D6.8 Training Activities

HiDALGO2
CENTRE OF EXCELLENCE

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Lead Participant	USTUTT	Lead Author	Maksym Deliyergiyev (USTUTT)
Contributors	All	Reviewers	Iván Zaldívar (ATOS)
			Javier Cladellas (UNISTRA)

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Document Information

List of Contributors	
Name	**Partner**
Maksym Deliyergiyev	USTUTT
Lucienne Dettki	USTUTT
Lorenzo Zanon	USTUTT
David Caballero	MTG
Michał Kulczewski	PSNC
Christophe Prud'homme	UNISTRA
Zoltán Horváth	SZE
Harald Koestler	FAU
Marcin Lawenda	PSNC

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Quality Manager	Harald Koestler (FAU)	29/04/2024
Project Coordinator	Marcin Lawenda (PSNC)	29/04/2024

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List of Acronyms

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

Abbreviation / acronym	Description
AI	Artificial Intelligence
API	Application Programming Interface
BEM	Building Energy Models
CAD	3D Computer-Aided Design
CI/CD	Continuous Integration / Continuous Delivery
CMS	Content Management System
DES	Dynamic Energy Simulation
Devops	Development Operations
DMS	Data Management System
DSO	Distribution System Operators
EC	European Commission
Flops	Floating point operations
FMI	The Functional Mock-up Interface standard
GIS	Geographic Information System
HyTeG	Hybrid Tetrahedral Grids
HPC	High Performance Computing
IDM	Identity Management
IFC	3D file format for the Industrial Foundation Classes

IP	Internet Protocol
LBM	lattice Boltzmann method
LOD	Level of Detail
MathSO	Web platform which is used to deploy and monitor HPC workflows through a web portal without the need of HPC knowledge
MRT	Multiple-relaxation-time collision operators in the lattice Boltzmann method
NCC	National competence centres
NGOs	Non-Governmental Organizations
PDE	Partial Differential Equation
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	Renewable Energy Sources
SPT	Sediments and Pollution Transport
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	Urban Air Project
UB	Urban Buildings
US	Use Case
WF	Wildfires
WFO	Workflow Orchestrator
WPx	Work Package number
WRF	Weather Research and Forecasting Model
WRF-SFIRE	A coupled atmosphere-wildfire model, which combines the WRF with a fire-spread model, implemented by the level-set method.

Executive Summary

The primary goal of the WP6 is to maximize the project's impact and facilitate effective communication and dissemination of its results and offerings. This involves raising awareness among scientific and societal stakeholders about the project's achievements through training courses. Additionally, a key focus is placed on ensuring the long-term sustainability of the project outcomes beyond its completion, aligning with the individual and joint exploitation plans of the partners.

The training initiatives within HiDALGO2 are designed to address and bridge competence gaps between High-Performance Computing (HPC) experts and scientists working on Global Challenges within the current offerings of our collaborating partners. HiDALGO2's primary objective is to address the skills gap and better support Global Challenges scientists in scaling and optimizing their codes for HPC environments. This approach involves a dual focus: firstly, the development of new training activities takes into consideration both the specific needs requested by our audience and the outcomes derived from comprehensive training assessments in the first phase of the HiDALGO2 project. The foundational training material developed within the framework of HiDALGO2 will undergo substantial expansion. This expansion will encompass a range of topics and resources aimed at providing comprehensive education and skill-building opportunities. Notably, the existing material hosted on Moodle [1] will serve as a cornerstone for this expansion, leveraging its structure and accessibility to accommodate the newly added content (for more details see D2.4 [2] and D2.7 [3]). Through this initiative, learners will have access to an enriched repository of resources designed to support their understanding and proficiency in relevant domains. This discerning approach ensures the integration of HiDALGO2-specific interdisciplinary facets into the established training activities conducted by consortium members, thereby enriching the learning experience.

The training program emerges as a strategic extension of the HiDALGO2 research outcomes, translating the identified challenges into actionable training modules. This approach not only addresses immediate needs within the HiDALGO2 framework but also sets the stage for continued growth and collaborative research endeavours in the future. Through the development of comprehensive training courses and a catalogue of state-of-the-art techniques and methodologies, we will empower both Global Challenges scientists and HPC experts to make meaningful contributions to addressing global issues.

1 Introduction

1.1 Purpose of the document

The purpose of this document is to define the strategic objectives and essential considerations guiding the training initiatives within HiDALGO2. As an integral component of our commitment to excellence, these training endeavours are meticulously designed to address competence gaps identified within the existing offerings of our partners. Furthermore, the document highlights the imperative for specialized training sessions, particularly those related to flagship codes or associated tools. These sessions are envisaged to be delivered by either HiDALGO2 experts or through collaborative efforts with Interest Groups - **REQ-TRA-001** [4], such as

- Starting users: users who are new to HPC environments and may require introductory training and guidance to effectively utilize computational resources for their research or projects. They are typically in the early stages of learning and may benefit from support in navigating HPC systems and tools.
  - Environmental scientists and researchers specializing in air quality and pollution, or in water quality and pollution;
  - Engineers and developers working on sensor networks and air quality monitoring systems;
  - Engineers and developers working on sensor networks and water quality monitoring systems;
  - Architects and urban designers focused on sustainable building design and construction;
  - Real estate developers and property managers interested in smart building technologies.
- Super-users: experienced individuals proficient in utilizing advanced computational techniques and HPC resources for complex analyses. They possess deep expertise in their respective fields and often contribute to the development and optimization of computational workflows and models.
  - Building engineers and energy consultants seeking to optimize building energy efficiency;
  - Energy researchers and analysts studying renewable energy technologies and policies;
  - Renewable energy developers and operators involved in solar, and wind projects.
- Policy makers: decision-makers and policymakers at governmental, organizational, or institutional levels responsible for shaping environmental policies and regulations. They rely on scientific research and data analysis, including air quality assessments, to inform policy development and implementation strategies aimed at addressing environmental challenges.
  - Urban planners and policymakers interested in improving air quality in cities;
  - Energy economists and policymakers exploring the transition to a sustainable energy future.
- Non-Governmental Organizations (NGOs): organizations dedicated to environmental advocacy, conservation, and activism. They may utilize HPC

resources to conduct research, data analysis, and modelling to support their advocacy efforts, influence policy decisions, and raise awareness about environmental issues such as air quality and pollution.

- Fire ecologists and environmental scientists studying wildfire behaviour and ecology;
- Fire-fighters and emergency responders involved in wildfire management and suppression;
- Remote sensing specialists and GIS analysts monitoring wildfire risk and impact.

This deliverable serves as a strategic roadmap, analysing the current scope for training activities within HiDALGO2. It defines the necessary steps for the generation of training courses and their corresponding curriculum. Moreover, the document identifies and creates a comprehensive catalogue that encapsulates the current state-of-the-art across domains, such as

- Urban Air Project (UAP),
- Urban Buildings (UB),
- Renewable Energy Sources (RES),
- Wildfires (WF),
- Sediments and Pollution Transport (SPT);

with a special emphasis on Global Challenges. Through this deliverable, HiDALGO2 seeks to lay the groundwork for a robust and impactful training program that aligns with our commitment to advancing knowledge and proficiency in relevant domains.

The deliverable coincides with the achievement of all pilot use cases (for a more detailed pilot description, see D5.3 [5]) 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. This collaborative approach ensures that participants benefit from a diverse range of perspectives and expertise, fostering an enriched educational environment. 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 Relation to other project work

This deliverable not only establishes the research lines to be pursued in each of the project's use cases but also encompasses a roadmap outlining the main results anticipated in the development of the WP5 activities.

The training task will collaborate closely with the technical work packages and the pilots to develop and refine training materials. By leveraging synergies with Task T6.4, which focuses on increasing visibility and participation in training activities, we aim to maximize the impact of our efforts. This collaboration ensures that the training initiatives are aligned with the project's objectives and cater to the specific needs of our audience. Through these concerted efforts, we seek to enhance communication, dissemination, and community building within the HiDALGO2 project while ensuring the long-term sustainability of our outcomes.

The focus and findings of the research activities outlined in "D5.3 Research Advancements for the Pilots" [5] will serve as a foundation for the development of a comprehensive training program for all HiDALGO2 domains. The research activities conducted in D5.3 likely explore modern techniques, methodologies, or technologies relevant to the HiDALGO2 project domains. The comprehensive training aims to leverage these research findings as a foundation. By designing the training initiative around the specific requirements and challenges identified within the HiDALGO2 use cases, the program can provide targeted education and skills development directly relevant to the project's objectives. Therefore, the training initiative will be designed to address specific requirements and challenges identified within the use cases, ensuring a direct and practical application of the research findings. Furthermore, it establishes critical connections with other work packages such as WP3 and WP4, where research outcomes are expected. Additionally, it emphasizes collaboration with the rest of WP6, incorporating tasks related to the publication of scientific papers and the establishment of scientific and technical collaborations with external entities and projects.

The training program will prioritize addressing challenges outlined in the use cases, with a particular emphasis on enhancing the efficiency and reliability of results, resolving complex phenomena, and identifying, developing, and integrating innovative solutions. The curriculum will draw directly from the insights and advancements gleaned during the research activity, providing participants with practical and up-to-date knowledge.

This deliverable includes a brief description of the initial infrastructure and services available to the HiDALGO2 project, including available hardware and software for pilots and web services. For a more detailed description of these services see "D2.4 Infrastructure Provisioning, Workflow Orchestration and Component Integration" [2] and "D2.7 HiDALGO Dashboard and Services" [3].

1.3 Structure of the document

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

Chapter 1 *Introduction*. It 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 brief description of each of the *HiDALGO2* pilot cases and their use cases - benchmarks of the different levels of designs and implementations. What codes are used and what codes will be used in preparation for specific training courses.

Chapter 3 describes the training categories.

Chapter 4 describes our collaboration efforts with CASTIEL 2, EuroCC 2 and other CoEs concerning training activities.

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 Training infrastructure and software stack

This section delves into the critical components of our training infrastructure, including pilot projects, software stack, management systems, and the requirements for effective training delivery.

2.1 HiDALGO2 pilots

HiDALGO2 considers the development of Use Cases in the following pilots:

Urban Air Project (UAP). The main objectives of the UAP are to create, operate, and provide computational solutions to city policymakers for planning and regulation, and to inform citizens about the state of air quality and wind comfort. The following research challenges must be addressed: considering new physics in the air quality simulation solution, improving current solvers, coupling the solution with wildfires (WF) and urban buildings (UB), and improving workflow orchestration.

Urban Buildings (UB). The primary objectives of the UB pilot are to estimate and describe the energy consumption in the building sector. Two research lines are considered in this pilot: 1) the generation of the city's geometry from GIS data, which will provide a watertight mesh that will be the basis for both building simulation and coupling with the UAP pilot; 2) the building description, for which different LOD (Level of Detail) have been identified: from a simplified bounding box description to the generation of a multi-zone model from an IFC file.

Renewable Energy Sources (RES). With the increasing number of renewable energy sources installations, such as photovoltaic and wind farms, it is important for Distribution System Operators (DSOs), but also for individuals, to understand the physical phenomena and maximise the outcome. In RES focus is given on understanding how weather conditions influence energy production and provide more detailed predictions of both. Three specific challenges are tackled: Energy production from the wind farms, Energy production from photovoltaic systems and damages prediction to the DSO infrastructure.

Wildfires (WF). WF pilot aims to extend forest fire simulation to two scales, the landscape scale and the wildland-urban interface scale, and to estimate their potential consequences. This dual approach involves a twofold commitment: firstly, the development of bespoke solutions tailored to enable superior, more efficient simulations in HPC environments. Secondly, a concerted effort to enhance the methods and procedures used in practical scenarios, with a special focus on operational perspectives.

Sediments and Pollution Transport (SPT). To address environmental risks posed by a river pollution with contaminants like microplastics and biochemical substances HiDALGO2 developed the advanced numerical simulations, which should provide deeper insights into pollution transport in rivers, aiding in the enhancement of control and prevention strategies. However, simulating river pollution transport is challenging due to the complex physics involved. This includes fluid simulation with a free surface to model river flow, particle simulation for sediment transport, and the coupling between fluid and particles. Additionally, pollution simulation involves partial differential equations, adding further complexity. Overcoming these Global Challenges is crucial for creating accurate models reflecting real-world scenarios.

Table 1: Data samples generated with the main HiDALGO2 algorithms

Pilot	Main Algorithms	Input Data	Output Data
UAP	– Computational Fluid Dynamics (CFD) for airflow simulation – Navier-Stokes equations for fluid flow formulation – Advection-diffusion equations for pollutant dispersion – Integration with WRF simulations for weather data – Integration with real-time sensors for digital twins – Integration of multiple solvers: UAP-openFOAM, RedSIM	– Boundary conditions from external weather databases, real-time sensor data.	Airflow simulation results, pollutant dispersion data
UB	Multi-zone models for building descriptions Reduced Basis Method for precise parametric models Data assimilation and parameter estimation using ensemble methods Monte Carlo algorithms for solar shading chart computation FMUs executed in co-simulation using Dymola (Modelica), fmpy (Python), fmi4cpp (C++) Geometry generation facilitated by Ktirio-city and GMSH, core components handled by Feel++	– GIS description of district/city to extract geometric and material information on the building envelope; – Climate data for the building models; – Building envelope information extracted from GIS descriptions, climate data, building standards; – IFC files (for the higher level of detail among building models); and Use/occupation scenarios, energy consumption and source (electric, gas, fuel)	– Heat flux and temperature on building surfaces; – Greenhouse gas emissions (especially CO2 and NOx) per building; – City geometrical discretization; and solar shading mask per building surface.
RES	Combines mesoscale and regional weather forecast models (WRF and EULAG) for wind flow modelling and solar energy forecasts	– Global Weather Forecast data for initial simulation time stamp;	Energy production estimation data

Pilot	Main Algorithms	Input Data	Output Data
	Utilizes RES.WIND and RES.SOLAR modules for wind and solar energy scenarios respectively RES.WIND_URBAN handles wind modelling over urban areas – RES.WIND_ENERGY and RES.SOLAR_ENERGY calculate energy production based on wind and solar data	–SRTM and EU-DEM repositories for terrain topography; –CORINE repository for land cover information; – Building information provided by cities or publicly available data for urban area.	
WF	Fire growth models integrate spatial information on fuel types, terrain factors, and evolving weather conditions Fire behaviour models predict fire spread rates, flame height, and intensity Two main groups of fire simulation models: raster analysis and vector analysis Raster analysis simulates fire expansion on a regularly spaced grid covering the landscape – Use cases identified: landscape level and urbanization level	– Boundary conditions, weather data, real-time sensor data; – Global Weather Forecast data for initial simulation time stamp; – Building information provided by cities or publicly available data for urban area.	– Vector data: wind, maximum spread and flame geometry. – Scalar data: temperature, pressure, smoke density, etc. fields. – Heat flux and temperature on building surfaces.
SPT	Hydrodynamics simulation will be performed with a highly parallel Lattice Boltzmann algorithm, as available within the waLBerla framework, using a submodule named Mesa-PD. – Heat simulation and species transport with the multigrid finite element solver HyTeG. – Coupling between the subsystems will be achieved using the communication routines provided by the frameworks.	– Mostly rely on synthetical data, as is typical for such direct numerical simulations. – Physical and geometric parameters are available from precursor projects and the literature.	– River flow data, including the sediment. – River pollution transport data.

This summary provides a concise overview of all main algorithms, and the use case scenarios they address in all pilots. More technical details, one may find in the "D5.3 Research Advancements for the Pilots" [5] .

2.2 Training software stack

In this section we provide a more detailed description of each of the HiDALGO2 software packages, which can be an object of the training courses in Y2 to Y4.

OpenFOAM, which stands for Open Source Field Operation and Manipulation [6], is an open-source computational fluid dynamics (CFD) software package, which provides a comprehensive suite of tools for the simulation of complex fluid flow and heat transfer phenomena. Developed in C++, *OpenFOAM* allows users to conduct simulations across a wide range of applications, including aerodynamics, heat transfer, chemical reactions, and more. With its modular and extensible architecture, *OpenFOAM* empowers users to customize and extend functionalities to suit specific simulation requirements. Notice that several EuroHPC JU projects use OpenFOAM for different applications, for examples, see Solid Earth science applications by ChEESE CoE [7], a customized solver for the heat equation to define the temperature distributions in solid bodies for user-defined heat fluxes developed by EXCELLERAT CoE [8]. While for the HiDALGO2 this software package is a key framework for UAP and WF.

Fluid-Solver/RedSIM is a fully SZE-developed code which solves the compressible Navier-Stokes and the compressible Euler equations [9]. RedSIM is genuinely designed and implemented for GPUs and from the same source code it supports multi-GPU and MPI+Pthread GPU platforms. This software package is a key framework for UAP.

Dakota is a powerful open-source software package developed by Sandia National Laboratories [10]. It serves as a framework for optimization, uncertainty quantification, and sensitivity analysis of complex computational models. *Dakota* facilitates the exploration of design spaces, the assessment of parameter uncertainties, and the optimization of systems across various scientific and engineering disciplines. Its modular design allows users to seamlessly integrate *Dakota* with their existing simulation codes, making it a versatile tool for researchers and engineers seeking to enhance the robustness and efficiency of their computational models. This package is widely used in the fields of computational science, engineering, and applied mathematics. Researchers, scientists, and engineers working on simulations and modelling in diverse areas, including aerospace, energy systems, materials science, and environmental studies, find *Dakota* valuable. It is especially beneficial for those dealing with complex simulations and seeking to perform optimization, uncertainty quantification, and sensitivity analysis to gain insights into the behaviour of their systems or designs. *Dakota's* versatility makes it a go-to tool for users aiming to improve the reliability and performance of computational models in various applications.

Feel++ is an open-source finite element library designed for solving partial differential equations (PDEs) [11]. It provides a comprehensive set of tools and functionalities for numerical simulations, encompassing a wide range of applications in computational science and engineering. *Feel++* is particularly focused on high-performance computing, making it well-suited for simulations involving complex geometries, multi-physics, and large-scale problems. Its modular and extensible architecture allows users to efficiently implement and customize numerical algorithms for diverse PDE problems. *Feel*++ is employed by researchers, scientists, and engineers working in the fields of computational physics, applied mathematics, and engineering. Its versatility makes it suitable for users involved in the simulation and analysis of various physical phenomena, including fluid dynamics, structural mechanics, heat transfer, and more. The library is well-adapted to high-performance computing environments, attracting users in academia and industry who require robust and scalable numerical solutions for their complex simulation problems. *Feel*++ is especially beneficial for those seeking a flexible and efficient framework for solving PDEs across diverse scientific and engineering applications. This software package is a key framework for UB.

Dymola (Modelica language) is a commercial modelling and simulation software tool that supports the Modelica language [12]. Developed by Dassault Systèmes, *Dymola* is widely used for modelling and simulating complex multi-domain systems. It enables engineers and researchers to create models of physical systems, including mechanical, electrical, thermal, and control components, using the object-oriented modelling language Modelica. *Dymola* excels in system-level simulation, offering a versatile platform for the design, analysis, and optimization of dynamic systems. *Dymola* is utilized by engineers, researchers, and practitioners involved in the design and analysis of dynamic systems across various industries. It finds applications in automotive engineering, aerospace, energy systems, mechatronics, and other fields where complex multi-domain systems need to be modelled and simulated. Users in these domains leverage *Dymola* for system-level simulations, optimization, and virtual prototyping, making it a valuable tool for those working on the development and improvement of dynamic systems and control strategies. This software package is a key framework for UB.

fmpy is a Python package that facilitates working with Functional Mock-up Units (FMUs) in Python environments. FMUs are standardized models used for co-simulation and model exchange in various simulation tools. *fmpy* simplifies the integration and interaction with FMUs, enabling users to import, simulate, and analyse models seamlessly within Python environments. It supports both Model Exchange and co-Simulation FMUs, making it a versatile tool for researchers, engineers, and developers working with model-based simulations. *fmpy* is employed by a diverse user base, including researchers, engineers, and developers working in the fields of systems modelling, simulation, and control. It is particularly useful for those who use Python as their primary scripting language and need to interact with FMUs for co-simulation or model exchange. Users in industries such as automotive, aerospace, energy, and control systems find *fmpy* valuable for integrating and simulating FMUs within their Python-based workflows. The package caters to individuals and teams seeking a streamlined and Pythonic approach to working with FMUs in various simulation and modelling scenarios. This software package is a key framework for UB.

Salome is an open-source platform designed for pre-processing, post-processing, and meshing in numerical simulations [13]. It offers a comprehensive suite of tools for creating and manipulating geometrical models, generating meshes, and preparing input data for various simulation codes. *Salome* provides a unified environment that supports different simulation software and facilitates the integration of diverse engineering and scientific disciplines. Developed by the open-source community, *Salome* is highly extensible and customizable to meet the specific needs of users in simulation and modelling. *Salome* caters to a diverse user base including engineers, researchers, and scientists involved in numerical simulations across different industries. It is commonly used in fields such as aerospace, automotive, nuclear engineering, and other domains where complex simulations require robust pre-processing and meshing capabilities. *Salome* is particularly valuable for users who need a versatile and open-source platform that supports interoperability with various simulation codes. Its user-friendly interface and extensive functionality make it suitable for both beginners and experienced professionals engaged in simulation and analysis tasks.

GMSH is an open-source finite element mesh generator with a focus on simplicity and efficiency [14]. It allows users to create, manipulate, and refine 3D computational meshes for numerical simulations in various scientific and engineering applications. *GMSH* supports a range of mesh formats and provides a scripting language for advanced customization. Due to its lightweight design and versatility, *GMSH* is widely used for both academic and industrial purposes, offering users a powerful tool for mesh generation in the context of finite element simulations. *GMSH* is utilized by researchers, engineers, and scientists across diverse fields where finite element simulations are conducted. It finds applications in areas such as structural mechanics, fluid dynamics, electromagnetics, and acoustics. *GMSH* is particularly favoured in academic settings for teaching and research, as well as in industrial environments for preparing meshes for simulation codes. Its user-friendly interface and scripting capabilities make it suitable for users ranging from beginners to experienced simulation experts who require efficient and customizable mesh generation for their numerical simulations.

FMI standard - the Functional Mock-up Interface (FMI) standard is not a standalone package but rather a standardized interface for model exchange and co-simulation of dynamic system models. *FMI* enables the exchange of models between different simulation tools, allowing seamless interoperability. It defines a set of conventions and APIs for model description, simulation control, and result retrieval, fostering compatibility among diverse simulation environments. *FMI* is widely adopted in the modelling and simulation community to enhance collaboration and facilitate the integration of models from various sources. The *FMI* standard is particularly relevant for users working with multiple simulation tools or collaborating across different disciplines. *FMI* finds applications in industries such as automotive, aerospace, energy, and control systems, where the exchange and co-simulation of models are essential for system-level analysis and optimization. Users benefit from the standardization provided by *FMI*, enabling the seamless integration of models created in different simulation environments.

PETSc, short for Portable, Extensible Toolkit for Scientific Computation, is an open-source software package for the parallel numerical solution of scientific applications [15]. Developed at Argonne National Laboratory, *PETSc* provides a framework for the scalable and efficient solution of linear and non-linear algebraic systems, ordinary and partial differential equations, and more. It is designed for high-performance computing environments and offers a wide range of functionalities, including linear solvers, preconditioners, time-stepping integrators, and parallel mesh and data management. Users in academia, research institutions, and industry leverage *PETSc* for solving large-scale scientific problems on parallel computing architectures. Its flexibility and extensibility make it suitable for a diverse range of applications, from simulating complex physical systems to solving computationally demanding mathematical problems in parallel environments. This software package is a key framework for UB.

waLBerla a widely applicable lattice Boltzmann simulation code, which is an alternative to classical Navier-Stokes solvers for computational fluid dynamics simulations [16]. All of the common lattice Boltzmann method (LBM) collision models are implemented (SRT, TRT, MRT). Additionally, a coupling to the rigid body physics engine *pe* is available [17].

HyTeG is a C++ framework for extreme-scale matrix-free finite element simulations with strong focus on geometric multigrid [18].

2.3 Training management system

The HiDALGO2 Moodle platform is hosting our training activities [1], and is a robust and versatile open-source learning management system. This platform can effectively address **REQ-TRA-003** [4] by providing specifically tailored for the HiDALGO2 training initiatives. Moodle provides a user-friendly environment for participants to engage with diverse educational content. With intuitive navigation and interactive features, Moodle facilitates seamless access to training modules across various categories, including High-Performance Data Analytics (HPDA), Artificial Intelligence for Global Challenges (AI), Visualization Techniques (VIS), and more. Participants can benefit from a structured learning experience, leveraging multimedia resources, discussion forums, and assessment tools. Moodle ensures a collaborative and dynamic space, fostering effective knowledge acquisition and skill development within the realm of advanced scientific computing.

To accommodate diverse schedules and geographical constraints, HiDALGO2 offers web seminars and online modules on Moodle [1], delivering training content in accessible and flexible formats. Moodle enables wider participation and facilitates continuous learning opportunities for stakeholders across various regions. The currently available list of courses covers a wide range of topics, including:

- Reproducible Software Environments & Benchmarks with Ansible and Spack.
- HPC usage tutorial.
- Cloudify and CKAN.
- Urban Air Pollution: QuickStart Tutorial for Beginner.
- Web-based portal and visualization for EuroHPC applications.
- Building Energy Simulation.
- Urban Buildings digital twins at the Exascale.

The Dashboard also allows users the opportunity to browse through available services, e.g. Moodle for educational courses related to the simulation use cases and running them on HPC, customer services such as the Zammad ticketing service, or go through the public Wiki for information on the project [2].

A further objective of the project is to deploy and run the simulation use cases from the HiDALGO2 system to the EuroHPC JU sites, e.g. LUMI in Finland. This has already been achieved in a limited scope through SZE's UAP pilot, and will be extended to all other HiDALGO2 pilot applications.

2.4 Prototype training cluster

The Prototype HiDALGO2 cluster has a dual purpose, one of which is to serve as the training infrastructure for project participants. It consists of one access node and four compute nodes, facilitating SSH key-based access for users. Communication between the access node and compute nodes occurs via private IP addresses, with plans to integrate it with QCG and MathSO in the future, for details see D2.4 [2].

Additionally, the JupyterHub service offered by HiDALGO2 serves as an efficient platform for HPC training events [2]. It provides users with a collaborative and interactive environment for exploring and experimenting with computational resources.

Through Jupyter notebooks, participants can easily access and utilize HPC resources without the need for extensive setup or maintenance tasks.

The integration of JupyterHub with the Prototype cluster streamlines resource allocation and management, ensuring efficient utilization during training events. Users authentication via HiDALGO2 IDM (Keycloak) enhances security and facilitates seamless access to the platform.

2.5 Requirements for the training infrastructure

The training infrastructure should address the following list of requirements **REQ-TRA-002** to **-004**, **REQ-DMA-009** to **-014**, **REQ-POR-027** to **-029**, **REQ-HPII-001**, **REQ-HPII-014**, **REQ-PIL-009**, and **REQ-PIL-012** [4]. For the sake of clarity and completeness, these requirements can be mapped to the following groups.

The **first group** of requirements relies on access to high-performance computing clusters or supercomputers equipped with sufficient computational power and memory to support intensive simulations and data processing tasks. The training infrastructure should be scalable to accommodate varying numbers of participants and workload demands of complex simulations related to Global Challenges, ensuring consistent performance and responsiveness during training sessions. Optimization of hardware and software configurations to maximize performance, efficiency, and throughput for HPC applications and simulations. Remote access capabilities enable participants to connect to the training infrastructure from anywhere, allowing for flexible and convenient access to training resources. Collaboration tools such as video conferencing, discussion forums, and shared workspaces facilitate communication, interaction, and knowledge sharing among participants and instructors.

- Environmental scientists and researchers: require access to HPC clusters for running complex simulations related to air or to water quality modelling and pollution dispersion studies.
- Urban planners and policymakers: access to HPC infrastructure for analyzing urban airflow patterns and assessing the impact of air quality improvement measures in cities.
- Engineers and developers: need HPC resources for developing and testing sensor networks, air and water quality monitoring systems, optimizing algorithms for real-time data processing.
- Architects and urban designers: utilize HPC clusters to simulate and optimize sustainable building designs, incorporating airflow and energy efficiency considerations.

A **second group** of requirements - the availability of HPC software tools and libraries commonly used in scientific computing, such as MPI, OpenMP, CUDA, and parallel programming frameworks.

- Environmental scientists and researchers: require access to parallel programming frameworks like MPI and CUDA for accelerating CFD simulations.
- Fire ecologists and environmental scientists: need HPC software tools for simulating WF behaviour and ecological impacts, leveraging parallel processing capabilities for large-scale simulations.

A **third group** of requirements - access to domain-specific software packages and simulation tools relevant to Global Challenges, including CFD software, weather and climate modelling tools, environmental modelling software, etc.

- Architects and urban designers: require integrated development tools and compilers for developing and optimizing building simulation models for energy efficiency and airflow analysis.
- Urban planners and policymakers: access to CFD software and environmental modelling tools tailored for urban airflow and air quality modelling in HiDALGO2.
- Building engineers and energy consultants: Need user-friendly development environments with support for Fortran, Python, and parallel programming models to optimize building energy performance.
- Engineers and developers: need access to software packages for developing sensor networks, air quality monitoring systems, and data assimilation techniques for real-time decision support.
- Fire ecologists and environmental scientists: access to WF modelling software and climate modelling tools for studying wildfire risk and behaviour.

A **fourth group** of requirements - a user-friendly development environment with integrated development tools, compilers, debuggers, and performance profiling tools to facilitate code development, optimization, and debugging. Support for popular programming languages used in HPC, such as C/C++, Fortran, Python, and parallel programming models like MPI and OpenMP.

A **fifth group** of requirements - comprehensive training materials, tutorials, and documentation covering various aspects of HPC, parallel programming, optimization techniques, and domain-specific applications related to Global Challenges. Interactive learning resources, including code examples, case studies, and hands-on exercises, reinforce concepts and facilitate practical learning experiences. In addition, as was outlined in D2.4 and D2.7 HiDALGO2 implemented robust security measures to protect sensitive data, user credentials, and intellectual property associated with training materials and simulations. Regular updates, maintenance, and monitoring of the training infrastructure to ensure reliability, availability, and performance consistency.

- Environmental scientists and researchers: require training materials covering parallel programming techniques and optimization strategies for CFD simulations relevant to air and water quality modelling.
- Urban planners and policymakers: need tutorials and documentation on HPC applications for urban airflow modelling and air quality management, including case studies and hands-on exercises.
- Fire ecologists and environmental scientists: require comprehensive training resources on wildfire modelling techniques, including code examples and interactive learning materials.

This list is not exhausted and will be evaluated and eventually refined and extended with new needs identified by the pilot's stakeholders and the HiDALGO2 technical team (e.g. in order to fulfil the needs identified by other technical work packages) along the project's development phases.

3 Training activities and training categories

The HiDALGO2 training initiatives include High-Performance Data Analytics (HPDA), Artificial Intelligence for Global Challenges (AI), Visualization Techniques (VIS), Data in High-Performance Computing (DAT), Simulation and Modelling (SIM), Scientific Conferences and Workshops (C+W), Training for Special Communities (COM), and other specialized topics.

Also, in this section we describe the terminology for a specific type of event, primarily addressing what to label as a "*training*" event within the context of the organization's activities. The need for clarification arises from a history of conducting various activities labelled as "*workshops*" with some featuring elements that could be categorized as training due to the inclusion of hands-on sessions or panels.

Furthermore, we define our goals for the training format, including options for online, on-site, or hybrid events. The decision-making process involves assessing the feasibility of on-site or hybrid training events at High-Performance Computing (HPC) centres engaged in the HiDALGO2 pilots. This consideration extends to HPC infrastructures that can be accessed, questioning the capacity of the training event, particularly in scenarios where reliance on computations facilities which not are part of the HiDALGO2 project. Resolving these issues involves clear definitions, strategic planning, and a comprehensive understanding of the resources available for effective and impactful training sessions.

3.1 Training categories

To delineate what constitutes a "training" event within HiDALGO2 organization's activities we define terminology for different types of events. This helps in identifying and categorizing activities accurately, ensuring stakeholders understand the focus and format of each event.

In this section, one may explore our comprehensive training programs aimed at fostering proficiency, collaboration, and innovation in the ever-evolving landscape of scientific research and computation:

Table 2: Description of the training categories

Category	Tag	Description
High Performance Data Analytics	HPDA	Focuses on techniques and tools for efficiently processing and analysing large volumes of data in high-performance computing environments.

Category	Tag	Description
Artificial Intelligence for Global Challenges	AI	Addresses the application of artificial intelligence methodologies to tackle significant global issues, emphasizing the intersection of AI and real-world challenges
Visualization Techniques	VIS	Encompasses the study and application of visual representation methods to interpret complex scientific data, aiding in the comprehension and communication of intricate concepts. Provide a foundational understanding of the role and significance of visualization techniques in the context of high-performance computing. Explore how visualization contributes to gaining insights from complex simulations in UB, UAP, RES, WF and SPT. Instruct participants on effective data preparation and preprocessing techniques for diverse datasets generated during HiDALGO2 simulations. Address challenges related to data size, format, and structure specific to each project domain. Familiarize participants with state-of-the-art visualization tools and platforms suitable for handling large-scale datasets from UB, UAP, RES, WF and SPT. Tailor training content to cover domain-specific visualization techniques for UB, UAP, RES, WF and SPT. Explore interactive visualization methods that allow users to dynamically interact with simulation results. Provide hands-on experience with tools that facilitate real-time exploration and analysis of complex datasets. Introduce visual analytic approaches to enhance the integration of computational analysis and human insights. Showcase how visual analytics can lead to the discovery of patterns, trends, and anomalies in simulation data. Instruct participants on techniques for handling and visualizing multi-dimensional data specific to the complexities of UB, UAP, RES, WF and SPT. Demonstrate the seamless integration of visualization techniques within the overall simulation workflows of the respective projects. Highlight the role of visualization in aiding decision-making and improving understanding. Share best practices for optimizing visualization workflows and addressing challenges specific to each project domain. Provide hands-on exercises and practical applications, allowing participants to apply visualization techniques to their own project datasets. Encourage participants to bring their visualization challenges for discussion and resolution.
Data in HPC	DAT	Explores the management, storage, and utilization of data in the context of HPC environments, emphasizing strategies for efficient data handling.
Uncertainty quantification and ensemble methods	UQEM/ VVV	Provide in-depth knowledge of uncertainty quantification techniques specific to UB, UAP, RES, WF and SPT simulations. Identify and comprehend the various sources of uncertainty in UB, UAP, RES, WF and SPT simulations within the context of exascale HPC. Gain insight into the impact of uncertainties on simulation outcomes and the need for robust quantification methods. Familiarize participants with ensemble methods as powerful tools for uncertainty quantification. Cover statistical

Category	Tag	Description
		approaches, sensitivity analyses, and probabilistic methods applicable in exascale computing environments. Apply uncertainty quantification and ensemble methods to practical UB, UAP, RES, WF and SPT simulation scenarios. Analyse and interpret results to make informed decisions in the presence of uncertainties. Explore the role of uncertainty quantification in optimization and model calibration processes. Develop skills in refining UB, UAP, RES, WF and SPT simulation models based on ensemble results.
Scientific Conferences and Workshops	C+W	Covers the organization and participation in scientific conferences and workshops, fostering collaboration, knowledge exchange, and advancements in various scientific domains.
Simulation and Modelling	SIM	Designed to provide participants with foundational knowledge and skills applicable across all pilots. It focuses on fundamental concepts and tools essential for modelling and simulation tasks in diverse domains. The training covers a wide range of topics to ensure participants have a comprehensive understanding of modelling principles and techniques.
Others	OTH	Encompasses training categories that may not fall explicitly into the aforementioned classifications, representing a diverse range of specialized or emerging topics in scientific education and training.

3.2 Adapting training to stakeholder needs

We utilize questionnaires and surveys to gather feedback from stakeholders regarding their training needs, preferences, and proficiency levels in specific areas such as High-Performance Data Analytics (HPDA), Artificial Intelligence for Global Challenges (AI), Visualization Techniques (VIS), Data in High-Performance Computing (DAT), Simulation and Modelling (SIM), Scientific Conferences and Workshops (C+W), and Training for Special Communities (COM). This includes quantitative assessment of participant performance, knowledge retention, and behaviour change before and after training interventions.

Feedback from stakeholders gathered through surveys and questionnaires, is integrated into the evaluation process to iteratively improve training activities. Statistical analysis helps in identifying trends, strengths, and areas for improvement, ensuring continuous enhancement of training effectiveness.

Our training format goals include options for online, on-site, or hybrid events. We assess the feasibility of on-site or hybrid events at High-Performance Computing (HPC) centres engaged in the HiDALGO2 pilots. This evaluation considers access to

HPC infrastructures and the capacity of training events, especially when relying on computation facilities outside the HiDALGO2 project.

In addition to traditional workshops and discussions, HiDALGO2 actively engages stakeholders through hands-on sessions and hackathons. These interactive events provide participants with practical experience and facilitate the exploration of cutting-edge techniques and methodologies in HPC and related fields.

3.3 Collaborations with CASTIEL 2, EuroCC 2 and CoEs

The strategies and approaches used and developed within HiDALGO2 will be shared with all project stakeholders to educate and consult the user community with respect to HPC compatible software engineering and development.

Moving forward, we will continue to establish the HiDALGO2 brand and identity as a central entry point to services and skills for European HPC in the Global Challenges area. This will also be further strengthened by cooperating with the European National Competence Centres under the EuroCC 2 project and other Centres of Excellence, thus reaching a larger audience Europe-wide, and especially industry stakeholders, via the CASTIEL 2 Coordination and Support Action, which is in-line with the **REQ-TRA-001** [4]. As a coordinating entity of both CASTIEL 2 and EuroCC 2, HLRS/USTUTT utilizes its network and contacts to establish collaborations, ensuring synergy between training activities and the broader European HPC ecosystem.

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.

3.4 Already delivered trainings

In this section, we elaborate on the diverse range of training activities undertaken within HiDALGO2, aimed at empowering stakeholders with the requisite skills and knowledge in HPC domains. These activities encompass various formats, tailored to address specific needs and foster interdisciplinary collaboration.

- HiDALGO2 achievements were prominently featured in a show reel exhibited at the HiPEAC 2024 conference, January 17-19 in Munich, Germany. Such showcase events serve to highlight the project's advancements and contributions to the HPC community, fostering visibility and recognition.
- Events such as the "Workshop Uncertainty Quantification - HiDALGO2, SEAVEA and CIRCE" held on November 17, 2023, exemplify our commitment to collaborative learning and knowledge exchange. Discussions during this workshop sparked the initiative to organize a joint Hackathon between HiDALGO2 and SEAVEA in Q2 of 2024, aiming to leverage synergies and expertise across projects to address shared challenges.

– The lecture course, which gives a short overview over Dynamic Energy Simulations (DES), followed by a simulation workflow and some of HiDALGO2 advances - “HiDALGO2: Building Modelling and Simulation, Visualization and Computing” held in March 28, 2024 at the Strasbourg University in collaboration between the European CoE HiDALGO2 project, NCC Germany and Ktirio [19] platform. Participants learned how to build generate Building Energy Models (BEM) from 3D Computer-Aided Design (CAD) geometry, with a focus on refining physical models to closely mirror real-world building behaviour. Moreover, this course offered a unique opportunity to delve into two specialized aspects of simulation technology: the simulation of daylight for architectural applications and the use of light transport simulation. Through the lens of light transport simulation, which harnesses ray tracing algorithms, attendees will gain an understanding of its dual utility in creating photo realistic images from numerical 3D models and visualizing volumetric data fields, crucial for scientific visualization. Furthermore, the discussion was encompassing the evolution of light transport simulation in tandem with the capabilities of modern GPUs, now equipped with RT cores.

4 Roadmap

This chapter introduces HiDALGO2's training roadmap, outlines the next objectives and necessary steps taken for the upcoming years and addresses **REQ-TRA-004** and **REQ-HPII-016** [4].

HiDALGO2's infrastructure provisioning comprises the underlying hardware (e.g., EuroHPC JU supercomputers) and software (e.g., Jupyter Notebooks) that are required to execute HiDALGO2's pilots and Web services, which together make up the HiDALGO2 ecosystem.

Regular assessment of training effectiveness and participant feedback. Tailored sessions for addressing specific challenges faced by participants in their projects.

Table 3: HiDALGO2 training roadmap for M16-M48

Month	Training activities
M16-M22: Foundations and Proficiency Building	**Multi-Zone Models for UB:** Overview of multi-zone models for LOD-0 and LOD-1 building descriptions. Introduction to Dymola (Modelica) and Feel++ for building simulations. Introduce the objectives and challenges of building thermal regulations. Understand how to calculate the thermal balance of a room using manual methods. Acquire or update knowledge to solve thermal problems. – Introduction to building thermic – Geometry/ geography – Digital Tools for Building Modelling **Basic WF Simulation in the landscape:** These trainings will focus on the analysis of large fires occurring over vast territories, incorporating dynamics and effects in the lower atmosphere (PBL). Training topics are centred around the use of the WRF/SFIRE model for simulating fire spread and smoke emission and dispersion in the landscape: – Data Input: Description of meteorological scenarios, definition of scales and resolution, static data sources (forest fuels, terrain model, etc.), territory division for parallel processing, downscaling domain description, preparation of files feeding the WRF-SFIRE model. – Simulation: Parametrization, organization of executions in HPC, use of WRF/SFIRE software, storage of results.

Month	Training activities
	– Interpretation: Data extraction, data analysis in simple visualization tools (Vapor, Paraview, Panoply, and SZE Web tool). – Advanced Visualization: Integration of simulations, geometric models, geographic data into immersive experiences in Unreal Engine, compilation, utilization **Organization of the several hackathons**: WRF/SFIRE Hackathon: Includes possible invitations to other CoEs using this software and the creators of the software from the US. Hackathons or short seminars on visualization. Focused on the use of visualization tools for data analysis and exploration of future developments and innovations.
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.

Month	Training activities
	– Observe the influence of the building's orientation on energy needs. – 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 SPT:** 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. 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.

Month	Training activities
	Organization of several hackathons: HPC modelling in urban areas using OpenFOAM/fireFOAM and other similar CFD solutions. 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.
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 SPT:** 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. 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.

Month	Training activities
	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 SPT for holistic simulations. Collaborative projects to address cross-cutting challenges. Apply the acquired knowledge to simulate material transport in water (SPT) 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.

Month	Training activities
	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 SPT 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.

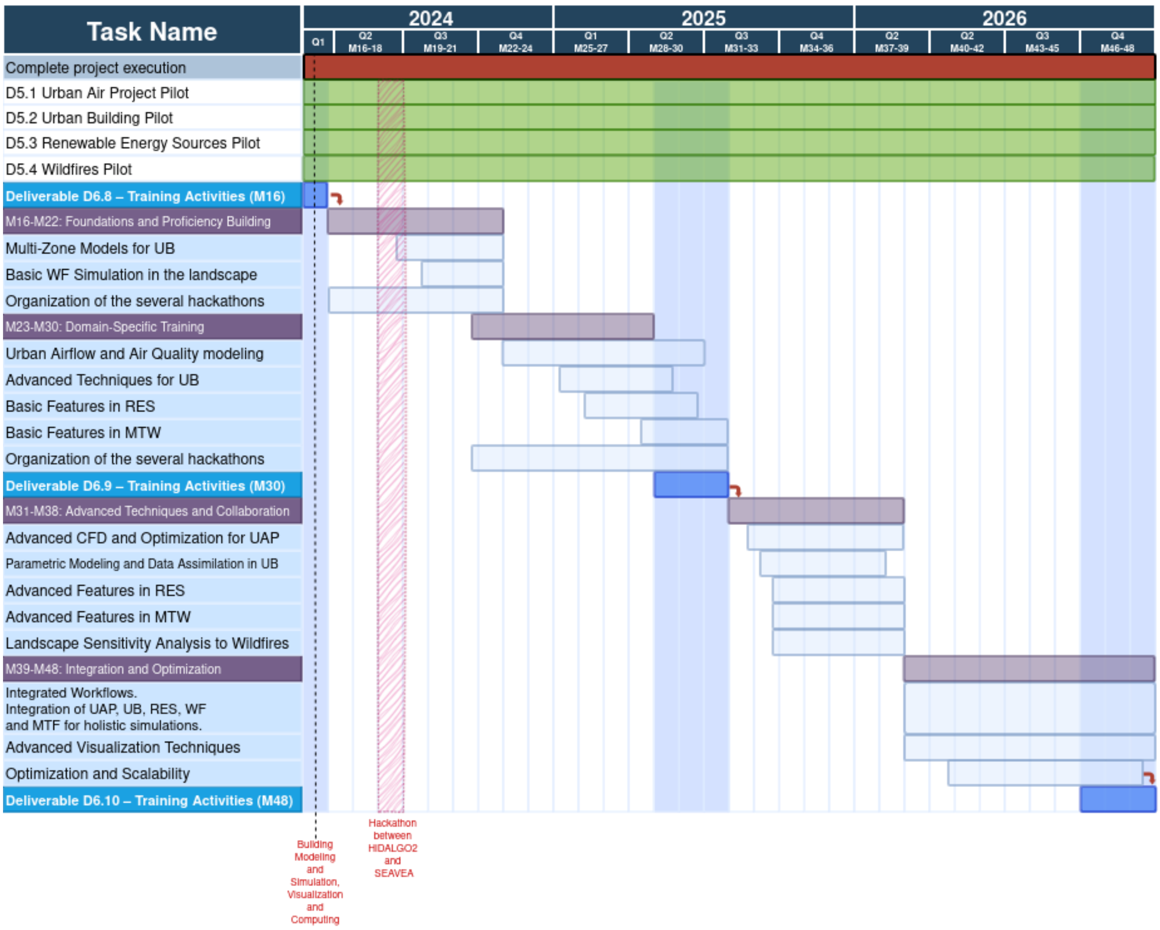

Figure 1: HiDALGO2 training roadmap

4.1 Outlook

The next training activities will be reported in two future deliverables: D6.9 in M30 and D6.10 in M48. In deliverable D6.9 we are going to analyse our training techniques, methodologies, and materials, the way we approached our end-users to set the stage for the follow-up training programs that will be delivered in M31-M48. While D6.10 will provide comprehensive insights into the progress made to reduce the skills gap for the Global Challenges scientists within the HiDALGO2 project.

5 Conclusions

This deliverable outlines the comprehensive HiDALGO2's training roadmap unwavering commitment to advancing knowledge and proficiency in the domains of UAP, UB, RES, WF and SPT. This strategic initiative is poised to bridge competence gaps and align with the project's overarching goal of addressing global challenges. The roadmap identifies key areas of focus, including the integration of flagship codes and tools, thereby creating a robust framework for skill development. The coordination between HiDALGO2 experts and Interest Groups ensures a diverse and enriched training experience.

Importantly, this document aligns with the achievement of successful pilot use cases, underlining the symbiotic relationship between research outcomes and training initiatives. By leveraging findings from pilot projects such as UAP, UB, RES, WF and SPT, the training program directly addresses challenges and requirements identified within these use cases, fostering a seamless transition from research to practical application.

The roadmap reflects the essence of collaboration, extending its reach to other work packages such as WP3, WP4, and WP6. The emphasis on collaboration with external entities and projects reinforces the commitment to holistic success. By actively intertwining research outcomes with broader project objectives, the training program contributes significantly to the overarching success of HiDALGO2.

Looking ahead, the training program is not merely a static curriculum but an evolving entity. It envisions the exploration of new research avenues, fostering a dynamic environment that encourages collaboration and joint development with external research groups.

In conclusion, this deliverable lays the groundwork for a transformative training program that not only imparts practical knowledge but also cultivates a collaborative ecosystem.

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