synthetic data and real-world parameters.
- **Advanced Visualization:** Training will feature the use of Unreal Engine for immersive, real-time 3D visualization. Specialized techniques such as vector field rendering in VR will enable more intuitive interpretations of simulation results.
- **Model Validation and Iterative Refinement:** Practical sessions will guide users through validation techniques using experimental datasets and existing benchmarks, enabling refinement of algorithms and assumptions.
- **Scalability and Performance Optimization:** Emphasis will be placed on preparing workflows for EuroHPC systems, with targeted optimization efforts using PETSc and other libraries to ensure efficient scaling across all domains.
- **Collaborative Development and Knowledge Sharing:** A continuous schedule of hackathons, workshops, and conference presentations will be maintained to reinforce skill acquisition and facilitate cross-disciplinary collaboration.

Table 4. Updated HiDALGO2 training roadmap for M31-M48 with respect to D6.8

Month	Training activities
M31-M38: Advanced Techniques and Collaboration	**Advanced CFD and Optimization for UAP:** Advanced turbulence modelling for turbulent airflow. Integration of optimization and uncertainty quantification techniques. Deep dive into geometric multigrid techniques. **Parametric Modelling and Data Assimilation in UB:** Advanced usage of Dymola (Modelica) and Feel++. Ensemble methods for parameter estimation. **Advanced Features in RES:** Wind/PV: using own models for wind and PV profiles Running and processing ensembles (using mUQSA) Energy production: creating own AI-based models RES-damages: creating own probability module **Advanced Features in MTW:** Explore advanced collision models in LBM (SRT, TRT, MRT). Understand the coupling between fluid and rigid body physics using waLBerla. Implement and optimize LBM simulations for river flow modelling. Deep dive into geometric multigrid techniques.

Month	Training activities
	Learn the theory behind matrix-free finite element simulations. Implement and optimize simulations using HyTeG for heat and species transport. Understand the importance of coupling between different simulation subsystems. Learn about communication routines provided by waLBerla and HyTeG frameworks. Implement coupling strategies for integrating fluid dynamics, heat transport, and species transport simulations. **Landscape Sensitivity Analysis to Wildfires**: Ensembles simulation and its use with AI engines. In these trainings multiple simulations are carried out with initial conditions varying in time and space to generate final maps of fire passage probability (burn probability) and smoke presence probability. Also, we are going to use our results with AI engines for similarity analysis with real fires. Training activities focus on the use of specific software for ensemble simulation generation and operational use of AI tool for search and analysis of pre-calculated simulations: – Planning and organization of multiple simulations. Input data, generation of fire origin points (random, systematic, known points, etc.), variability of atmospheric conditions (wind direction and speed, humidity, etc.). – HPC simulation of simulation ensembles. Parallelization organization. Storage and indexing of results. – Generation of burn probability and smoke probability maps. – Results interpretation. Data analysis using visualizers, data mining. – Advanced Visualization: Integration of results in immersive environments for exploration and visual analysis of the simulation ensemble, visual analysis of landscape sensitivity to dynamic factors (wind, humidity, origin, etc.).
M39-M48: Integration and Optimization	**Integrated Workflows:** Integration of UAP, UB, RES, WF and MTW for holistic simulations. Collaborative projects to address cross-cutting challenges.

Month	Training activities
	Apply the acquired knowledge to simulate material transport in water (MTW) scenarios. Incorporate synthetic data and real-world parameters into simulations. **Advanced Visualization Techniques:** Integration of Unreal Engine for immersive visualization. Utilizing vector fields for enhanced realism in VR environments. Validate simulation results against experimental data and existing models. Identify discrepancies and refine simulation models accordingly. Enhance control and prevention strategies based on insights gained from simulations. **Optimization and Scalability:** Scalable solutions using PETSc in UB and other modules. Optimization of algorithms and workflows for EuroHPC infrastructures. Optimize simulation parameters of the UAP, UB, RES, WF and MTW and performance for scalability on HPC systems. **Continued Collaboration and Skill Development:** Participation in scientific conferences and workshops. Collaboration sessions address specific challenges in each domain. Organization of the several hackathons.

6.1 Forward strategy for training portfolio

As HiDALGO2 enters its final project phase, the forward strategy for the training portfolio will focus on sustainability, extensibility, and alignment with European HPC priorities. Building on the momentum of past activities, the strategy is structured around the following key pillars:

1. **Consolidation of Training Resources.** Existing training materials, including lecture recordings, hands-on modules, and domain-specific workflows, will be curated into a structured and accessible HiDALGO2 Training Catalogue. This catalogue will serve as a persistent learning resource beyond the project

lifetime, enabling both self-paced learning and reuse by partner institutions, NCCs, and external stakeholders.

2. **Modular and Scalable Curriculum Design.** Future training content will adopt a modular architecture, allowing reuse across domains and varying levels of expertise. Modules will be designed for scalability: from introductory tutorials to expert-level workshops - and adaptable for both online and in-person delivery. This will ensure long-term relevance and facilitate integration into national and European training frameworks (e.g., EuroCC2, CASTIEL2).
3. **Targeted Training Tracks.** The portfolio will support the continuation and evolution of training tracks focused on core project domains:
    a. Urban environment modelling and air quality (UAP)
    b. Energy-efficient building simulation (UB)
    c. Renewable energy system modelling (RES)
    d. Wildfire and environmental risk prediction (WF)
    e. Material transport in water systems (MTW)

    Each track will emphasize HPC-readiness, Exascale preparation, and advanced simulation and visualization capabilities, ensuring alignment with HiDALGO2's scientific objectives.
4. **Cross-Domain Integration and Co-Learning.** Recognizing the growing complexity of global challenges, the training strategy will prioritize cross-domain co-learning opportunities, particularly in integrated workflows, visualization, and data-driven optimization. These joint activities will foster interdisciplinary collaboration and better reflect the real-world nature of HPC-driven problem-solving.
5. **Strengthening Community Engagement.** The project will continue to engage the broader HPC and scientific communities through:
    a. Co-organization of hackathons and thematic workshops.
    b. Collaboration with EuroHPC JU, NCCs, and HPC centres
    c. Participation in international conferences and open science events

    These activities aim to reinforce training impact, share best practices, and support the transfer of expertise to a wider audience.
6. **Sustainability.** A key objective for the final phase will be to ensure long-term sustainability of the training assets. This includes:
    a. Transitioning select materials to public platforms (e.g., GitHub, Zenodo)
    b. Embedding selected modules in academic or NCC training curricula
    c. Exploring partnerships for maintenance and dissemination post-project

Through this forward-looking strategy, HiDALGO2's training portfolio will evolve into a mature, reusable, and extensible knowledge base that supports both current and future stakeholders in HPC applications to address critical global challenges.

6.2 Upcoming collaborations and events

Upcoming Fall Trainings (Fire Damage, City Energy)

Looking ahead to October 2025, two trainings will expand on critical pilot challenges:

- “Fire Damage, Reconstruction, and Urban Air Pollution” (with NCC France) will explore cross-domain effects of urban fires.
- “From Building to City Energy” (with NCC Czechia) will address energy simulation scaling strategies across urban infrastructures using KAROLINA supercomputing resources.

7 Conclusions

Between M17 and M30, HiDALGO2 has successfully transitioned from planning to impactful delivery within its training program, advancing both technical depth and stakeholder engagement. Through a diverse portfolio of applied trainings, hackathons, and collaborative events - often co-delivered with NCCs and CASTIEL2 - the project has fostered knowledge transfer across key domains such as wildfire modelling, urban simulation, CI/CD and benchmarking workflows, and energy systems.

The integration of real-world pilot use cases into training formats has proven especially effective in engaging participants and demonstrating the value of HiDALGO2 technologies in addressing global challenges. Collaborative delivery, focused sessions, and cross-disciplinary themes have further enhanced the reach and quality of training efforts.

While notable progress has been achieved, the reporting period has also highlighted areas for growth. Few advanced technical topics remain under development, and some pilot domains have yet to receive balanced training attention. Nonetheless, the groundwork laid during this phase positions the project well for its final stage, which will emphasize integration, scalability, and sustainability.

Looking ahead, the advanced modules planned for M31–M48 will drive HiDALGO2 toward its goal of delivering a cohesive, cross-domain training ecosystem. With a strong foundation of collaborations, a forward-looking curriculum strategy, and an expanding catalogue of reusable learning assets, HiDALGO2 is poised to make lasting contributions to the European HPC training landscape and to empower communities tackling complex societal and environmental challenges.

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