D6.6 Project Exploitation and Sustainability



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List of Acronyms

Abbreviation / acronym	Description
AI	Artificial Intelligence
B2B	Business to Business
B2G	Business to Government
BIM	Building Information Modelling
CA	Consortium Agreement
CFD	Computational Fluid Dynamics
CHT	Conjugate Heat Transfer
CI/CD	Continuous Integration / Continuous Deployment
CoE	Centre of Excellence

Abbreviation / acronym	Description
CPU	Central Processing Unit
DX.Y	Deliverable X.Y
DMS	Data Management System
DoA	Description of Action
DSO	Distribution System Operator
EAS	Eviden Argos Suite
EC	European Commission
ECC	Exploitation Coordination Committee
ER	Exploitable Result
EU	European Union
EUR	Euro
EuroHPC JU	European High Performance Computing Joint Undertaking
FAU	Friedrich-Alexander-Universität Erlangen-Nürnberg
FN	Future Needs
FSE	Fire Spread Engine
GA	Grant Agreement
GHG	Green House Gas
GPU	Graphics Processing Unit
GUI	Graphical User Interface
HaaS	Hardware as a Service
HLRS	High-Performance Computing Centre Stuttgart
HPC	High Performance Computing
HPCaaS	High Performance Computing as a Service
HPDA	High Performance Data Analytics
HRB	Horizon Results Booster
I/O	Input/Output
IP	Intellectual Property
IPR	Intellectual Property Rights
KER	Key Exploitable Result
KPIs	Key Performance Indicators
KUB	Ktirio Urban Buildings

Abbreviation / acronym	Description
LSTM	Long Short-Term Memory
ML	Machine Learning
MTG	Meteogrid
MTW	Material Transport in Water
mUQSA	multipurpose Uncertainty Quantification and Sensitivity Analysis
NGOs	Non-Governmental Organizations
PC	Project Coordinator
PESTLE	Political, Economic, Social, Technological, Legal and Environmental analysis
PGF	porousGasificationFoam
PM	Person-Month
PSNC	Poznan Supercomputing and Networking Center
PU	Public (dissemination level)
QM	Quality Manager
R&D	Research & Development
RedSim	Reduced Simulations
RES	Renewable Energy Sources
SaaS	Software as a Service
SMEs	Small-Medium Enterprises
SWOT	Strengths, Weaknesses, Opportunities and Threats analysis
SZE	Széchenyi István University
ToC	Table of Contents
TRLs	Technology Readiness Levels
UAP	Urban Air Project
UNISTRA	Université de Strasbourg
USD	United States Dollar
USTUTT	University of Stuttgart
WF	Wildfires
WP	Work Package
WRF	Weather Research and Forecasting
WUI	Wildland Urban Interface

Executive Summary

Deliverable 6.6 (D6.6) establishes the final operational, commercial, and legal roadmap for transitioning the HiDALGO2 Centre of Excellence into a self-sustaining European service provider beyond its Month 46 funding deadline. Moving beyond early exploratory concepts, this report consolidates the technical maturity of the project's 33 exploitable results under a clean single-ownership framework and a hybrid licensing model that balances Open Science mandates with commercial protection. Rebuilt around direct feedback from two Advisory Board review cycles, D6.6 details a defensible financial model where routine exascale consulting engagements yield a 28% contribution margin to cover the Centre's annual standing capability cost. By securing an operational break-even target of just 6 to 7 engagements per year across all five environmental pilot domains, bridging initial public procurement lags through mixed research grant portfolios, and enforcing post-grant governance via the signed Exploitation Agreement (D6.7) and the Exploitation Coordination Committee, HiDALGO2 delivers a realistic, low-risk market framework aligned with the European Green Deal, EuroHPC JU objectives, and Destination Earth through 2030.

1. Introduction

1.1 Purpose of the document

The primary purpose of this document (D6.6) is to present the final outcomes of the exploitation and sustainability strategy for HiDALGO2, establishing a clear operational roadmap for transitioning the project's technological breakthroughs into long-term viable services. While the interim Deliverable 6.5 (D6.5) outlined initial strategy findings and focused primarily on future developments, D6.6 pivots to the present, developments of the project's results, stakeholders, and customer groups. It serves as a guide to the consortium's final business plans, financial models, joint licensing strategies, and exascale-ready service offerings through 2030.

This final deliverable solidifies the commercialization pathways for three priority customer segments: big companies, research and academia, and national and local government entities. By defining concrete business models, this document translates the project's technical results into practical service categories, including high-performance computing as-a-service (HPCaaS), advanced training, co-design, and tailored software development. Ultimately, the strategy ensures that HiDALGO2's results remain highly impactful, accessible, and aligned with the strategic objectives of the EU beyond the initial funding period.

1.2 Relation to other project work

This deliverable "Project exploitation and sustainability" is directly related to Work Package 6 and one deliverable of the project.

- **Task 6.1: Market Analysis and Sustainability Roadmap** serves as the primary foundation for this report. While the interim phase established the SWOT/PESTLE methodology and identified broad customer segments, T6.1 has concluded the final market sizing, market estimates and the concrete Sustainability Roadmap detailed in Section 3.
- **Task 6.2: Project Exploitation and IPR Management** provides the legal and operational framework for the exploitation plans. Under T6.2, the consortium finalized individual exploitation plans for each result, tracked the development of the project's 33 exploitable results and established the final Intellectual Property Rights (IPR) tracking directory.
- **Task 6.4: Awareness Creation, Collaboration and Community** Support focused on building networks with early adopters, including local city units, housing associations, and regional civil protection agencies. The user feedback

and operational relationships fostered under T6.4 directly validate the target customer segments and business cases analysed in Section 4.

- **Task 6.5: Project Branding, Dissemination and Communication** managed the external branding, newsletters, social media presence, and major outreach events, including the HiDALGO2 EU Clustering Event. These communication activities represent how the exploitable results of the project have been disseminated through all the available channels detailed more in D6.3 and D6.4.
- **Relation to D6.5**: Submitted in February 2025 (M26) as an interim plan, D6.5 focused on future capabilities and initial strategy findings. D6.6 serves as its direct successor, updating the initial SWOT/PESTLE and market audits with final-stage project data, finalized business models, IPR and exploitation agreements based on the latest developments.

Beyond these relational points, the exploitation and sustainability tasks serve as the central connection for all project results. Consequently, this deliverable is linked to all Work Packages and Tasks.

1.3 Structure of the document

This document is structured in 7 major Sections in addition to the introduction (1).

Section 2 presents the methodology and workplan that was carried out for the exploitation and sustainability plan.

Section 3 presents the Market Assessment & Sustainability Plan.

Section 4 presents the Business Model and Financial Analysis.

Section 5 presents the Exploitation Strategy and Governance actions taken within the project.

Section 6 presents the Final Exploitation Report.

Section 7 presents the Research Roadmap to 2030.

Section 8 presents the Risk assessment and mitigation.

1.4 Progress since D6.5 and response to Advisory Board feedback

D6.5 was submitted in month 26 (Feb. 2025) and set out the exploitation and sustainability position at that point. It established the frameworks, listed the exploitable results and gave a first account of the market and of the intended business model. This deliverable is the final version. Instead of restating what D6.5 already settled, it concentrates on what has changed and most of that follows from external review.

Two rounds of Advisory Board review

The Advisory Board (AB) examined the exploitation and sustainability work at the plenary meeting in Strasbourg in June 2025 and again at the plenary meeting in Győr in June 2026. Written feedback was received from Board members after both. The feedback was consistent across the two rounds and across members, which is why it has been taken as the organising principle for this deliverable.

The common thread, expressed in different words by different members, was a request for the commercial case to be evidenced. The frameworks were in place, the results were identified and the intent was clear. The Board asked for figures traceable to their assumptions, for the competitive position to be tested and for the parts to be connected so that the whole reads as a single business case.

Addressing AB points

Table 1 records each substantive point raised and where in this deliverable it is dealt with. It serves as an index to the document.

Table 1. Advisory Board points and where each is addressed

Point raised by the Advisory Board	How it is addressed	Section
Re-run the cost model on more realistic assumptions	Cost model rebuilt around five categories with each figure derived from a stated assumption. A routine engagement is now costed at 56 000 EUR against roughly 3 500 EUR in D6.5.	4.1, 4.3
There is no cost line for sales or lead generation, although the role is central to the model	Sales and lead generation added as a cost category. Its size follows from the number of bids needed to win one contract.	4.1, 5.2
Much of the market data dates from 2021 and 2022	Sector figures refreshed to 2025 base years, with base year stated and divergence between published estimates reported.	3.4
The figures describe whole sectors, not what HiDALGO2 can address	Three levels distinguished. Sector total for context, addressable market for scale, engagement value as the working figure.	2.1, 3.4

Point raised by the Advisory Board	How it is addressed	Section
What do competitors offer, what do they charge and where are they weak	Competitors identified per use case as organisations, not software, with indicative price levels and a strengths and weaknesses assessment	3.5
Technical advantages must map to benefits the customer values	Value proposition restated in customer terms. Three defensible claims are made and three claims that cannot be supported are named	3.5
A realistic end-to-end business case should be shown in one place	A single engagement worked through from customer problem to profitability, covering services, price, full cost structure and result	4.3
How many comparable projects are needed to reach profitability	Break-even analysis against the standing cost of the capability, with a sensitivity table	4.4
How long can the costs be carried before revenue arrives	The period before first income is estimated at twelve to eighteen months, with the cost of carrying it stated and the funding route described	4.4, 5.3
The five use cases should be prioritised by likely demand	Use cases ranked, with the criteria and the evidence for each position given	3.2
Demonstrations would be a first step towards external user access	Recorded as the mitigation for the absence of a commercial track record	8
A lighthouse engagement should direct industrialisation	Addressed through the demand ranking and the worked engagement, which together define where a first reference engagement should be sought	3.2, 4.3
What would the Lead Generator actually do	The role defined as active business development in four parts and costed	5.2, 4.1
Stakeholders and customers are not the same thing	Distinction adopted and applied throughout the deliverable	2.1, 3.2
Focus the PESTLE analysis on factors specific to HiDALGO2	Reduced to the six factors that bear on this offer and an inconsistency with the SWOT resolved	3.1
How will teams be kept together if a follow-on project is delayed	New section on resourcing and continuity, covering the mixed funding portfolio, the functions that must be	5.3

Point raised by the Advisory Board	How it is addressed	Section
	maintained and what changes if a follow-on is delayed	
Can EuroHPC resources be relied on for commercially contracted work	Treated as a dependency of the business case, with alternatives set out and recorded as a risk	5.3, 8

What is new in this deliverable

Three parts of this document did not exist in D6.5 in any form.

- Section 4, covering the cost model, pricing, a worked business case and break-even analysis. D6.5 contained cost figures. The business case and the viability test are new in this deliverable.
- Section 5.3, on resourcing and continuity. This addresses how capability is maintained between engagements.
- Section 3.5, on the competitive landscape, which develops the analysis D6.5 identified as necessary.

The remaining sections were present in D6.5 and have been revised, with the market sizing in Section 3.4 and the risk assessment in Section 8 changed most substantially.

2 Report on Methodology and Workplan

This Section outlines the foundational methodology and structured workplan applied to establish HiDALGO2's final exploitation and sustainability framework. It details the processes used to conduct the competitive market assessment, manage partner exploitation plans and IPR, execute targeted dissemination and outreach campaigns, and systematically monitor and evaluate the project's progress against its designated key performance indicators (KPIs).

2.1 Market assessment and sustainability

The market assessment and sustainability work is carried out under Task 6.1, led by PSNC with contributions from USTUTT and Future Needs, running from month 13 to the end of the project. Its outputs are D6.5 and this deliverable. This section describes how the work was done and where the method changed after D6.5.

Methods development

D6.5 was written at month 26, when the pilots were still under development and external engagement had not yet begun. It established the frameworks and gave a first reading of the market on the evidence available at that point. Since then the pilots have been used with external organisations in all five domains, the Advisory Board has reviewed the exploitation work twice and considerably more evidence has become available.

The Board asked for figures traceable to their assumptions, for current market data, for the competitive position to be demonstrated and for the business case to be readable end to end. The method set out below reflects those points and the fuller evidence base the project has since built.

Market sizing

Three levels are distinguished. The reasoning starts from the most concrete level and works upwards.

- **Engagement value.** What a single contract is worth. This is estimated by sizing the work involved, pricing it from the cost model and checking the result against public procurement practice and thresholds. It is the only level that can be estimated with reasonable confidence.
- **Addressable market.** The share of a sector corresponding to what the consortium can actually deliver. It is obtained by identifying the realistic customer population in Europe and the rate at which such organisations commission this kind of study.

- **Sector total.** Published market research figures, used only for context. These describe fields dominated by instrumentation, monitoring hardware and software licences, which is not what HiDALGO2 sells.

Published figures are refreshed to the most recent available and their base year is stated. Where estimates from different providers diverge, which is common and sometimes by a factor of two, this is reported openly.

Competitive analysis

The unit of comparison is the organisation a customer would hire instead, not the software that organisation uses. Simulation packages, whether commercial or open source, are tools available to any provider including HiDALGO2 partners, so they are not competitors for the same work. For each use case the analysis identifies commercial providers and non-commercial ones separately, since public bodies and research institutes are often better treated as potential partners than as rivals.

For each competitor group the analysis records what is offered, the indicative price level and where the group is strong and weak. Claimed advantages are then tested against a single question, which is whether the advantage corresponds to something the customer values. Advantages that do not pass that test are excluded and weaknesses the consortium cannot mitigate are also stated.

Terminology

Customers are those who acquire a service and pay for it. Stakeholders are those who shape or fund the wider effort without buying a service, including ministries, funding agencies and research collaborators. D6.5 used the two terms together. Separating them makes the extent of genuine commercial interest easier to read and they are kept separate throughout this deliverable.

Business model and cost derivation

The cost model is based on categories that reflect how costs are actually incurred within a given project, with each value derived from a specific assumption. The Section analyses a single representative project from the identification of the client's problem to the assessment of profitability and then presents generalized data in the form of scenarios based on that example. Profitability is evaluated in two ways. The first is the number of such projects needed to cover the fixed cost of maintaining the capability. The second is how long that capability must be maintained before the first revenue arrives.

Limitations

Two limitations should be stated. The figures are first-order estimates based on judgement about effort and on public procurement practice, not on completed commercial engagements, because commercial delivery has not yet begun. And competitor pricing is inferred from published day rates and typical study values, because tender outcomes are not usually disclosed. Both would be improved by actual market experience and the assumptions are presented openly so that they can be corrected as that experience accumulates.

Scope and related deliverables

Task 6.1 also calls for an assessment of data availability and quality and of the usability, interfaces and limitations of the HiDALGO2 toolset. It asks in addition for gaps revealed in national preparedness during the demonstrations and for guidance on privacy and ethical issues.

- Data availability, quality, curation and access are covered by the Data Management Plan, D1.5 and its update D1.6, produced under Task 1.3 with SZE acting as Data and Ethics Manager. D1.6 reports the datasets of all five pilots and records that no personal or otherwise sensitive data has been identified in the project.
- Privacy and ethical compliance is covered in D1.6. It sets out the national and European instruments that apply, including the General Data Protection Regulation and the Data Governance Act, together with the position on the EU AI Act.
- Usability, interfaces and the limitations of the toolset are reported in WP2, in the Dashboard and Services deliverables and in the WP5 implementation reports on the pilot applications.
- Gaps revealed during the demonstrations, including those bearing on national preparedness, are reported with the pilots in WP5.

This deliverable draws on those findings only where they affect the commercial case. First is the data line in the cost model in Section 4.1, which reflects what the pilots showed about the cost of acquiring and licensing input data. Second, the data protection entry in Section 8 reflects the compliance position set out in D1.6.

2.2 Exploitation plan and IPR management

To formulate the final exploitation strategy, the consortium built upon the methodology established in D6.5, aligning it directly with European Commission frameworks [1] and the Explore-Exploit Continuum [2] . The main outcomes were: identifying and categorising all exploitable results, creating a structured framework for

overseeing, managing, and protecting the project's IPR, developing exploitation plans and establishing a research roadmap.

The process followed was guided by the following phases.



Figure 1. The 5 stages of the Exploitation Methodology

The initial phase focused on identifying Key Exploitable Results (KERs), defining results beyond software to include datasets, roadmaps, platforms and training curricula. Then, based on the specificity of each result, the team established clear IPR and ownership. Building on this, FN mapped relevant stakeholders, industry partners, and early adopters, defining target end-user segments across companies, citizens, and public entities. This allowed the consortium to formulate precise value propositions, ensuring that each result met the concrete operational needs of its designated target audience.

The final phase of the methodology assessed the commercial and practical viability of these results through continuous exploitation pathways planning and the definition of appropriate licensing strategies, distinguishing between open-source and proprietary paths. This evaluation enabled the selection of tailored exploitation pathways, balancing commercial routes like product development and service creation with non-commercial routes such as further academic research and standardization.

Finally, the project addressed all the future research plans, results, long-term partnerships and possible future financing in the research roadmap to ensure sustainability of HiDALGO2 beyond its project lifecycle.

This methodology was executed as a recurring, annual process managed by Future Needs (FN). FN maintained constant communication with all partners to develop, refine, and continuously re-evaluate the project results frameworks. To streamline this process and minimize administrative overhead, FN conducted regular consortium meetings, held 1-on-1 meetings and designed structured templates. This collaborative effort ensured that all partners actively contributed to the exploitation of the project's results.

To further strengthen the exploitation and outreach potential of its KERs, HiDALGO2 actively participated in the European Commission's Horizon Results Booster (HRB) program, specifically under Service 3.5 (Audio Visual Service). Collaborating as part of a joint Project Group alongside two complementary exascale Centres of Excellence, EXCELLERAT P2 and Plasma-PEPSC, the consortium worked to exploit common synergies. Through a co-design process involving partners and the HRB team, the Project Group produced a joint promotional video attended go to market trainings and workshops from experts.

2.3 Dissemination and communication of exploitable results

Unlike the dissemination reports (such as D6.3), which reported on standard metrics like website traffic and social media growth, here this subsection will focus a bit more on the extra mile the project took to present its results to the world.

The dissemination and communication of HiDALGO2's exploitable results was specifically tailored to accelerate results adoption among three core stakeholder groups: Big Companies, Research/Academia, and National and Local Government. Rather than broadcasting general project awareness to the public, the consortium focused on strategic transfer of the project's codes, datasets, and portals directly into the hands of potential users who can sustain them.

To engage the Research and Academic community, scientific outcomes were published in high-impact open-access journals and deposited in public repositories like Zenodo and ResearchGate, complemented by open-science web infrastructures such as the Ktirio Cases portal [3], the the SZE Computational Fluid Dynamics Renderer (CFDR) web viewer [4] , and the HiDALGO2 Moodle platform [5] . A major pathway for academic knowledge transfer was active and recurring participation at European and international supercomputing forums. The consortium maintained annual participation in established scientific venues, most notably: the International Conference on Parallel Processing and Applied Mathematics (PPAM), where HiDALGO2 co-organized the dedicated Advancements of Global Challenges Applications (AGCA) workshop, alongside recurring presence at HiPEAC, International Supercomputing Conference (ISC), First International Conference on AI-based Systems and Services (AISyS), where the project received the Best Paper Award, and the EuroHPC Summit. Furthermore, capacity-building training sessions, such as the joint Uncertainty Quantification (UQ) Hackathon in Stuttgart (introducing the "mUQSA" toolkit alongside CIRCE and SEAVEA) and the collaborative CI/CD benchmarking sessions with the Karolina supercomputer, drew an audience predominantly composed of academic researchers, PhD candidates, and external software developers seeking to apply CoE frameworks to their own simulation workflows.

To reach National and Local Government entities, public decision-makers, and emergency responders, the consortium moved beyond traditional scientific

dissemination to deliver direct, operational capacity building and localized policy tools. Primary engagement focused on civil protection bodies and municipal authorities that require real-time, mandatory decision support. Key highlights included specialized, hands-on operational training delivered directly to first responders from the Spanish Military Emergency Unit (UME) and the Spanish National School of Civil Protection, integrating coupled fire-atmosphere and Wildland-Urban Interface (WUI) tools into real-world disaster response workflows. At the municipal level, direct outreach campaigns engaged urban planners and environmental agencies; to demonstrate how localized digital twins translate complex climate projections into actionable municipal renovation and toxic gas management strategies. Some of them include, the Strasbourg Eurometropolis, the Strasbourg Climate Agency (Agence du Climat), and city authorities in Stockholm and Győr.

To drive adoption among Big Companies and Industrial Partners, dissemination activities focused on co-design partnerships, commercial fairs, and targeted B2B networking events. Industrial engagement included collaborative validation campaigns with major engineering consultancies like Nepsen to refine building energy KPIs for professional regulatory audits, as well as co-design initiatives. Furthermore, consortium partners presented specialized toolkits at commercial and industrial venues, including the AI EnergyNN fair (targeting Distribution System Operators and energy grid operators) and specialized offshore engineering sessions demonstrating waLBerla's aquatic sediment transport modeling for wind turbine foundations and laser welding applications.

The primary wheel for showcasing the project's final exploitable results was the dedicated HiDALGO2 Clustering Event, held on 4 November 2025 at the High-Performance Computing Centre Stuttgart (HLRS). Coordinated and designed by FN, this event was structured show to engineers, businesses, scientists the tools of the project and the services they can offer. The event successfully brought together over 40 physical attendees, representing policymakers, research institutions, industry professionals, and technology-focused Small-Medium Enterprises (SMEs). Live demonstrations and showcases highlighted the operational capabilities of the entire HiDALGO2 toolset and Dashboard, featuring displays of exascale-ready digital twins like the Ktirio urban building dashboard, the Stockholm air quality model and virtual reality simulations of wildfire behaviour. The whole event was covered visually, with interviews, videos and recorded sessions, which gave the project an amazing opportunity for its results to reach an even bigger audience.



Figure 2. Pictures from the Clustering Event in Stuttgart

2.4 Monitoring and evaluation

Exploitation is monitored so that the plan can be corrected accordingly. Two mechanisms are used, an internal one based on indicators and an external one based on review.

Indicators

The indicators below are those used for exploitation and sustainability specifically. They are deliberately few and they are split between what can be measured during the project and what only becomes measurable afterwards. They are listed in Table 2.

Table 2. Exploitation and sustainability indicators

Indicator	Status at the time of writing
Exploitable results identified and categorised	Complete, reported in Section 6
Assets recorded with owner and licensing conditions	Complete, in Annex I of the Exploitation Agreement
Exploitation Agreement signed by participating partners	Due month 45, signature expected before this deliverable is submitted
External organisations engaged per use case	Achieved in all five domains, listed in Section 3.2
Use cases ranked by likely demand	Complete, in Section 3.2
Catalogue of services published	Delivered
Cost and revenue model with derived figures	Complete, in Section 4

Tender opportunities identified and bids submitted	Not yet applicable, begins with business development
Engagements won and revenue received	Not yet applicable, first indicator of commercial viability
Functions maintained between engagements	To be monitored after the project, listed in Section 5.3

Several of these have no target figure attached and that is intentional. Setting a target for engagements won before any business development has taken place would produce a number with no basis. The break-even analysis in Section 4.4 gives the figure that matters, which is roughly seven engagements a year and that becomes the target once the first bids have established a realistic win rate.

Review

Three levels of review apply:

- Within the consortium, exploitation is a standing item at plenary meetings and is reviewed by the Project Coordination Committee between them. This is where indicators are checked and where changes to the plan are agreed.
- By the Advisory Board, annually at a plenary meeting. The Board is external to the consortium and reviews the exploitation position as a whole.
- By the European Commission at the formal project reviews.

After the project the Exploitation Coordination Committee takes over the internal function, since it is constituted under the Exploitation Agreement and survives the end of the Grant Agreement. Its remit includes reviewing opportunities and agreeing revenue distribution and monitoring the indicators in the lower part of the table above follows naturally from that.

How review findings are used

The review conducted by the Advisory Board in June 2025 serves as the clearest example of how this mechanism operates. It is described here because it illustrates the purpose of the entire process. The Board asked for the cost model to be re-run on more realistic assumptions and for the market data to be updated. It questioned whether the claimed advantages actually translated into benefits for the customer. It also requested a full business case (covering the entire project lifecycle) and an estimate of the scale of operations required to ensure the project's viability. It also asked how operational capability would be maintained if a follow-on project started late.

Each of these points influenced the final form of the document. The cost model was revised and the figures within it were significantly increased. Market data were updated

and the competitive analysis was reworked to focus on what the customer actually acquires. A detailed business case and a break-even analysis were added. A new section on resources and business continuity was added. Section 1.4 maps the specific comments to the relevant parts of the document where they were addressed.

This is the intended approach: the review yields specific comments, these comments lead to plan modifications and the changes made are recorded so that their adequacy can be assessed during the subsequent review.

3 Market assessment and sustainability plan

This Section assesses the market the consortium would be entering and what sustaining the results requires. It answers three questions in sequence. The first is where HiDALGO2 stands relative to the conditions it faces. The second is who would buy the services and what that is worth. The third is what has to continue after the project for any of it to happen.

It follows the method in Section 2.1 and differs from D6.5 in three respects. Market figures are refreshed and separated into sector context, addressable market and engagement value. A competitive analysis is added, developing the point D6.5 identified as necessary. Customers are distinguished from stakeholders throughout, which changes what counts as evidence of demand.

The Section is deliberately selective. The five use cases are ranked by likely demand, claimed advantages are limited to those a customer would pay for and weaknesses that cannot be mitigated are stated. The customer segments and engagement values that follow are the inputs to the business model in Section 4 and the priorities set in Section 3.2 determine where effort is concentrated in Section 5.

3.1 Strategy Analysis

Two analyses are used. A SWOT analysis sets out where the consortium stands relative to the market it wants to enter. A PESTLE analysis covers the external conditions that will help or hinder it. Both were introduced in D6.5 at framework level. They are developed here with the content that bears directly on HiDALGO2. The economic factor appears in both analyses, so its treatment is aligned across them. Figure 3 summarises the result.

SWOT analysis

Table 3 sets out the internal position and Table 4 the external one.

Table 3. Internal position of strengths and weaknesses

Strengths	Weaknesses
Specialists from established European research institutes, with combined competence across CFD, weather modelling, HPC engineering and visualisation that few single organisations hold.	Little experience of commercial activity. Most consortium members are researchers who have not sold services before.

Working knowledge of exascale-class systems and of the software engineering needed to use them.	No financial reserve to carry a start-up period and no institutional mechanism in several partners for contracting commercially without an affiliated entity.
Validated models and workflows in five domains, developed and tested over the project.	No commercial track record. The consortium has not delivered paid work in these fields, so it has no references to show a first customer.

Table 4. External position: opportunities and threats

Opportunities	Threats
Regulatory obligation. EU directives on air quality, water and energy oblige public bodies to assess and act, which creates demand that does not depend on discretionary spending.	Weak initial demand. Public bodies may prefer familiar suppliers and a first contract is difficult to win without references.
Few providers combine high-resolution simulation with the capacity to run it at scale, so the specific niche is not crowded even though the wider consultancy market is.	Established consultancies with existing client relationships, sales capacity and delivery track records.
Growing use of digital twins and scenario modelling in public planning, which is the form in which these services are increasingly procured.	Public budgets under pressure, with spending in several member states redirected towards defence and fiscal consolidation.
Cities and regions already engaged during the project, which shortens the path to a first reference customer.	Loss of technical capability between projects, which would leave assets that cannot be offered at short notice.

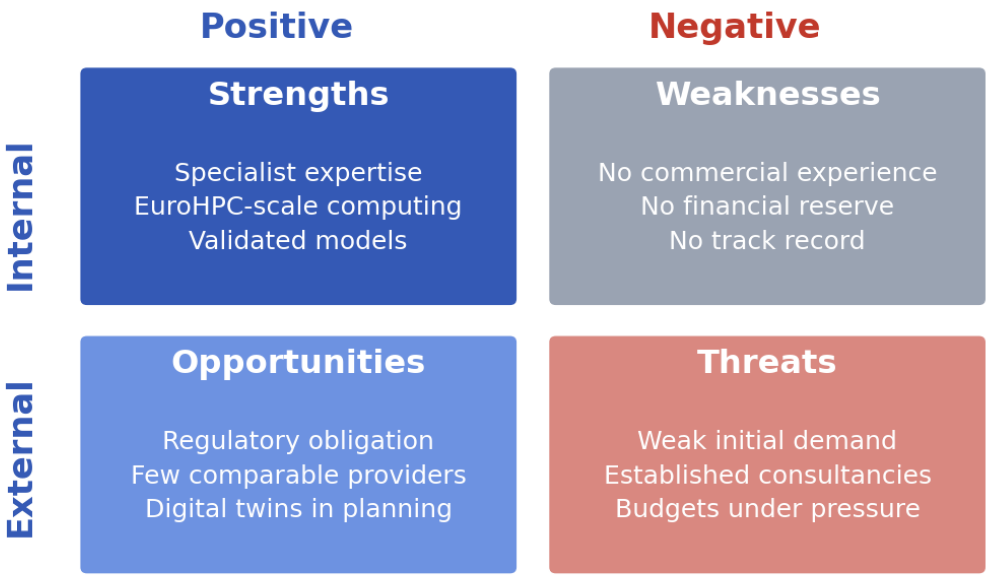


Figure 3. SWOT summary for HiDALGO2

PESTLE analysis

The factors that matter to this offer are the following.

- **Political.** Public budgets in several member states are being redirected towards defence and consolidation. Environmental modelling competes for a share of spending that is not growing and in some countries is contracting.
- **Economic.** Procurement is cost-sensitive and increasingly tightly scrutinised. Price matters more than it did, which favours a provider whose rates sit below commercial consultancy levels.
- **Social.** Public awareness of air quality, flooding and wildfire risk is high and rising, which sustains political attention even where budgets are constrained.
- **Technological.** Simulation at high resolution is becoming more accessible and cloud-based competitors are lowering the barrier to entry. The technical advantage held today should not be assumed to persist.
- **Legal.** EU environmental directives create obligations to assess and report, which is the most reliable driver of demand. Data protection and public procurement rules shape how the work can be contracted and delivered.
- **Environmental.** Adaptation to climate change is now an operational requirement for cities, utilities and regional authorities, no longer only a long-term concern, which is the underlying reason the services have a market at all.

Refining the economic factor

In document D6.5, the economic situation in the EU was considered an opportunity, based on the assumption that European countries are willing to invest in quality of life. However, the previously mentioned political factor allows for a more precise perspective on this issue. A general willingness to invest is a less reliable source of demand than it might initially seem. This type of spending is usually one of the first to be cut when budgets tighten. Actions that public authorities are obligated to implement are more permanent. Therefore, this opportunity is best viewed in terms of regulatory requirements and the offer should be structured in relation to the obligations the customer must fulfil.

Choosing a strategy

D6.5 stated that the factors would be weighted in this deliverable so that a strategy could be selected from four standard options. Each factor is given a weight within its group, with the weights in each group summing to one and a score from one to five for how strongly it applies. The weighted scores are then compared within the internal pair and within the external pair. Table 5 shows the result.

Table 5. Weighted SWOT scores

Group	Dominant factors	Weighted score
Strengths	Specialist expertise 0.40, exascale-class computing 0.35, validated models 0.25	3.75
Weaknesses	No commercial experience 0.40, no financial reserve 0.35, no track record 0.25	4.00
Opportunities	Regulatory obligation 0.35, few comparable providers 0.25, digital twins in planning 0.20, organisations already engaged 0.20	3.55
Threats	Weak initial demand 0.30, established consultancies 0.30, budgets under pressure 0.25, loss of capability 0.15	3.45

Weaknesses outweigh strengths, at 4.00 against 3.75 and opportunities outweigh threats, at 3.55 against 3.45. On the standard reading this indicates a competitive strategy, sometimes called mini-maxi, in which the favourable external conditions are used to work around the internal weaknesses. The two margins are narrow, so the conclusion should be treated as a direction, not a precise finding.

Practical meaning

A competitive strategy implies three things and each is already reflected elsewhere in this deliverable.

First, demand should be taken where it is least discretionary. That means concentrating on work a public body is obliged to carry out, as argued above and applied in the ranking in Section 3.2.

Second, the missing track record should be borrowed instead of waited for. Bidding jointly with partners who hold a delivery record and using the organisations already engaged during the project as first references, are the mitigations recorded in Section 8.

Third, the internal weaknesses have to be worked on directly, since a favourable environment does not remove them. The financial reserve, the business development capacity and the continuity of the teams are the subject of Sections 4.4 and 5.3.

An aggressive strategy would require strengths to outweigh weaknesses, which is not yet the case. A defensive strategy would require the external conditions to be hostile, which the analysis does not support. The competitive reading sits between the two and matches the position the consortium is actually in.

3.2 Customer segments

A distinction is introduced here, following Advisory Board feedback and applied throughout this deliverable.

Customers and stakeholders

Customers are those who acquire a service and pay for it. They are the subject of the business model in Section 4. Stakeholders are those who shape or fund the wider effort without buying a service, which includes ministries, funding agencies and research collaborators. Both matter, but they are approached differently and they should not be counted together. Applying the distinction shows that part of the interest recorded to date is commercial and part of it is not.

Customer types

- **Local and regional government.** Cities, regional authorities and their agencies, buying assessments that support planning decisions or discharge a regulatory duty.
- **Utilities and network operators.** Distribution system operators, water authorities and similar bodies, buying analyses that direct investment or reduce operational risk.

- **Industrial and commercial organisations.** Developers, engineering firms and energy companies, buying studies as an input to their own projects or bids.

Research organisations and universities appear in the tables below, but mainly as partners and collaborators, not as paying customers. They are treated as stakeholders unless they are procuring a service.

Prospective customers by use case

The project has engaged external organisations in all five domains during its lifetime. These contacts are the most reliable evidence of demand available, because they represent interest expressed without a contract being offered. Table 6 lists them by use case.

Table 6. External organisations engaged, by use case

Use case	Organisations engaged during the project	Customer type
Urban Air	Győr, Illkirch, Poznań, Stockholm, Stuttgart	Local government
Urban Buildings	Strasbourg, Bordeaux	Local government
Renewable Energy	A Polish Distribution System Operator	Utility and operator
Wildfires	Regional governments of Madrid and Valencia, University of Aveiro	Regional government
Material Transport in Water	Italian Institute of Technology, Technical University of Dresden	Research, stakeholder not customer

Priority by likely demand

The Advisory Board asked that the five use cases be ranked by priority. The ranking below uses three criteria. The first is whether a regulatory obligation drives the need. The second is whether the organisations engaged are able to purchase services. The third is how directly the result supports a decision the customer has to take anyway. The ranking is given in Table 7.

Table 7. Use cases ranked by likely demand

Priority	Use case	Reasoning
1	Wildfires	The need is operational and the benefit is immediate. Regional authorities are already engaged and prediction of

		fire spread supports decisions that must be taken regardless of budget climate.
2	Urban Air Project	Air quality obligations under EU directives create recurring assessment work. Five cities have been engaged and the customer type is one that procures studies routinely.
3	Renewable Energy	A commercial operator has shown interest and the value is expressed directly in avoided cost. The buyer is better funded than a municipality.
4	Urban Buildings	Genuine interest exists, but the work is more likely to be funded through research and innovation programmes than bought as a service, which lengthens the route to revenue.
5	Material Transport in Water	Contacts to date are academic. The route is scientific collaboration, not sale, at least initially.

This ranking determines where effort is concentrated if resources are constrained, as discussed in Section 5.3. It is a judgement based on the evidence available and should be revised as real tender opportunities appear.

Channels and relations

Identifying a customer is not the same as reaching one. Five channels are available and they differ in cost and in how quickly they produce work.

- **Public procurement portals.** Most public customers must advertise, so tenders can be followed systematically at national and European level. This is the lowest-cost channel and the main one for regulated demand.
- **Direct approach.** The Lead Generator contacts organisations whose stated needs match a service, as described in Section 5.2. Slower, but it reaches work that is never tendered.
- **Events.** Conferences, trade fairs and workshops in the five domains, where opportunities surface early enough to prepare for.
- **The portal.** The project dashboard, adapted as a single entry point for external enquiries, so that interest arriving unprompted has somewhere to land.
- **Referral.** Organisations engaged during the project and partners who already hold client relationships in a domain, introducing the consortium to work it would not otherwise see.

The European Commission services described in Section 5.2, in particular the Horizon Results Platform and the Innovation Radar, act as a sixth channel at no cost. They are passive, so they supplement the others instead of replacing them.

Relations with customers are handled in three stages. During an engagement a single named contact from the Service Provider is responsible for the customer, which

matters because the delivery team is drawn from several partners. At the close of an engagement the results are presented in a workshop and not only sent, since that is where follow-on needs usually emerge. After delivery the surrogate models described in Section 4.3 give the customer a reason to stay in contact, because further sites can be screened without commissioning new simulations.

The aim in each case is repeat work. A first engagement is expensive to win, as Section 4.1 shows, so the value of a customer lies in the second and third contract more than in the first.

3.3 Key partners

Partners fall into two groups. Those inside the consortium, who own the assets and will deliver the work and those outside it, whose involvement makes the work possible or more valuable.

Within the consortium

Each asset listed in the Exploitation Agreement has an owner and ownership carries the right to decide whether the asset is offered commercially. In practice partners take one or more of three roles, described in Section 5.2. They own intellectual property, they deliver services, or they generate and qualify opportunities. Most partners will do the first and, where they choose to take part, the second. The third requires business development capability that is unevenly distributed across the consortium and this is one of the constraints on how much commercial work can be pursued.

PSNC holds an additional role as chair of the Exploitation Coordination Committee and as the partner leading the legal framework, which is described in Section 5.1.

Outside the consortium

- Cities, regions and operators already engaged during the project. These are prospective customers and they are also the source of the references a first commercial engagement depends on.
- EuroHPC and national computing centres, whose resources the delivery model relies on. The terms of that reliance are examined in Section 5.3.
- Research institutes and universities working in the same domains. Some are potential competitors for publicly funded work, but most are more useful as collaborators, particularly where a bid needs domain credibility the consortium does not hold.
- Other centres of excellence and European initiatives, which provide a route to joint offers that are larger than any single centre could bid for.

The boundary between partner and competitor is not fixed. Organisations such as national research institutes may compete for one opportunity and collaborate on the next. This is normal in the sector and it argues for maintaining relationships across the sector.

3.4 Market size estimation

The Advisory Board made two points about the market sizing in D6.5. The figures have been refreshed to current base years and the analysis now separates the sector total from the part HiDALGO2 can address, which is much smaller. Both points are dealt with here.

Method

Three levels are distinguished. The sector total gives context and shows that the field is substantial. The addressable part is the share of that sector that corresponds to what the consortium can deliver, which is far smaller. The engagement value is what a single contract is worth and it is the figure that connects to the business model in Section 4. Only the third can be estimated with any confidence and the reasoning therefore runs upwards from it. Figure 4 shows the three levels.

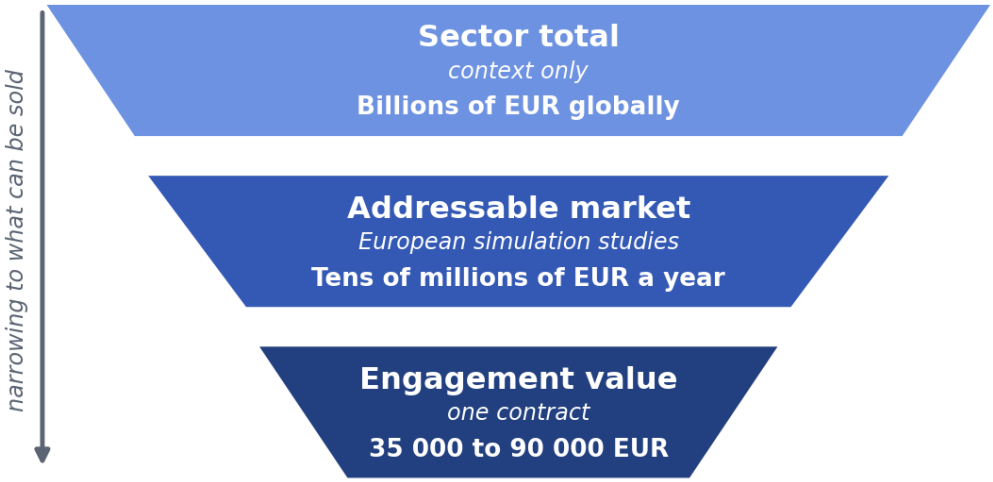


Figure 4. From sector total to the value of a single engagement

Sector context

Table 8 gives the reference sector for each use case and its current size.

Table 8. Reference sectors and current size

Use case	Reference sector	Size and outlook
Urban Air	Air quality monitoring, global	Around USD 7.2 billion in 2025, projected to roughly double by the mid-2030s at about 8% annual growth. Europe accounts for the largest regional share, above 40% [12] .
Urban Buildings	Building information modelling, global	About USD 9.0 billion in 2025, forecast to reach USD 15.4 billion by 2030 at about 11% annual growth. The European share is about USD 2.4 billion in 2025 [13] .
Renewable Energy	Renewable energy generation	Measured in hundreds of billions of euro and growing steadily. The figure is too broad to be informative and the addressable estimate below is used instead.
Wildfires	Forest wildfire detection systems, global	About USD 740 million in 2023, projected to exceed USD 1.26 billion by 2032 at about 6% annual growth [14] . The related aerial firefighting market is roughly USD 5 billion.
Material Transport in Water	Water quality monitoring, global	Around USD 6 billion in 2025, projected to roughly double by the mid-2030s at about 7% annual growth [15] .

Two cautions should be noted regarding all this data. Published estimates for the same sector vary significantly depending on the provider, sometimes even by a factor of two, because different entities define the sector in different ways. Furthermore, measurement equipment, software licences and monitoring hardware dominate these sectors, not simulation-based research. Consequently, the aggregate data for the individual sectors merely confirm that this is a large and growing field. They do not indicate what resources are available for the HiDALGO2 project.

What can be addressed

The addressable part is the provision of high-resolution simulation studies and the analysis derived from them, delivered as consultancy to organisations that need the result for a decision. This excludes hardware, monitoring networks and software licensing, which is most of the value in the sectors above. Within Europe, the realistic customer population is of the order of several hundred organisations across the five domains. These are larger cities and regional authorities, network and water operators and the engineering firms serving them. Only a small fraction of these organisations will commission such a study in any given year. On that basis the addressable market for this kind of work is measured in tens of millions of euro annually across Europe.

Engagement values

The most useful figure is what one engagement is worth. The values below are indicative and were derived by sizing the work involved and checking it against the cost model in Section 4.1 and against public procurement practice. For reference, the EU threshold above which open tendering is required for central government services is approximately 143 000 EUR, which is a natural boundary between a routine engagement and a major one. Table 9 gives the indicative values.

Table 9. Indicative engagement values by use case (EUR)

Use case	Typical engagement	Routine	Larger or multi-year
Urban Air	Pedestrian comfort and pollutant dispersion study for a city district	40 to 70 000	120 to 200 000
Urban Buildings	Building energy and comfort simulation for a development or campus	35 to 60 000	100 to 180 000
Renewable Energy	Infrastructure risk and yield prediction for an operator	45 to 80 000	130 to 220 000
Wildfires	Ensemble fire spread modelling for a regional authority	50 to 90 000	150 to 260 000
Material Transport in Water	Scalar transport and surrogate modelling for a water body	35 to 60 000	110 to 190 000

These values are consistent with the cost model in Section 4.1 (Table 13), where a routine engagement is costed at about 56 000 EUR and priced at 78 000 EUR. Section 4.4 sets out how many such engagements would be required for the activity to sustain itself.

3.5 Competitive landscape

The Advisory Board asked three questions about competitors. What do they offer, what do they charge and where are they weak. It also warned against claiming technical advantages that do not correspond to anything the customer values. This section answers the three questions and takes the warning seriously.

Identification of competitors

The competitor is the organisation a customer would hire instead, not the software that organisation uses. This distinction matters because simulation packages such as commercial CFD solvers or open-source alternatives are tools available to everyone, including HiDALGO2 partners. They are not bidders for the same work. Table 10 identifies the competitors per use case.

Table 10. Organisations competing for the same work

Use case	Commercial providers	Non-commercial providers
Urban Air	Ricardo, RWDI, Trinity Consultants, WSP	National environment agencies, university groups
Urban Buildings	RWDI, SLR, engineering and facade consultancies	Building research institutes
Renewable Energy	DNV, Ricardo, Wood, DHI	Operator research units, energy institutes
Wildfires	Technosylva and specialist geospatial firms	Forest and civil protection agencies, research laboratories
Material Transport in Water	DHI and hydraulic engineering consultancies	Deltares, university hydraulics groups

The established providers are large organisations. RWDI, a Canadian wind engineering consultancy, employs of the order of eight hundred people and has delivered tens of thousands of projects in wind and microclimate engineering. DHI, a Danish water modelling firm, employs about a thousand people in around thirty offices worldwide and has supplied water modelling tools for decades. Ricardo has worked in air quality measurement and modelling for decades and maintains national-level air quality data infrastructure. These are not marginal competitors and the consortium should not present itself as facing an empty field.

What they charge

Day rates for established environmental and engineering consultancies in Western Europe generally sit above 1 000 EUR for senior specialist staff. A defined study of the type described in Section 3.4 is usually priced in the same range as the engagement values given there, or above them. The rate implied by the HiDALGO2 cost model is 600 to 700 EUR per day, as set out in Section 4.2. Price is therefore a genuine advantage and it is one of the few that can be stated without qualification.

Strengths and weaknesses

Table 11 sets out where competitors are strong and where they are weaker.

Table 11. Competitor strengths and weaknesses

Where competitors are strong	Where they are weaker
Existing client relationships and frameworks, often built over decades. A city that has used a consultancy before will usually use it again.	Standard methods applied at moderate resolution. Where a question genuinely requires high-resolution or coupled modelling, the tooling is often not there.
Sales and bid capacity as a permanent function, not something fitted around delivery work.	Limited access to large-scale computing, which constrains what can be attempted within a commercial timescale.
Commercial reliability. Contractual delivery, insurance, references and the ability to absorb a problem without the work stopping.	Higher cost, which matters increasingly as public procurement becomes more price-sensitive.
Regulatory familiarity, including knowing how a result must be presented to satisfy a particular authority.	Less depth in emerging methods such as ensemble uncertainty quantification and surrogate modelling.

The value proposition

The Advisory Board's warning applies here. Access to EuroHPC systems and the combined expertise of the consortium are facts about the consortium, not benefits to a customer. A customer buys an answer to a question and what matters is whether the answer is better, faster, cheaper or more defensible than the alternative. On that basis three claims can be defended.

- **Resolution and coupling.** Where a question depends on local terrain, building geometry or the interaction between weather and a local process, the results are more detailed than standard consultancy methods produce. This is a real advantage, but only for questions that genuinely require it. For routine assessments it is not worth paying for.
- **Uncertainty handled explicitly.** Ensemble methods give a range of outcomes, not a single figure. That supports decisions about risk. This is valuable to a customer allocating a reinforcement or mitigation budget.
- **Price.** The rates above are lower than established consultancies charge, for work of comparable or greater technical depth.

However, the consortium doesn't yet have experience in implementing commercial projects. It's the existing market players who possess the knowledge of regulatory requirements in individual jurisdictions. The ability to respond quickly at the level typical of established consulting firms is limited because the same teams also handle research. These are the weaknesses outlined in Section 3.1 and they are real.

3.6 Sustainability plan

Sustainability means that the results of the project remain available and continue to develop after the funding ends. That can happen in more than one way and not every result needs the same route.

Three goals

- **Commercial.** To obtain income from services so that the capability behind them can be maintained and developed. This is the subject of Sections 4 and 5.
- **Scientific.** To continue developing the models and the operational capability, funded partly by the commercial work and partly by continuing research projects, so that the offer does not fall behind.
- **Social.** To continue disseminating knowledge about responsible management of natural hazards and the effects of urban development. This produces no income directly, but it sustains the visibility and credibility on which the other two depend.

Sustained results

The results fall into several kinds and the route differs by kind, as shown in Table 12.

Table 12. Categories of result and their sustainability route

Kind of result	Examples	How it is sustained
Integrated platform	Data management system, workflow orchestration, uncertainty quantification tooling, portal	Maintained as shared infrastructure by the partners operating it and used in delivering commercial engagements
Pilot applications and workflows	The five use case workflows and their demonstrators	Commercial route for those ranked highest in Section 3.2, maintained but not actively developed for the others
Models and surrogate models	Simulation models and the reduced models derived from them	Developed further through both research projects and paid adaptation work
Datasets	Case collections and geometry data	Open publication, with maintenance by the owning partner
Software tools	Visualisation bridges, renderers and supporting components	Open source where already released, with paid support and adaptation as an option

Not everything is sustained commercially and that is deliberate. Open datasets and open-source components create the visibility and credibility that support the commercial offer and they cost little to keep available. The commercial route applies to a narrower set of results where a customer needs, a distinctive capability and a viable delivery model coincide. Figure 5 shows the three routes and what each sustains.

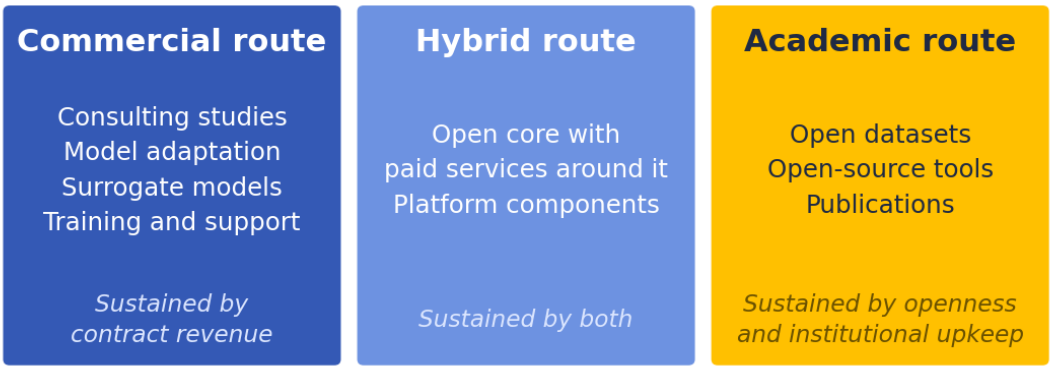


Figure 5. Sustainability routes for the different kinds of result

What this requires

The commercial objective depends on the business model defined in Section 4 and on the governance and resource arrangements outlined in Section 5. The scientific objective depends on partners maintaining research funding in these areas, as discussed in Section 5.3. The societal objective depends on continued dissemination activities. These are the least resource-intensive of the three objectives, but they are also the first to be abandoned when attention moves elsewhere. Responsibility for these activities rests with the Exploitation Coordination Committee under its permanent remit.

4 Business model and financial analysis

This Section concerns how the services described in Section 3 would be paid for and whether they can sustain themselves. It responds to the Advisory Board's request for figures detailed enough for the business case to be judged.

Section 4.1 sets out what an engagement costs and how each figure is arrived at. Section 4.2 covers how the work is priced and where revenue comes from. Section 4.3 follows one engagement through from first contact to final result. Section 4.4 asks how many such engagements are needed to cover the standing cost of the capability and how long that capability has to be carried before the first income arrives.

All figures are first-order estimates. They are presented with their assumptions visible so that each one can be challenged and replaced as better market information becomes available.

It is worth naming the position the project is in, because it is a recognisable one. In the final year of a grant, centres of excellence commonly hold results that are technically mature and have attracted genuine user interest. What they lack is an operating model to sustain those results once the funding stops. The gap in that situation is neither technical nor a gap in demand. It is the absence of a financing and delivery logic. Where that is the case, further development work and further user engagement do not improve matters. What is needed is a sustainability plan with an operating model and a revenue logic attached and that is what this Section sets out.

4.1 Cost model

The cost model in D6.5 treated the whole offer as a single consultancy category and arrived at roughly 3 500 EUR for a realistic engagement. The model has been rebuilt around five categories that reflect how an engagement actually incurs cost. Compute, data and the cost of winning the work are now itemised separately, which accounts for most of the difference from the earlier figure.

Cost categories

- **Personnel and effort.** Specialist time for model setup, calibration, production runs, analysis and reporting.
- **Hardware and compute.** Node-hours for production and validation runs, together with storage for inputs and results.
- **Data.** Acquisition and licensing of meteorological, terrain and asset data that the project does not already hold.
- **Sales and lead generation.** Business development, event presence and the preparation of bids, including those that are not won.

- **Overhead and audit.** Coordination, quality assurance, financial audit and administration.

Institutional indirect costs are treated inside the person-month rate, outside the overhead line, so the two do not overlap.

Two scenarios

The realistic scenario is a single mid-size study delivered with existing functionality, needing no significant change to the models or the workflow. The optimistic scenario is a larger engagement involving several partners, where the model is adapted to the customer's requirements and the work extends over a longer period. Table 13 gives the figures for both.

Table 13. Cost model per engagement, by scenario

Cost line	How the figure is reached	Realistic	Optimistic
Personnel and effort	3.5 person-months in the realistic case and 10 in the optimistic case, at about 9 000 EUR per person-month for a senior specialist	32 000	90 000
Hardware and compute	Ensemble of production and validation runs, of the order of 40 000 to 60 000 node-hours, priced at indicative rates, plus storage	6 000	18 000
Data	Licences for meteorological and high-resolution terrain data and preparation of asset data supplied by the customer	3 000	7 000
Sales and lead generation	About three bids prepared for each one won, at roughly 3 000 EUR of effort per bid	9 000	22 000
Overhead and audit	Approximately 12% of the direct cost lines	6 000	15 000
Total cost		**56 000**	**152 000**

The sales and lead generation figure is derived from the tender volume discussed in Section 4.4. If roughly one bid in three succeeds, then each won engagement carries the cost of the two that did not. This is why the line cannot be a token amount and it is the single largest addition to the earlier model after personnel.

Basis of the figures

The figures are first-order estimates prepared by the consortium. They are not European averages.

The person-month rate is checked against the HiDALGO2 budget. The grant plans about 4.47 million EUR of personnel cost for 814 person-months. This gives about 5 500 EUR per person-month, or about 6 900 EUR with the 25% flat rate for indirect costs. The model uses 9 000 EUR, because commercial work is delivered mainly by senior specialists, who cost more than the project average.

Compute is priced at indicative rates for partner-owned systems. The data line, the bid effort and the overhead share are the authors' estimates. Risk F in Section 8 covers the case where these estimates prove too low, and the model will be revised after the first engagements.

The revised total is about sixteen times the earlier figure for a comparable engagement. The increase comes from realistic staff rates, from itemising compute and data and from charging the cost of acquisition to the work it wins. Figure 6 compares the two scenarios line by line.

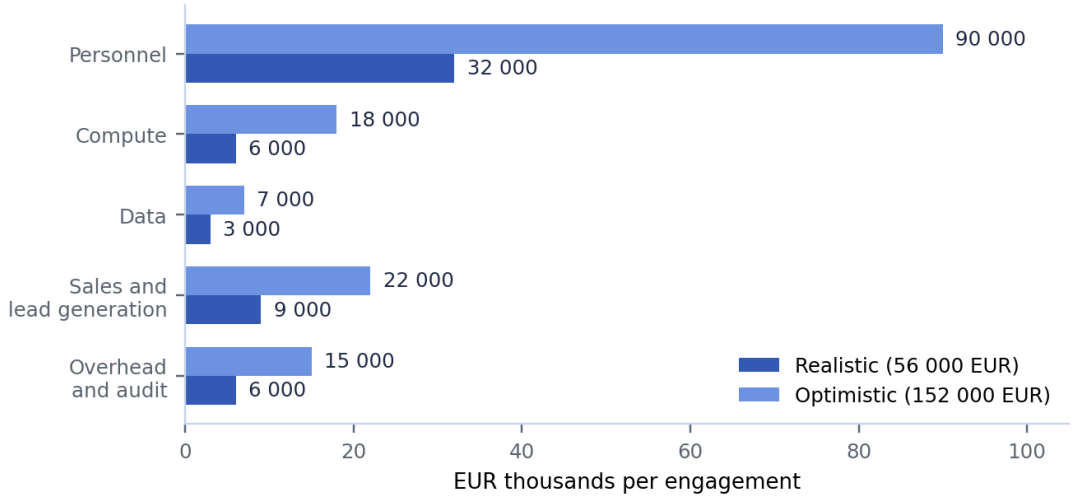


Figure 6. Cost structure per engagement, realistic and optimistic scenarios

4.2 Revenue model and pricing

Pricing must achieve two goals at once. The offer has to be acceptable to a client who could also approach a commercial consultancy. It also has to leave a margin large enough to maintain capability between contracts.

Results compatibility with a commercial path

This Section discusses results suitable for implementation along a commercial or hybrid path, however this does not apply to all results. A result is compatible with the commercial path if it addresses a specific user need. It must also offer value that is difficult to obtain elsewhere and be sustainable through contracts or other revenue. Typical examples include licensed software, managed operational processes,

consulting services and specialized technical support. A result, on the other hand, is compatible with the academic or public domain path when its value stems primarily from scientific applications, open reuse, or relevance to public policy. This category includes, among others, open-source research software, test datasets and training materials. Their continued existence depends on the openness, reproducibility of results and maintenance by a given institution or community. Many results fall between these two paths, implementing a hybrid model. An example would be an open database combined with paid services. This issue is linked to another crucial point that's easily overlooked: the chosen path must be tailored to the team's actual capabilities. A result with significant commercial potential won't be commercialized by a group lacking the necessary expertise, institutional support, or the will to undertake such activities. We return to this topic in section 5.3, which specifies the scope of commercial work a consortium can realistically implement.

Pricing basis

We use two pricing methods. The preferred method, which covers most studies, is a comprehensive flat-rate price, which is applicable when the scope of work can be determined in advance. This solution provides the client with budget certainty (which is particularly important for public institutions and utilities operating in regulated sectors) and rewards the consortium for efficient work. The time-and-materials pricing model is used where the scope of work is open-ended. It also covers extensions to completed studies, advisory work and further analyses that the client commissions in stages.

For time-and-materials-based pricing, the rate is based on the cost assumption for one person-month used in the cost model. The direct cost of a senior specialist, estimated at approximately 9 000 EUR per person-month, translates to approximately 450 EUR per working day. After accounting for implementation costs, the daily rate is 600 to 700 EUR. This is lower than rates offered by established consulting firms operating in these industries, which is a significant competitive advantage, but it also means that scale is crucial. The margin per day is small, so profitability depends on the continuity of orders, not on high unit rates.

Revenue by scenario

Three scenarios are carried forward from D6.5, now with figures attached. The baseline is the case where no customer is acquired. It produces no revenue, but it is not cost free, because the standing cost of maintaining the capability continues regardless. Table 14 compares the three.

Table 14. Revenue and contribution per engagement, by scenario (EUR)

Scenario	Cost	Price	Contribution	Margin
Baseline, no customer acquired	0	0	0	not applicable
Realistic	56 000	78 000	22 000	28%
Optimistic	152 000	210 000	58 000	28%

The margin is deliberately the same in both active scenarios. A larger engagement costs more and earns more, but it does not earn proportionally more, because the additional work is mostly additional effort, with little reuse of what already exists.

Sources of revenue

- Consultancy studies. The core offer and the basis of the worked example in Section 4.3.
- Model adaptation and development. Work to extend a model to a customer's specific case, priced separately from the study itself.
- Surrogate models and tailored tools. Delivered so that the customer can screen further cases without commissioning new simulations.
- Training and knowledge transfer. Workshops and support for customers who wish to run parts of the workflow themselves.
- Access and support services. Assisted use of the platform and the portal, where the customer wants the capability itself instead of a finished study.

Two routes to market

A distinction matters here and is drawn explicitly. Some customers will buy a study through ordinary procurement, as a service contract for a defined deliverable. Others, particularly cities and public bodies, are more likely to fund the same work through a research and innovation procurement programme, or as a partner contribution to a co-funded project. The technical work may be similar in both cases, but the contracting, the timescale and the price expectation are not. Bids therefore have to be shaped to the route and the pipeline discussed in Section 4.4 contains both kinds.

Margin allocation

The margin shown above does not constitute distributable profit. It funds model maintenance, technical team availability and business development activities necessary to secure further orders. Section 4.4 specifies the annual percentage of this amount required for a given area of expertise to cover its costs.

4.3 End-to-end business case

This section follows a single engagement from first contact to final result. The customer is a representative example and the figures are illustrative, but both are modelled on a contact established during the project. The purpose is to show in one place how the cost model, the pricing approach and the value proposition fit together.

The Client and the Problem Addressed

The client is a regional distribution system operator. An increasing number of distributed solar and wind energy sources are being connected to its network, which creates two problems. Extreme weather events cause damage to the grid infrastructure and the operator is unable to determine which parts of it are most vulnerable to such risk. Estimated capacity at potential connection points is also uncertain, as available data relates to the regional climate, not specific site conditions.

Currently, the operator relies on design standards and general reanalysis data that do not take into account the specifics of local terrain or microclimate. As a result, funds allocated for grid modernization are distributed evenly, instead of being directed to those areas where the greatest risk actually exists.

Why should a customer pay for service?

Infrastructure reinforcement programs implemented by an operator of this size involve annual expenditures in the millions of euros. The value of this study lies not in the simulation itself, but in the ability to redirect these expenditures. If the analysis allows for redirecting even a small portion of funds to facilities truly at risk, the costs incurred will be more than recouped. This is precisely the test that the proposed solution must pass and this is the main argument in favour of this proposal.

Delivered services

The engagement covers five services:

- preparation and quality control of terrain, asset and meteorological input data
- setup and calibration of the coupled weather and CFD workflow for the selected network area
- ensemble simulation of extreme wind and precipitation events on EuroHPC resources
- a surrogate model allowing the operator to screen further sites quickly, without new simulations
- delivery of exposure maps and a ranked site list, with a written report and a results workshop

The deliverable is a decision aid, not a software licence. The operator keeps the maps, the rankings and the surrogate model.

Price

The offer is priced as an integrated fixed-price package of 78 000 EUR for the defined scope. Further network areas can be added afterwards on a time and materials basis at an agreed day rate. Fixed pricing was chosen because it gives the operator budget certainty, which matters for a regulated utility and because the scope is well defined once the network area has been agreed.

Cost structure

Table 15 breaks the cost of the example engagement into its five lines.

Table 15. Cost structure of the example engagement

Cost line	Basis	Amount (EUR)
Personnel	3.5 specialist person-months at approximately 9 000 EUR per person-month, full cost	32 000
Hardware and compute	Production and validation runs plus storage	6 000
Data	Acquisition and licensing of meteorological and terrain data	3 000
Sales and lead generation	Share of business development effort per won tender	9 000
Overhead and audit	Coordination, quality assurance, audit and administration	6 000
Total cost		**56 000**

Result

The engagement returns a contribution of 22 000 EUR, about 28% of the price. That margin is not profit to be taken out of the activity. It funds the upkeep of the models and of the technical capability between contracts, which is what makes the next engagement possible at all. Section 4.4 sets out how many engagements of this kind are needed before that capability covers its own cost.

Two conditions the case depends on

First, the sales and lead generation line is a real cost and it is incurred before any revenue arrives. The team has to be kept together and business development has to be active while tenders are still being pursued. Section 5.3 addresses how that period is funded.

Second, the case assumes that EuroHPC resources are available for commercially contracted work. Current access schemes weight scientific innovation and open science, so this cannot be taken for granted. Section 8 records it as a risk, with partner-owned compute and commercial allocations as the alternatives.

4.4 Break-even and viability

Two questions follow from the worked example. How many engagements of that kind are needed before the capability covers its own cost and how long must that capability be carried before any revenue arrives. The second question matters as much as the first, because the costs come first and the income comes later.

Expenses to be covered

Between contracts the capability still costs money. Three things have to be paid for whether or not a tender is won:

- maintaining the simulation models, workflows and data pipelines so that they remain usable and current
- keeping key technical staff available, so that an engagement can start as soon as it is won
- business development that does not convert, meaning the tenders that are prepared and lost

Taken together these are estimated at 120 000 to 150 000 EUR per year, with 135 000 EUR used here as the central figure. This is a standing annual cost and it is separate from the per-engagement costs set out in Section 4.3.

How many engagements are needed

The example engagement is priced at 78 000 EUR against a cost of 56 000 EUR, so it contributes 22 000 EUR towards the standing cost. On the central assumption of 135 000 EUR per year, the capability covers its own cost at about seven engagements a year. Table 16 shows how that figure moves if the standing cost or the contribution per engagement turns out differently.

Table 16. Engagements per year required to cover the standing cost

Standing annual cost	Contribution 18 000 EUR	Contribution 22 000 EUR	Contribution 26 000 EUR
120 000 EUR	7	6	5
135 000 EUR	8	7	6
150 000 EUR	9	7	6

This is shown in Figure 7. Across five use cases and the partners able to deliver them, six to seven engagements a year means roughly one to two per use case. That is demanding but not implausible.

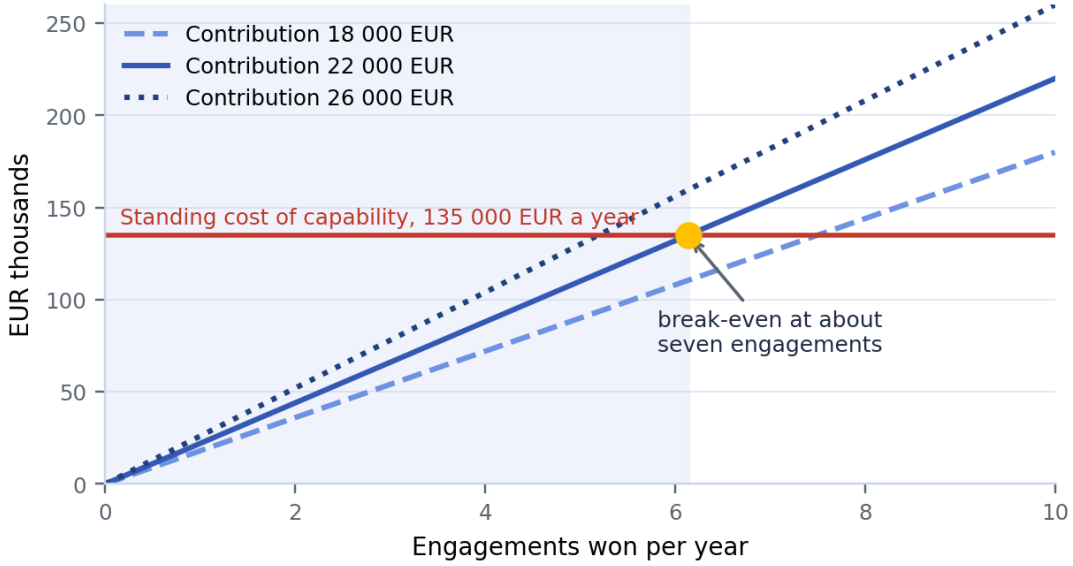


Figure 7. Engagements per year needed to cover the standing cost

Tender context

Not every tender ends in a win. If approximately one in three bids proves successful, winning seven contracts requires submitting approximately twenty bids per year. Preparing each bid involves people who also have to manage ongoing tasks. This illustrates the true scale of business development activities, described in section 5.2. It also explains why the sales and lead acquisition item in the cost model cannot have merely symbolic value.

The period before revenue arrives

Public procurement moves slowly. From first approach to a signed contract typically takes six to twelve months, delivery adds three to four months and payment terms add one to two more. On that basis twelve to eighteen months pass between starting serious business development and receiving meaningful income.

At the central standing cost of 135 000 EUR per year, that period represents roughly 135 000 to 200 000 EUR of cost carried before the first invoice is settled. Figure 8 shows how the cost accumulates before any income arrives. This is the main obstacle to viability and it cannot be met from the contracts themselves. It has to be bridged from other sources, chiefly publicly funded research projects running in parallel. Section 5.3 sets out how the teams and the funding portfolio are intended to work in that period.

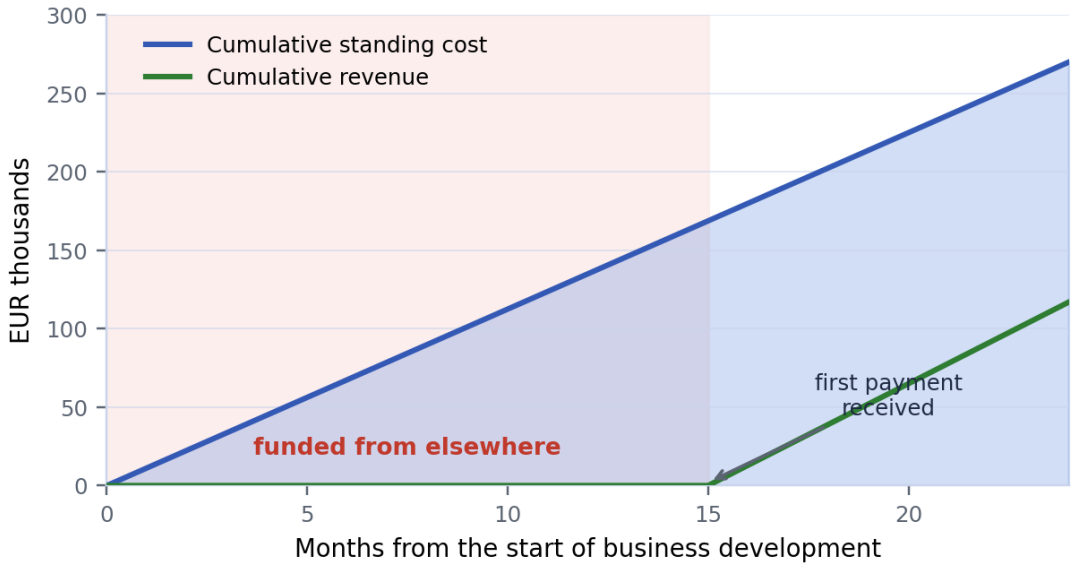


Figure 8. Cost carried before the first revenue arrives

Assessment

The margin per engagement is adequate. Viability does not turn on it. What matters is whether the tender pipeline can be kept active from the outset and whether the teams can be held together through the first twelve to eighteen months. If both hold, the service portfolio sustains itself at a realistic volume of work. If either fails, the individual engagements remain profitable but the capability behind them does not survive long enough to win them.

5 Exploitation strategy and governance

Section 4 showed that individual engagements can carry their own cost and contribute to the upkeep of the capability behind them. This Section deals with what has to exist for those engagements to be won and delivered at all. Three things are needed. A legal framework that lets partners contract jointly once the Grant Agreement has ended. A defined sequence of steps from asset to signed contract, with someone accountable at each step. And a way of keeping the teams and the technical capability in place during the period before the first revenue arrives.

5.1 Legal structure and exploitation agreement

The exploitation of HiDALGO2 results after the project cannot rest on the Grant Agreement or the Consortium Agreement, because both expire with the project. A separate instrument is therefore required and it has to be signed while the project is still running.

The exploitation agreement

That instrument is deliverable D6.7, the Legal Contract for HiDALGO2, led by PSNC and due in month 45. It takes the form of an Exploitation Agreement between the partners that wish to take part and it governs the joint exploitation of project results for the period beyond the project. It is built on the requirements of the individual partners and is not imposed uniformly, so partners with no commercial interest in a given asset are not obliged to participate in its exploitation.

Because D6.7 falls due in month 45 and this deliverable in month 46, the Agreement precedes this document. This Section therefore reflects what has been agreed. At the time of writing the text is with the partners' legal departments as the final step before signature, so details of wording may still change.

Agreement scope

- The Exploitation Coordination Committee, a standing body constituted under the Agreement itself. This matters, because it means the Committee survives the expiry of the Grant Agreement and the Consortium Agreement and does not lapse with them. PSNC chairs it.
- A list of Assets, set out in Annex I and organised by pilot, each with its owner and its associated intellectual property rights. This is the inventory from which any commercial offer is assembled.
- Provisions allowing public research organisations to act through affiliated entities, which several partners need in order to contract commercially at all.

- Treatment of assets released under open-source licences, so that open-source components and commercial services can coexist without conflict.
- Data protection obligations, which apply to work involving customer data and to the urban pilots in particular.

Relation to the wider exploitation work

The Agreement is the legal underpinning of the exploitation activity described in Task 6.2 and reported here. It does not by itself generate business. It removes the obstacle that would otherwise prevent partners from responding jointly to an opportunity. It also settles the questions of ownership and revenue in advance, instead of leaving them to be negotiated each time.

5.2 Action chain and lead generation

The Agreement makes joint exploitation possible. What turns that possibility into a contract is a defined sequence of steps, with a named role accountable at each one.

The action chain

Six elements have to be in place. The legal structure, described in Section 5.1. The governance arrangements that decide who acts on an opportunity. A catalogue of services, so that what is on offer can be stated plainly to a customer. The business model, set out in Section 4. A portal acting as a single entry point for enquiries. And a go to market approach that reaches the customers identified in Section 3. The first four are in place or drafted. The portal exists as the project dashboard and needs to be adapted for external enquiries. The go to market approach is the least developed of the six and is the main subject of continuing work. Figure 9 shows the chain and the state of each element.

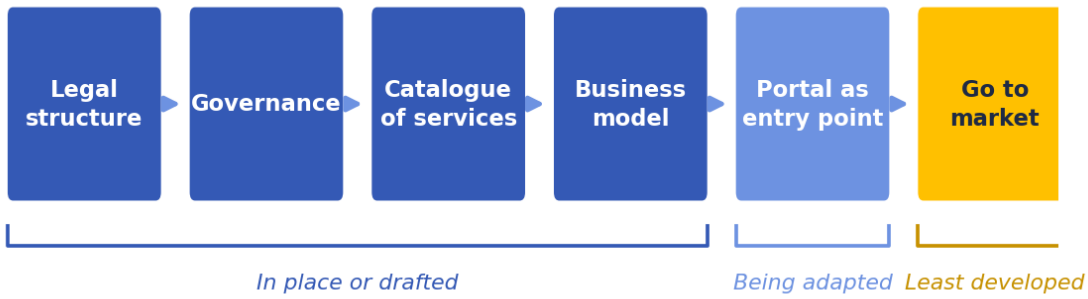


Figure 9. The exploitation action chain

Roles and responsibilities

Four roles carry an opportunity from asset to contract, as shown in Figure 10. Their responsibilities are set out in Table 17.

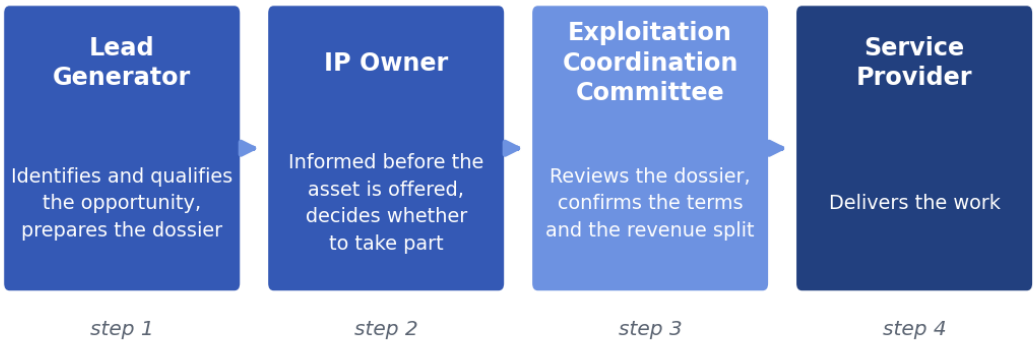


Figure 10. Governance phases and the role accountable at each

Table 17. Roles in the exploitation action chain

Role	Responsibility
Lead Generator	Identifies the opportunity, qualifies it and prepares the Business Opportunity dossier. Any partner may take this role for a given opportunity.
IP Owner	Holds the rights in an asset listed in Annex I. Must be informed before the asset is offered commercially and decides whether to take part.
Exploitation Coordination Committee	Reviews the dossier, confirms the arrangement and agrees the revenue distribution for that opportunity.
Service Provider	Delivers the work. In practice an IP Owner willing to provide the service, or several acting together.

Lead generation in practice

The Advisory Board asked what the Lead Generator actually does, noting that the term is now associated with automated and often unwelcome outreach. It is not that. It is an active business development function with four parts, set out in Figure 11.

- **Targeted research.** Following tenders, programmes and public bodies whose stated needs match a specific service, instead of approaching organisations indiscriminately.

- **Sector presence.** Attending conferences, trade fairs and workshops where the relevant customers are, so that opportunities surface early enough to bid for.
- **Qualification and dossier.** Assessing whether the opportunity fits what the consortium can deliver, then preparing the Business Opportunity dossier and informing the asset owners.
- **Hand over.** Passing the qualified opportunity to the partners who will deliver it, once the Committee has confirmed the arrangement and the revenue split.

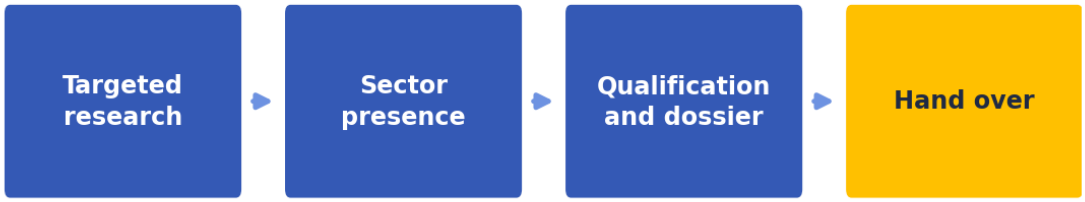


Figure 11. The lead generation sequence

This work costs money and it produces no revenue of its own. Section 4.1 charges roughly 9 000 EUR of it to each won engagement, on the basis that about three bids are prepared for each one that succeeds. Section 4.4 sets out what that means in volume, which is of the order of twenty submissions a year. Both figures follow from treating lead generation as real work, not as an incidental activity.

External support services

Several services provided by the European Commission are available at no cost and are useful at specific points in the chain. The IP Helpdesk advises on ownership, licensing and agreement questions, which matters most while the asset list and the Exploitation Agreement are being settled. The Horizon Results Booster provides structured support for exploitation strategy and business planning, which fits the stage this deliverable represents. The Horizon Results Platform and the Innovation Radar give visibility to results that are ready for potential users to find. This supports the go to market element, identified above as the least developed of the six. Systematic use of these services is a low-cost addition to the business development effort described here.

5.3 Resourcing and continuity

Section 4.4 identified the central difficulty. Between twelve and eighteen months pass between starting serious business development and receiving meaningful income. The standing cost of the capability during that period is of the order of 135 000 to 200 000

EUR. The contracts cannot pay for it, because they do not exist yet. This section sets out how that period is intended to be bridged.

Mixed portfolio

The intention is not to convert research groups into a commercial operation. It is to hold a mixed portfolio, in which the teams working on each pilot theme are funded mainly by publicly funded research projects and take on commercial work alongside it. Staff are retained on research funding and move onto a consulting engagement once it is won, returning afterwards. This has two consequences worth stating plainly. The commercial activity depends on the research funding continuing and the volume of commercial work that can be absorbed is limited by how much of the teams' time is already committed.

Current commitments

Under the Grant Agreement the partners are required to keep the project results available for five years after the project ends. D6.5 recorded that obligation and it continues to apply. It does not require the results to be developed, only kept usable. It does mean that the minimum level of upkeep described below is a commitment the partners have already made, not an option they may take.

Maintenance scope and reason

The four key functions relate to model custodianship, platform and portal operation, committee secretariat and business development. Table 18 explains why each cannot lapse.

Table 18. Functions that must be maintained between engagements

Function	Reason of maintenance
Model custodianship	Each pilot needs at least one person who can run and adapt its models. Without this the asset becomes documentation and no longer a capability.
Platform and portal operation	The dashboard and the workflow tooling have to remain usable, otherwise an engagement starts with reconstruction instead of delivery.
Committee secretariat	The Exploitation Coordination Committee must be able to convene and decide. This is a small but continuing administrative commitment.
Business development	Opportunities have to be pursued before they can be won, which is the cost discussed in Sections 4.1 and 5.2.

Lack of continuity of financing

The plan above assumes that partners hold a reasonable flow of publicly funded projects. A successor project to HiDALGO2 is the most obvious source, but it cannot be assumed and the gap between one project and the next is precisely when capability is most easily lost. If a follow-on is not approved promptly, the position changes in three ways.

- **Coverage narrows.** It will not be possible to keep all five pilot themes equally active. Priority follows the demand ranking discussed in Section 3.2 and the themes with the clearest customer interest are maintained first.
- **Custodianship becomes nominal for some assets.** An asset may be preserved in a documented and reproducible state without anyone actively developing it. This is an acceptable fallback, but the asset cannot then be offered commercially at short notice.
- **Other funding sources have to carry more.** National programmes, institutional core funding and smaller collaborative projects become the mechanism for holding teams together, in place of a single large project.

The consortium would remain in being under the Exploitation Agreement in all of these cases, since the Agreement does not depend on any project continuing. What would be at risk is the technical capability behind it, not the legal ability to contract.

Access to computing resources

The adopted cost model assumes that large-scale computing resources are available for commercial orders at specific rates. Access allocation mechanisms within EuroHPC are based primarily on scientific and technical criteria and contributions to open science and are not intended for the provision of paid consultancy services. Therefore, it cannot be assumed that access granted under the project will also apply to commercial undertakings.

There are three alternative solutions. Systems owned by partners can be used to carry out tasks of the scale described in Section 4.3, which is the most likely scenario in the near future. Commercial access to national or European systems can also be purchased, though this entails rates that would increase the computing costs included in the model. Where the nature of the computational workload permits, commercial cloud services may be used, although this typically involves higher costs. A practical approach is to plan initial activities so that they can be carried out on the partners' own resources. Access to large-scale resources should then be clarified before committing to work that depends on it. This issue has been identified as a risk in Section 8.

5.4 Mid-term and long-term strategy

Sections 4 and 5 so far describe how a single engagement works and what has to exist to win one. This section takes the longer view required under Task 6.1, which asks for a mid-term and long-term strategy built on four inputs.

How this market is expected to behave

The consortium has not yet bid for commercial work in these areas, so the observations below are expectations, not findings. They are drawn from how public procurement generally operates in the five areas the project works in: urban air quality, urban buildings, renewable energy, wildfires and material transport in water. They should be tested against real tenders as the consortium begins to bid and revised where they prove wrong.

First, a tender is expected to specify the result the buyer wants, not the method used to produce it. If so, high resolution counts for nothing on its own. It matters only where the required result cannot be produced any other way.

Second, price and evidence of comparable delivery are expected to carry most of the weight in the award criteria, with technical sophistication seldom scored as a separate item.

Third, the largest contracts are expected to be framework agreements running over several years, not single studies. These favour suppliers who can guarantee availability for that whole period.

If these expectations hold, the rule for bidding is straightforward. The consortium should compete where the specification itself calls for something only large-scale simulation can deliver. It should stay out of open competition for routine assessments, because those are decided on price and track record and the incumbents are stronger on both.

Confirming or correcting these expectations is the first task of the business development activity described in Section 5.2. The early tenders the consortium pursues will produce that evidence and Section 4.4 already notes that the win rate assumed in the cost model has to be checked the same way.

Where the money for new deployments comes from

Not every future deployment will be paid for by the customer. If another city or region wants what the pilots delivered, the funding can come from two directions. It can be bought directly, as the service contracts described in Section 4. Or it can be covered by a public programme, with the city taking part as a project partner instead of as a paying customer.

Both routes matter and they are approached differently. A contract is won through a tender. A programme is won through a proposal, usually with partners. Table 19 lists the sources available and what each is suited to.

Table 19. Funding instruments relevant to replication

Instrument	Type	Relevance
Horizon Europe, Clusters 4 and 5	Public, European	Collaborative projects extending the pilots to new domains and partners
EuroHPC JU calls	Public, European	Continued access to computing and to Centre of Excellence funding
Digital Europe Programme	Public, European	Deployment, not research, suited to rolling out a proven pilot
LIFE and Interreg	Public, European	Climate adaptation and cross-border regional replication
Pre-commercial procurement and public procurement of innovative solutions	Public, European and national	The route by which a city can fund development work it cannot buy as an ordinary service
National research and HPC programmes	Public, national	The main source of the parallel research funding described in Section 5.3
Cohesion and regional funds	Public, national	Allow municipalities to commission adaptation studies they could not otherwise afford
Operator and utility research budgets	Private	Direct funding from customers who carry the risk the analysis addresses
Engineering consultancies as channel partners	Private	Subcontracting into their frameworks, which supplies the track record the consortium lacks

The two instruments worth most attention are pre-commercial procurement and subcontracting to established consultancies. The first matches how public bodies actually buy work of this kind, which is the point raised in Section 4.2 about two routes to market. The second addresses the absence of references directly, by placing the consortium inside someone else's delivery record.

Other organisations in the field

Four groups of organisations work on similar problems. Each relates to the consortium differently:

- **Large European services.** Copernicus, Destination Earth, ECMWF and the Joint Research Centre model the environment across whole regions and continents. They produce the broad picture. They do not answer questions about a single street, building or valley.
- **Other Centres of Excellence** in high performance computing. The consortium already works with these through CASTIEL-2. They are partners for joint bids, not rivals.
- **National meteorological and environmental agencies.** Each holds the official mandate in its own country. Depending on the task, an agency may buy work from the consortium or compete for the same work.
- **Research organisations outside Europe.** These affect how fast methods advance. They have little effect on demand within Europe.

What this means for positioning. The large European services describe conditions across a region. A city or a network operator has to act at a much smaller scale, on one district or one stretch of infrastructure. That is the gap the consortium fills. The right position is therefore to work on top of those services, taking their output as the starting conditions for detailed local modelling and not to compete with them.

The plan in three stages

The points above lead to a plan with three stages. It follows the competitive approach identified in Section 3.1, which means building on favourable external conditions while the internal weaknesses are worked on.

Stage one, to the end of the project and the year after. The priority is to keep the capability alive and win a first customer. The Exploitation Agreement is signed and the four functions listed in Section 5.3 are maintained. Work is sought through research and innovation procurement and through co-funded projects, not through open commercial tendering. The organisations already engaged during the project are approached first, because they are the most likely source of a first reference.

Stage two, roughly one to three years. The priority is a track record. This means reaching the number of engagements per year set out in Section 4.4. Where a tender requires evidence of past delivery, the consortium bids together with an established consultancy that has it. The aim is to complete at least one engagement visible enough to be cited in every later bid.

Stage three, beyond three years. The priority shifts from volume to position. The consortium becomes the recognised provider of detailed local modelling that sits on top of the large European services. Further deployments are funded through the European programmes listed above. Only at this point, with real demand as evidence, is the question settled of whether a separate legal entity is needed.

6 Final Exploitation report

This Section presents the final exploitation report for the technologies, software systems, and data assets developed throughout the lifecycle of the HiDALGO2 project. It consolidates the project's exploitable results, establishing a clear record of their typology, technical maturity, and current Technology Readiness Levels (TRLs). It also details the operational framework for IPR management and licensing, ensuring full legal compliance with the Grant Agreement while safeguarding single-partner ownership and freedom to operate. Finally, it presents the concrete, partner-led exploitation plans, detailing the specific business models, pricing structures, and go-to-market pathways designed to transition these exascale innovations into self-sustaining commercial and public services beyond the project's funding timeline.

6.1 List of Exploitable Results

The definition and categorization of HiDALGO2's results has been a continuous, iterative process spanning the second half of the project's lifecycle. The initial identification of the project's exploitable assets was documented in D6.5 submitted in M26, which outlined a preliminary list of 27 exploitable results.

Over the next 20 months, this list was subjected to refinement and re-evaluation. FN collaborated with all consortium members, utilizing meetings, presentations and other events so that the exploitable results list and table are always up to date. To classify the 33 identified results, the consortium established a clear typology based on the technical architecture of the Centre of Excellence and the operational needs of its target user communities. KERs were selected and prioritized based on their high potential to drive downstream value, evaluated against three standard European Commission criteria: (a) degree of innovation, (b) exploitability, and (c) projected impact [6]. The results were mapped to five distinct types, each chosen for its specific suitability to HiDALGO2's exascale and environmental objectives:

- **Integrated Platforms**: Defined as standalone software platforms that embed complex algorithms with the primary purpose of solving multi-scale global challenges.
- **Innovative Solutions - SW**: Standalone software components, libraries, or solvers where high-performance simulation algorithms are directly embedded.
- **AI & ML Models / Methods**: Statistical and neural network workflows designed to automate workflow compositions, analyze massive simulation datasets, or establish fast-prediction models.
- **Datasets**: High-fidelity, structured databases and simulation outputs (such as atmospheric data, local microclimate parameters, or building stock geometries) formatted in standard files and metadata registries.

- **Systems / Models**: Coupled physical frameworks that integrate different environmental and mechanical processes, such as bridging meso-scale weather forecasts with micro-scale urban microclimates.

The compiled lists of results, representing the final consensus of the consortium, are presented in Annex 1. Table 25 lists the 14 prioritized KERs, while Table 26 details the 19 complementary Exploitable Results (ERs) that support the overall technical and dissemination objectives of the Centre of Excellence.

6.2 Intellectual Property Rights Tracking

From the start of HiDALGO2, the management of intellectual property was treated as a strategic enabler for collaborative innovation. The consortium began by establishing a clear, agreed baseline of pre-existing background assets brought into the project by each partner. This foundation ensured that all partners had immediate, royalty-free access rights to implement their respective tasks and run the environmental pilots without operational friction. As the project neared completion, this framework naturally transitioned to post-project exploitation, establishing fair, reasonable, and non-discriminatory conditions that protect academic research continuity while granting partners the legal freedom to package and deploy their services.

To maximize commercial exploitation and avoid post-project administrative friction, HiDALGO2 established clear IP boundaries and explicit ownership assignments from the outset. While work packages are executed collaboratively, individual results have clearly designated primary owners. This approach streamlines IP protection, decision-making, and licensing, while comprehensive access rights (as defined in the Consortium Agreement) ensure seamless integration across the consortium. This clean division of ownership allowed each partner to select the most appropriate protection and licensing pathways for their assets. As a result, the consortium successfully balanced public open-science objectives, by releasing core simulation engines under copyleft licenses (such as AGPL v3.0), with commercial interests, securing proprietary copyrights and trade secrets for high-TRL modules that serve competitive commercial markets. HiDALGO2 has adopted a balanced, hybrid licensing strategy specifically designed to align with the EU's Open Science mandates while simultaneously safeguarding the commercial competitive advantage of its industrial partners. This is managed through a clear distinction between open and closed-source proprietary licensing.

Beyond individual protection, the consortium has actively managed the strategic and societal impact of these results in alignment with European Union objectives. Partners are leveraging centralised dissemination channels to ensure the long-term discoverability of their single-owned assets. At the same time, the exploitation management has maintained careful oversight of licensing and technology transfers to

protect European competitive interests. To maximise the societal value of the project's innovations, the consortium has established a framework for granting royalty-free, non-commercial access to EU institutions, civil protection agencies, and public bodies. This ensures that HiDALGO2's digital twins and environmental forecasting models are readily available to support European environmental policy and emergency response operations.

All the above are presented in the two tables in Annex 2. FN has been monitoring the information on this table, filling out and updating the data in collaboration with the partners. The two tables present the IPR separately for KERs and ERs for the smooth commercialization of each result.

6.3 Exploitation Plans

To transition the project's technical results into long-term sustainable assets, the consortium has defined six specialized exploitation plans corresponding directly to the partner-led technological and pilot files. Rather than repeating generic market strategies across individual software components, each plan synthesizes the target markets, customer segments, pricing structures, and go-to-market pathways.

KER1, ER18: Cloud HPC Data Management and Orchestration Exploitation Plan (BULL)

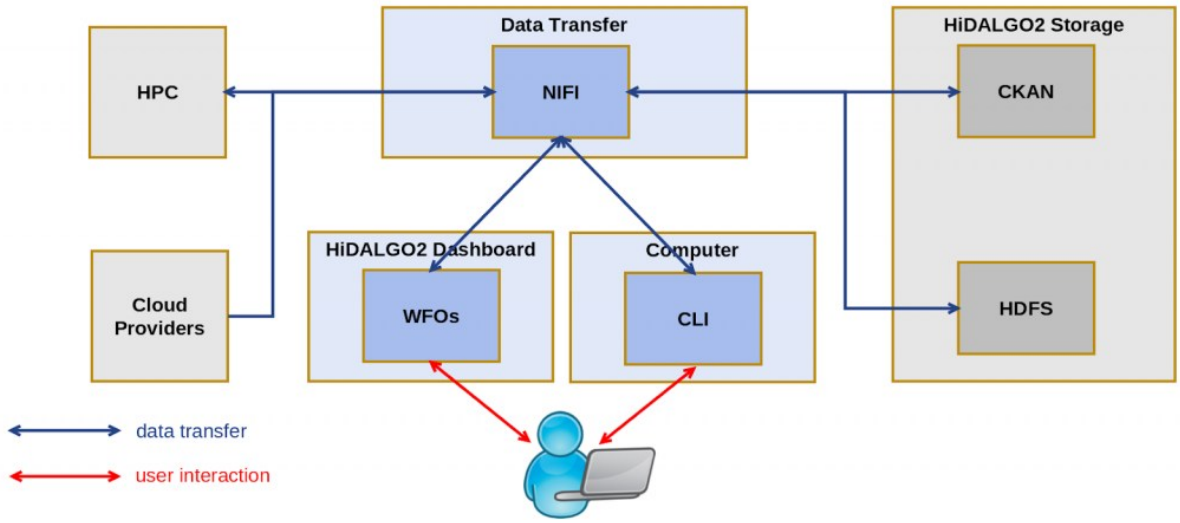


Figure 12. Cloud DMS workflow

This plan governs the commercial deployment of two closely integrated data-orchestration assets owned by Bull: the Data Management System (DMS) and the Bull Argos Suite (BAS), both designed to optimize massive data staging across

heterogeneous supercomputing and cloud infrastructures. Bull exploits these results individually and as combined data-staging layers. The revenue model is based on three main pillars: (1) on-premise installation in the customer's local infrastructure delivered as a one-time fixed-price service, (2) recurring subscriptions for evolutionary maintenance (including technical support, patches, and scalability updates), and (3) bespoke software development to customize the tools for specialized client workflows. It also capitalizes on Bull's position as a premier European HPC vendor. The primary channels target its existing Tier-0 and Tier-1 supercomputing clients and EuroHPC hosting sites (e.g., BSC, CINECA, Jülich), while certifying the DMS for integration with commercial cloud HPCaaS and HaaS providers.

ER14, ER15: QCG and mUQSA Exploitation Plan (PSNC)

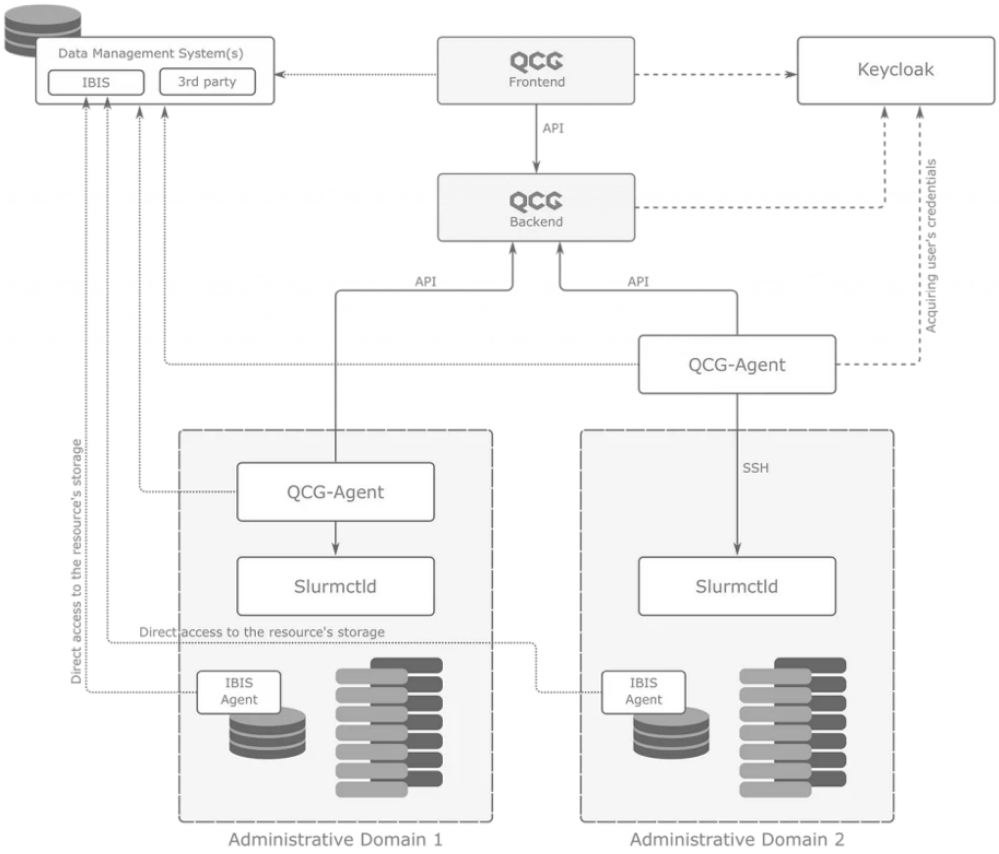


Figure 13. High-level architecture of QCG-Portal

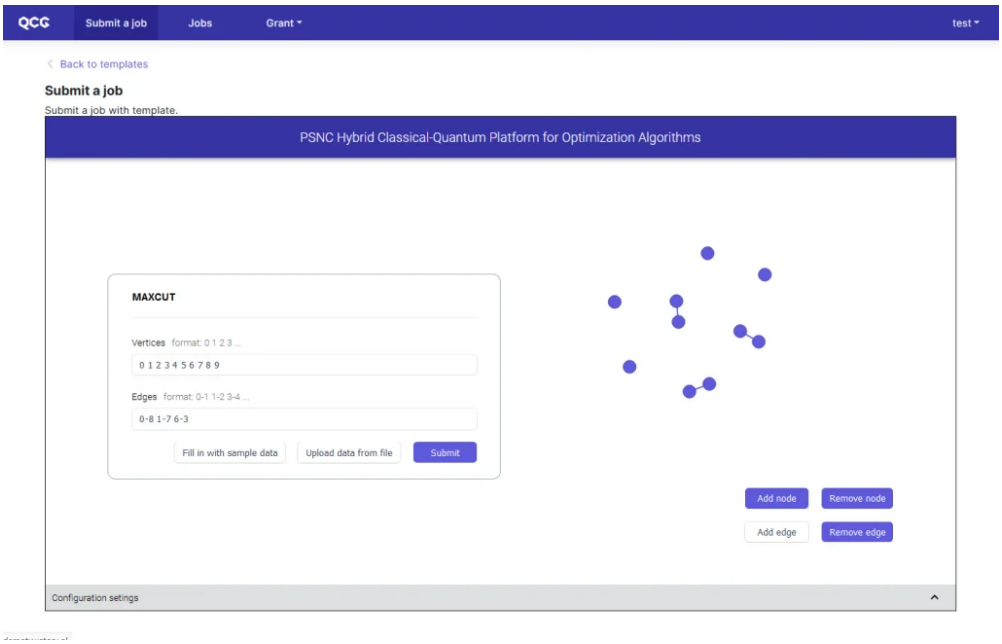


Figure 14. With Custom Application Views, the interface of QCG-Portal can be easily made intuitive and adjusted to specific needs of computational scenario

This plan governs the horizontal middleware suite consisting of the QCG-Portal and the mUQSA web platform for automated uncertainty quantification and sensitivity analysis. Managed by PSNC, the commercialization strategy utilizes a dual-delivery model targeted at research institutes, universities, HPC centers, and high-tech industrial enterprises (such as those in energy, construction, and public safety) in Poland and across Europe.

The above results are offered under a hybrid commercial structure. A cloud-based Software-as-a-Service (SaaS) model provides flexible, pay-per-use access to remote cloud resources without requiring clients to maintain their own physical computing infrastructure. This is complemented by an On-Premise enterprise license model, which charges fixed fees for software deployment, custom integration, and local infrastructure setup. It focuses on leveraging existing pilot collaborations and early-adopter networks to drive initial commercial validation, supported by targeted technical workshops and active participation in international supercomputing conferences.

KER4, KER8, KER9, ER4, ER5, ER6, ER7, ER8, ER9, ER10: Ktirio Urban Building Pilot Exploitation Plan (UNISTRA)

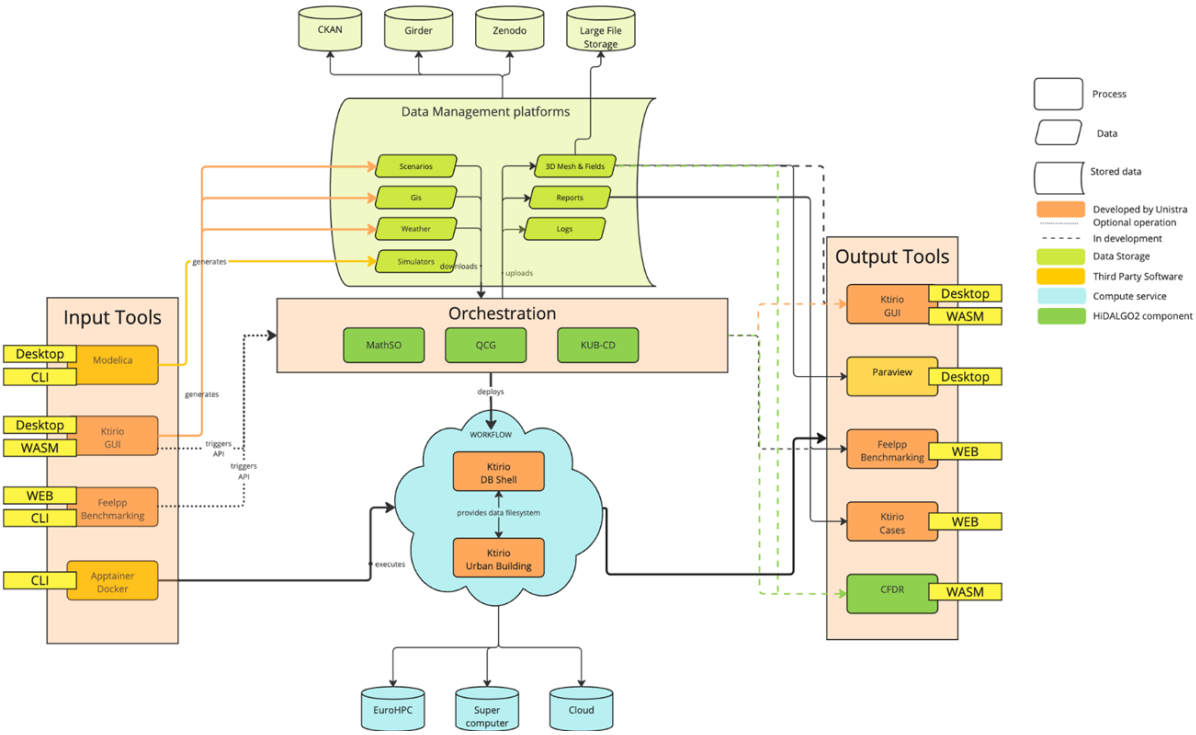


Figure 15. Control and Data flow presentation Ktirio Urban Buildings Pilot

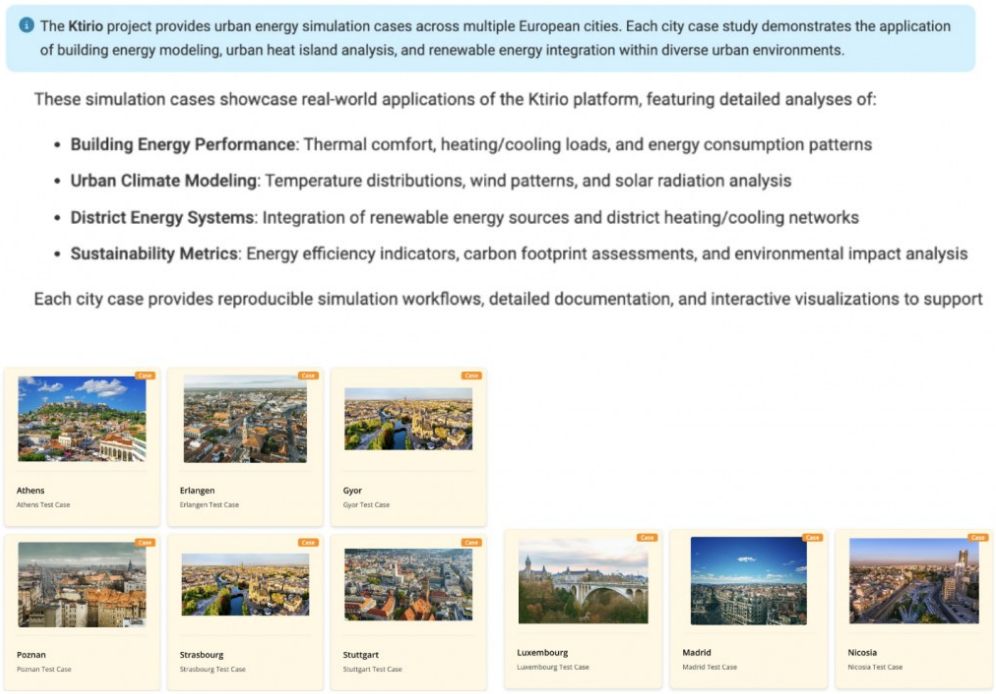


Figure 16. Ktirio.Cases dashboard for exploring building-, district- and city-scale simulation results and key performance indicators.

This plan covers the KUB energy simulation ecosystem, including the Ktirio Geom, GUI (Graphical User Interface), CKAN.Girder database, Cases dashboard, models, reporting modules, algorithms and software that go into KUB. They are designed to evaluate dynamic energy renovation and climate-adaptation scenarios at individual, district, and city scales. This plan implements the open science policy, working with a a lot of open source data, in combination with a dual-licensing policy. A core open-source version is maintained under GPL licensing to respect the principles of open science, encourage academic contributions, and guarantee model transparency. In parallel, a monetized commercial track is offered to industrial actors, integrating advanced diagnostic features, dedicated technical support, and hosted cloud computing via a SaaS model. The go-to-market strategy of these results focuses heavily on a strategic commercial partnership with engineering consulting firms, cities and housing associations. By co-constructing the platform's KPIs to align with regulatory building audits and energy diagnostic workflows, UNISTRA has secured a direct commercial channel to architectural firms, local municipalities, and social housing associations subject to EU Green Deal directives.

KER10, KER11, KER12, ER12, ER13: Wildfire Pilot Exploitation Plan (MTG)



Figure 17. Presentation of Wildfires Simulations at Spain's "Fire Day" Engineering Forum.

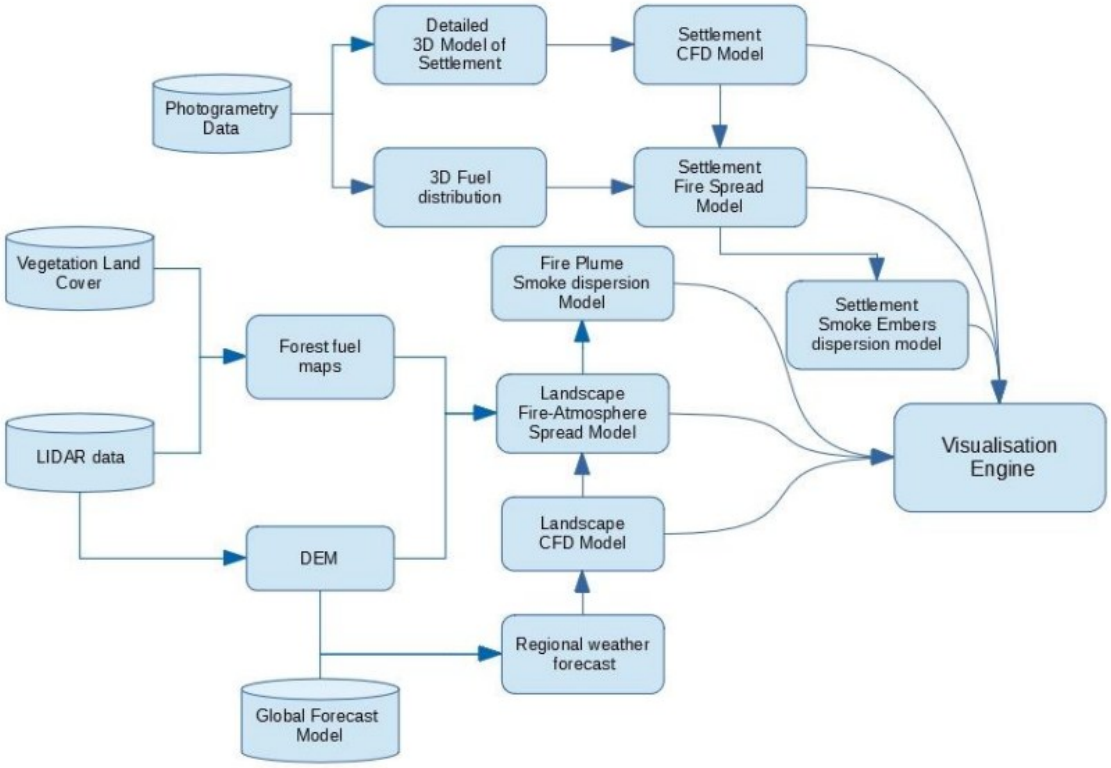


Figure 18. Control and data flow presentation for the Wildfires pilot

This plan covers MeteoGrid's (MTG) unified suite of five wildfire risk management and emergency response tools, including the Coupled Fire Spread & Smoke Dispersion Simulator Engine, the Multi-Scale Fire Analysis Consulting Tool, the Pyrocumulus Formation Predictor, the Vegetation Descriptor and interactive Local Digital Twins. The pilot's business model is tailored primarily for the business-to-government (B2G) public safety sector. Commercialization is driven through a combination of periodic or lifetime software licensing (with separate agreements for maintenance and evolutionary upgrades) and subscription-based access to on-demand hazard forecasting. It targets European (EFFIS), national (such as the Spanish Military Emergency Unit - UME, and AEMET), and regional emergency management and civil protection departments. Exploitation is sustained by integrating MTG's advanced simulators directly into the operational training programs of first responders and public safety planners, demonstrating immediate value in protecting lives and infrastructure at the Wildland-Urban Interface (WUI).

KER2, KER3, ER2, ER3: Urban Air Pilot Exploitation Plan (SZE)

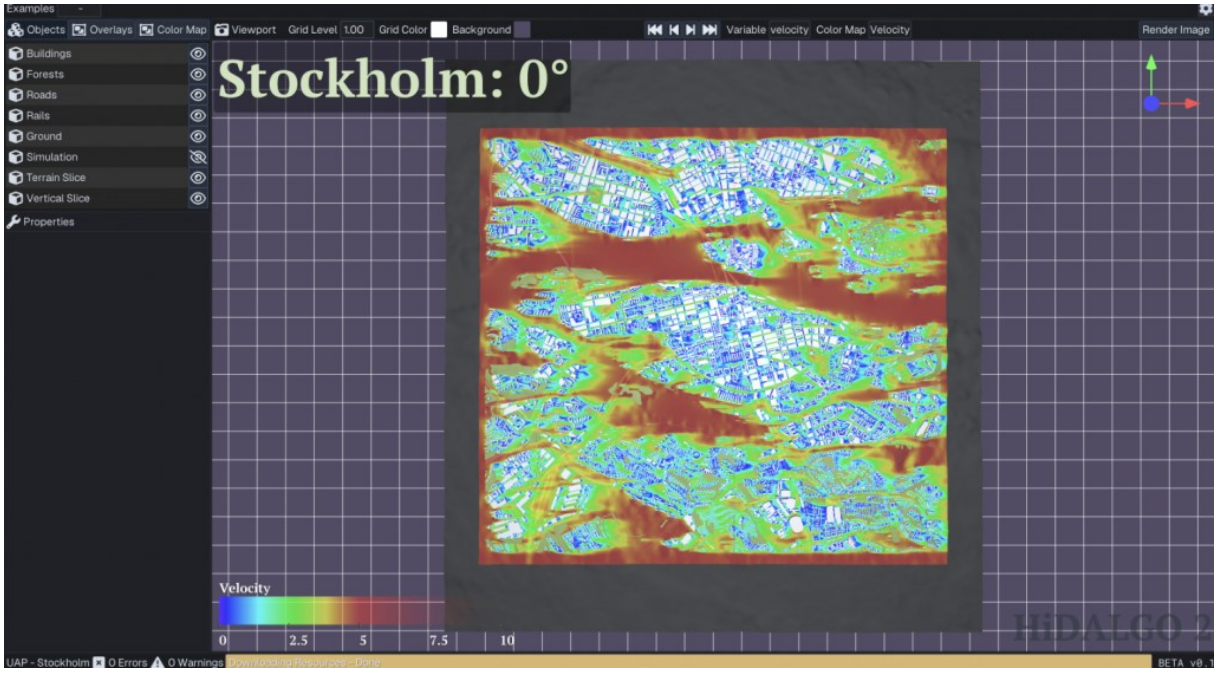


Figure 19. Ueban Air Quality Platform (CFDR Platform)

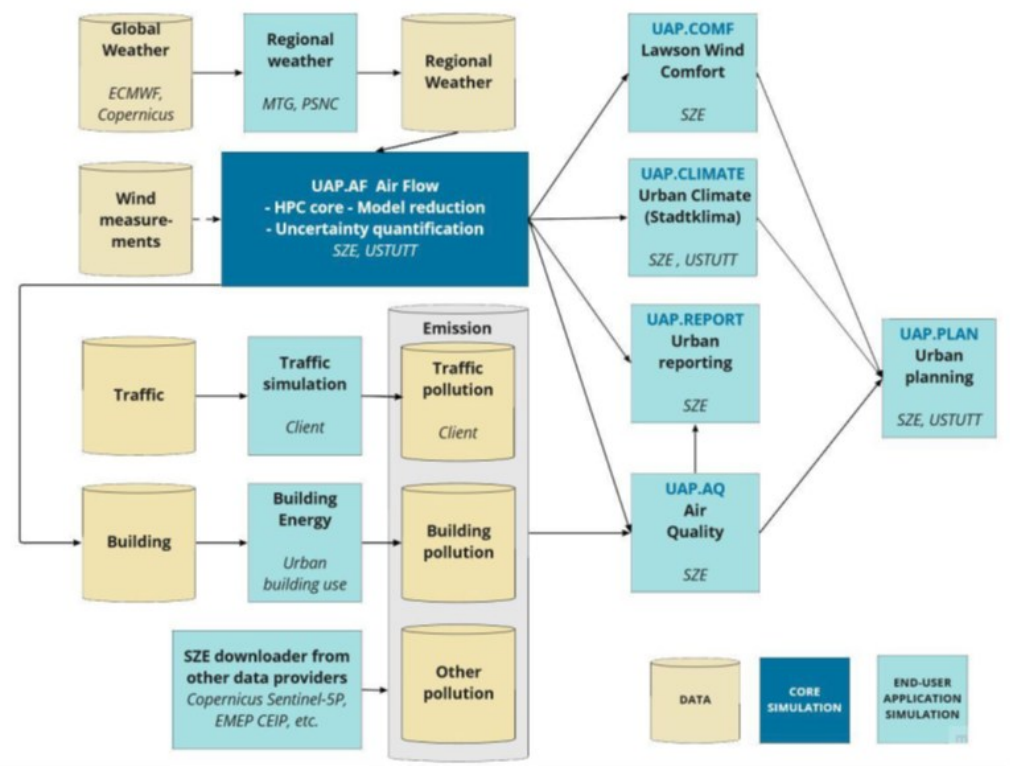


Figure 20. Control and data flow presentation for the Urban Air Project

This plan governs the urban microclimate and atmospheric simulation suite led by Széchenyi István University (SZE), comprising the MathSO Portal, RedSim (Reduced Simulations), CFDR, Software Tools for Urban Planning, and high-resolution Urban Air Comfort & Quality Maps. The toolset provides micro-scale Computational Fluid Dynamics (CFD) modeling to evaluate pedestrian wind comfort, pollutant dispersion, and faster-than-real-time accidental gas release, targeting municipal authorities, urban planning departments, environmental consultancies, and emergency response units. Commercialisation is driven through a hybrid service and software licensing framework managed by SZE. While basic demonstrators and public case studies (such as the Stockholm validation) are offered openly to engage stakeholders, the core software tools and GPU-accelerated solvers remain proprietary. The revenue model combines subscription-based access to the MathSO cloud portal for recurring simulation workflows, tailored B2B and B2G consultancy contracts for full-scale city microclimate audits, and on-demand computational service fees for specialized scenario modeling. SZE leverages existing pilot deployments across European partner cities (including Győr, Stuttgart, Poznań, Illkirch, and Stockholm) and industrial validation partners as operational references. Market reach is expanded through strategic collaborations with EuroHPC National Competence Centres (such as ENCCS in Sweden) to establish MathSO as a trusted simulation gateway on national supercomputing infrastructures, supported by direct engagement with local planning authorities, architectural engineering firms, and regional environmental protection agencies.

KER5, KER6, KER7, ER19: Renewable Energy Sources Pilot Exploitation Plan (PSNC)

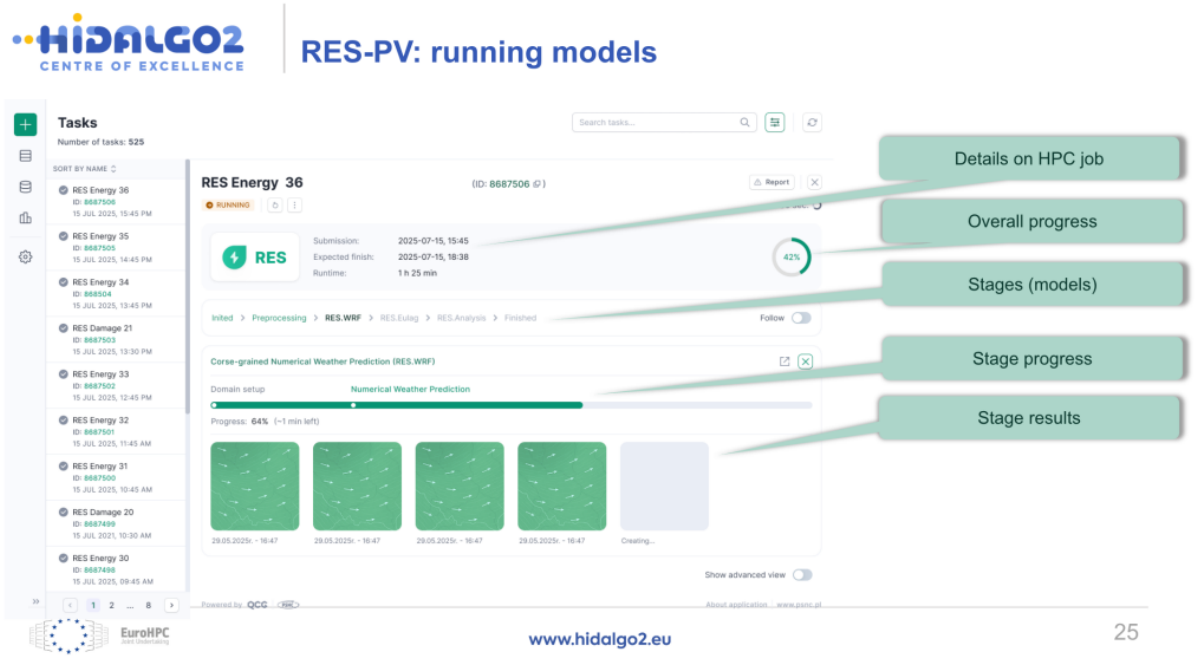


Figure 21. RES-PV Running Models

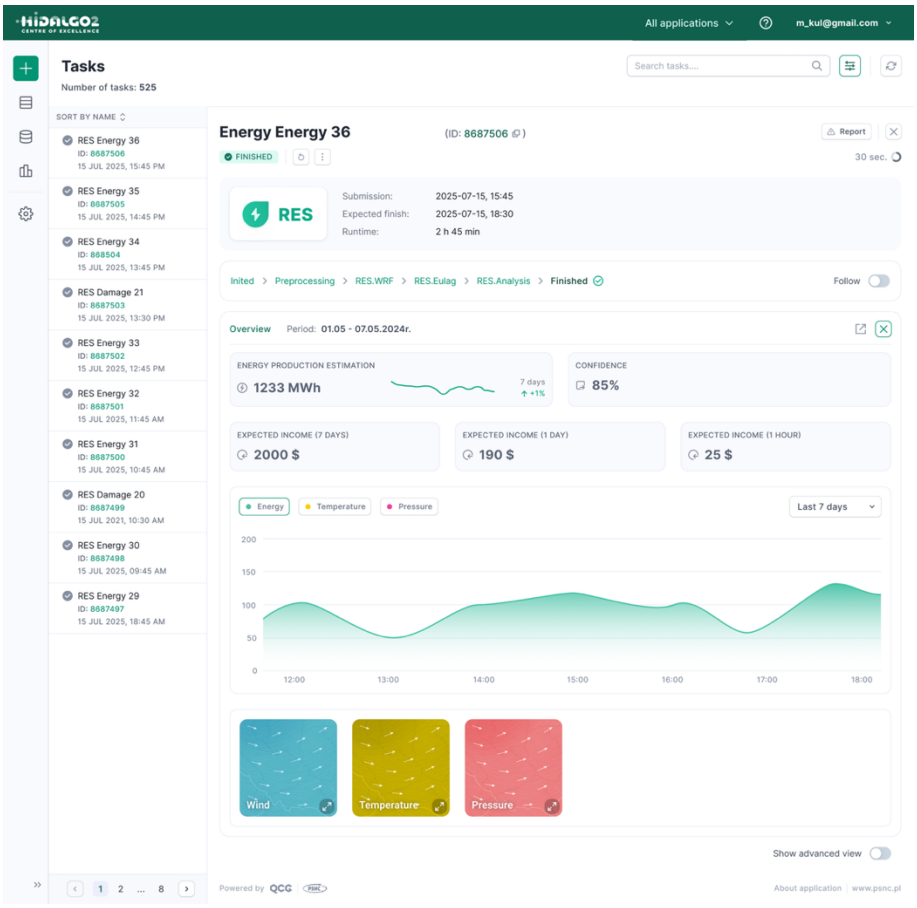


Figure 22. RES-PV: electrical energy production forecast

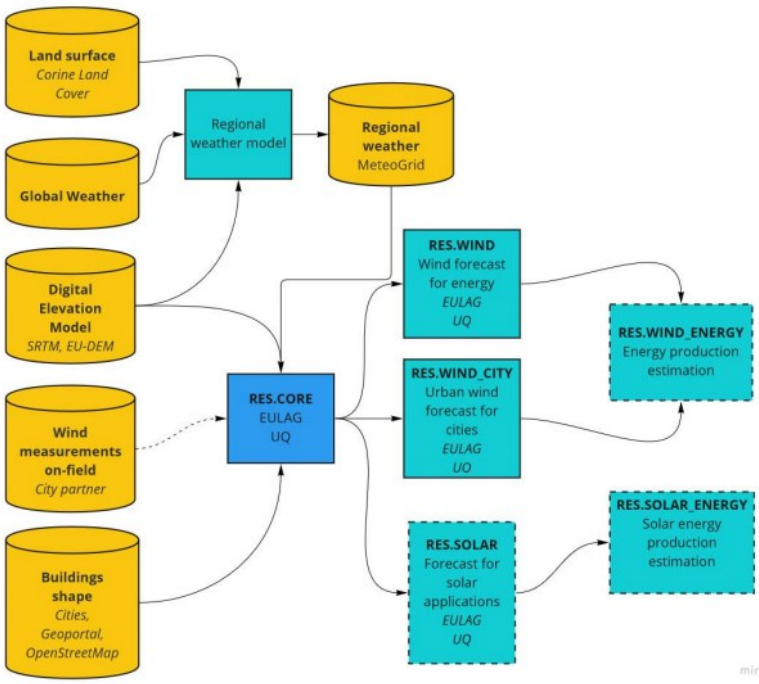


Figure 23. Control and data flow presentation for Renewable Energy Sources.

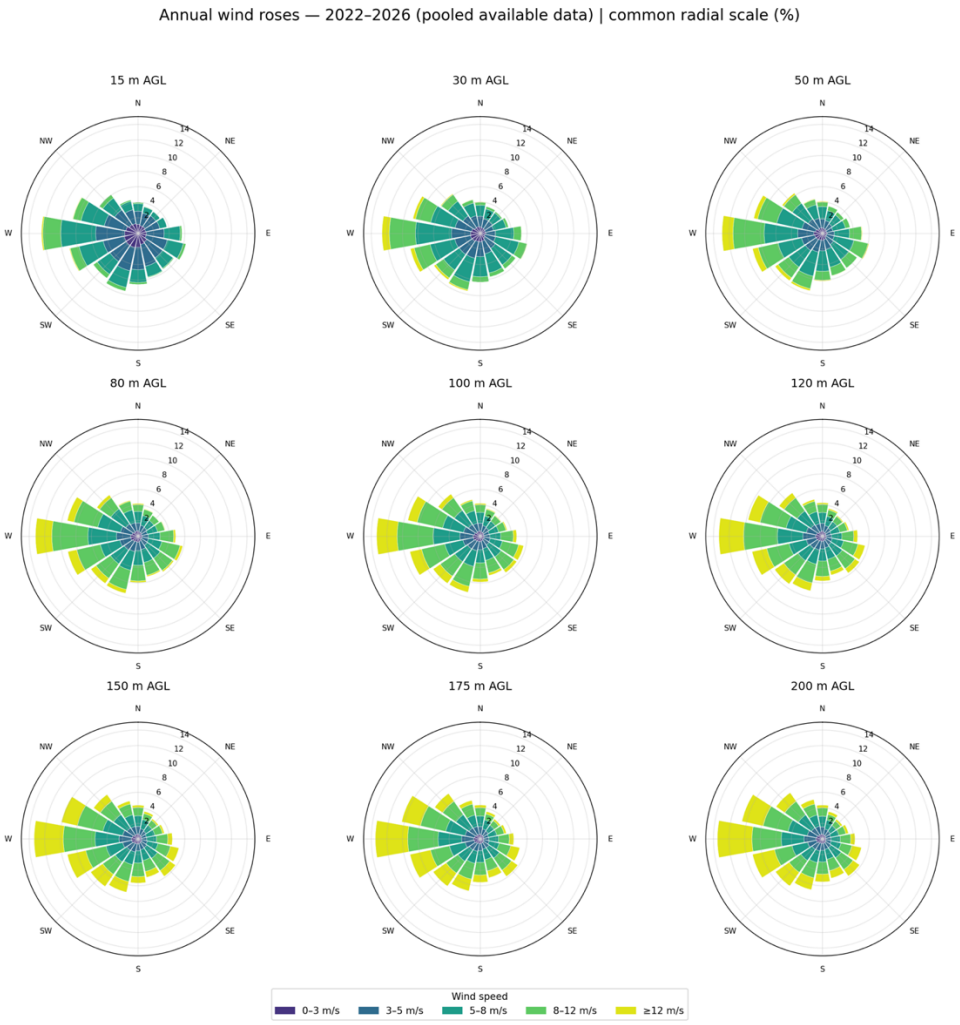


Figure 24. RES-wind analysis

This plan governs the commercial deployment of the specialized RES Toolkit, which features three core forecasting components: RES-wind (forecasts related to wind farms and wind turbines), RES-pv (forecasts related to photovoltaics), and RES-damages (damages to the infrastructure due to extreme weather events), available to be run through RES-runner.

The workflow is offered within RES-runner, provided solvers (WRF, EULAG) are available (i.e. downloaded and installed) by the end-user. The enhanced RES.WRF and RES.EULAG models are offered within the RES toolkit as as an Software-as-a-Service model, made available through the QCG-Portal. The pricing strategy depends on the usage. For a basic or advanced daily forecasting, subscription-based access is available and the billing is based on resources spend, which may include ensemble and uncertainty quantification runs. Custom consulting agreements are available in case help with the deployment of RES.runner on the end-users premises. The consultancy is also available in cases where a tailored RES toolkit configuration is requested by an end-user. There is also pay-per-use plan available in cases only small

batches of runs are required, e.g. when using the RES toolkit to find best spots for a new renewables infrastructure installations.

The commercial availability of the RES toolkit addresses Distribution System Operators (DSO) in particular. The primary value proposition focuses on grid stabilisation and risk reduction, allowing such operators to make highly accurate price bids to energy stock exchanges, and to react to potential infrastructure damages due to the extreme weather events. However, the toolkit addresses also wind/solar plant operators, either private individuals or companies, who are requested to report energy production estimation to theirs DSOs. Last but not least are the users who can use the service to justify selection of the area for a new RES infrastructure.

KER13, ER17: Material Transport in Water Pilot Exploitation Plan (FAU)

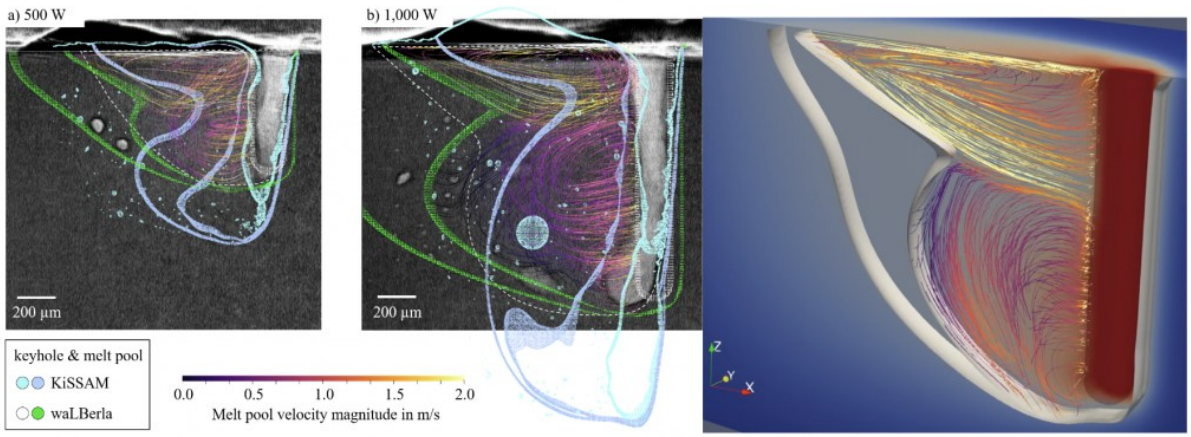


Figure 25. Laser Beam Welding Application - Predictions of Melt Pool and Keyhole depths

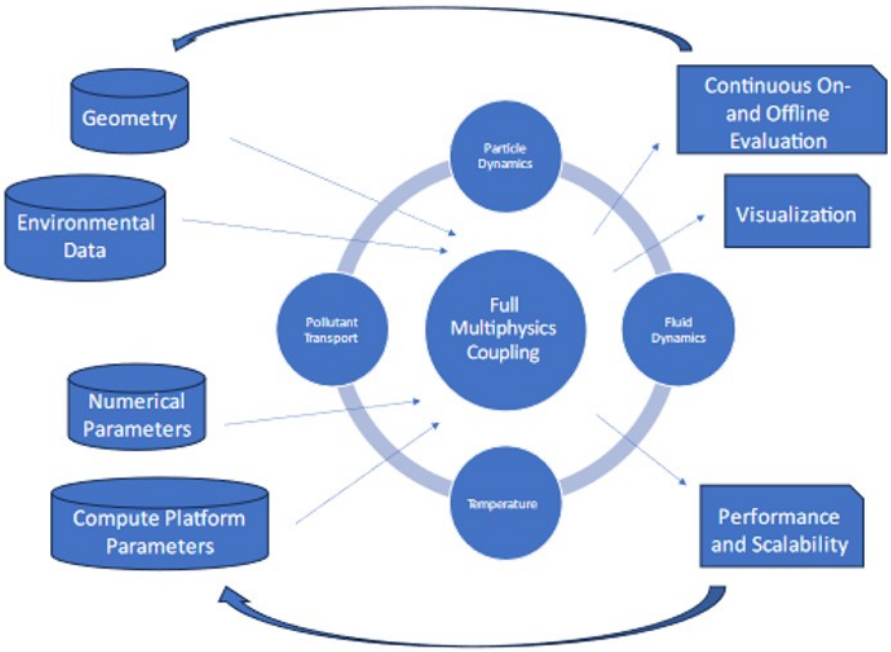


Figure 26. Control and data flow of Material transport in Water Pilot

This plan governs the aquatic sediment and scalar transport simulation suite led by FAU, centered on the waLBerla framework, Mesa-PD particle dynamics module, and HyTeG finite element solver. Aligned with its target stakeholder base, the pilot prioritises an Open Science sustainability route. The core simulation codes and deep-learning surrogate models are distributed under the open-source GNU AGPLv3 license to foster international scientific collaboration, supported by ongoing public research grants (such as Horizon Europe and national HPC allocations). Commercial exploitation is realized through targeted B2B engineering consultancy, adapting waLBerla's high-fidelity fluid-particle solvers to specialized industrial use cases, including modeling seabed erosion around suction bucket foundations for offshore wind turbines and predicting 3D melt pool dynamics in laser beam welding.

ER16: Parallel Scientific Visualization Exploitation Plan (USTUTT)

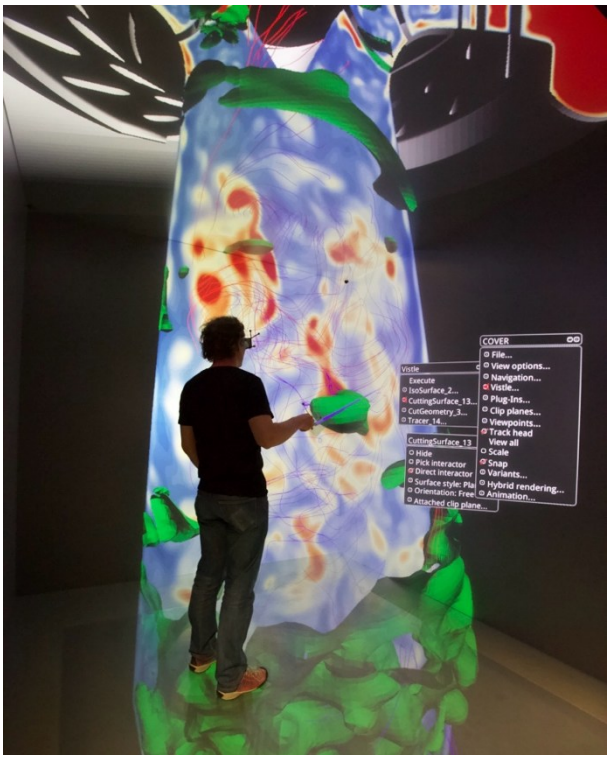


Figure 27. Flow in a pump turbine in CAVE at HLRS.

This plan governs the parallel post-processing, visualization, and immersive rendering system Vistle, designed to translate exascale CFD and environmental simulation outputs into high-fidelity, interactive 3D environments. Maintained as open-source assets under the Lesser General Public License (LGPL v2.1) to encourage wide academic reusability and community-driven development. HLRS exploits these results non-commercially to support researchers utilizing its supercomputing testbeds, while offering paid B2B consultancy, advanced developer training, and bespoke rendering pipeline development. Vistle exploitation plan aims to reach direct engagement with mid- to large-scale engineering enterprises and public institutions through international industrial forums, academic workshops, and HLRS's established B2B networks, establishing the tools as industry standards for exascale data exploration.

7 Research Roadmap to 2030

The HiDALGO2 Research Roadmap to 2030 represents the strategy designed to transition the Centre of Excellence from a structured research project into a self-sustaining, federated European service provider. While preceding Sections outlined the market dynamics, financial viability, and immediate exploitation strategies of the project's individual results, Section 7 shifts focus to the long-term technological and operational evolution. At its core, the roadmap is motivated by the necessity to making HPC simulations accessible, taking complex exascale-level simulations out of isolated laboratories and putting them directly into the decision-making workflows of public authorities, civil protection units, and green infrastructure operators. The goal in this Section is, to present how the project vision aligns with the EU goals, what goals where achieved and finally what are the plans after the end of the project.

7.1 2030 Vision and EU Goals Alignment

At its core, HiDALGO2's vision is to solve global environmental challenges through supercomputing simulations. By abstracting away the intimidating technical barriers of supercomputing, the project delivers practical tools that are easy to use and empower non-HPC experts—including local city planners, wind farm operators, and emergency responders—to tackle everyday environmental threats like air pollution, wildfires, and water contamination. This translates directly into safer, healthier cities and more resilient, better-prepared local communities for citizens. At the same time, these tools provide clear, data-based evidence to design smart green urban policies and respond instantly during emergency crises, so that cities and policymakers can take informed decisions. HiDALGO2 offers cost-effective, extreme-scale simulation services that help energy grid operators, engineering firms, and SMEs innovate while building Europe's sovereign digital economy.

Looking toward 2030, this project-focused roadmap is deeply intertwined with key European strategic directives to maximize scientific, economic, and societal impact. First, the Green Deal [7] sets a binding commitment for the EU to achieve climate neutrality by 2050, with a milestone to reduce emissions by at least 55% by 2030. A critical barrier to this is the European building sector, which is responsible for roughly 40% of the EU's energy consumption and 36% of its greenhouse gas (GHG) emissions. HiDALGO2 directly supports Green Deal objectives through its KUB and UAP ecosystems, which simulate energy consumption, thermal comfort, and GHG/NOx emissions at both the building and city scales to inform urban renovation strategies. Furthermore, the RES use case accelerates the transition to clean energy by advancing high-resolution predictive models and uncertainty quantification for wind and solar energy production, directly helping operators stabilise the green energy grid.

Second, the Digital Compass [8] outlines a vision for a digitally sovereign Europe, establishing a target that by 2030, 75% of European enterprises will have taken up cloud computing, big data, and AI. HiDALGO2 drives this digital transformation by chaining HPC data with Machine Learning pipelines and developing High-Performance Data Analytics (HPDA) frameworks capable of processing massive environmental datasets in place.

Through the development of unified web-based portals like MathSO and QCG, the project abstracts the underlying complexities of supercomputing, allowing users to easily configure, execute, and monitor massive Exascale simulations directly from a standard laptop.

Finally, EuroHPC's Multi-Annual Strategic Programme [9] and work programmes emphasise the urgency of transitioning to Exascale capabilities and developing highly scalable, energy-efficient, and AI-integrated applications. This transition to Exascale is essential because accurately modelling complex global challenges requires unprecedented resolutions and the ability to process massive datasets, demanding computational power that exceeds current systems to deliver actionable, reliable insights for society and industry. As a Centre of Excellence, HiDALGO2 fulfils this mandate by optimising existing parallel codes for next-generation architectures, driving toward ambitious technical targets in per-node parallel efficiency. Furthermore, HiDALGO2's future Research and Development (R&D) tracks are fully aligned with EuroHPC's push for hybrid HPC and AI workflows, the creation of digital twins, and the federation of computing resources across Europe, ensuring that user communities are fully equipped to exploit the post-exascale era.

7.2 Strategic Objectives & KPIs

The transition to Exascale computing and the successful mitigation of environmental challenges require a structured, measurable approach. To achieve the project's 2030 vision, the core activities are driven by four foundational pillars: Technological, Multidisciplinary, Socio-Scientific, and Collaboration.



Figure 28. The project's four foundational pillars

Technological Objectives

The technological pillar is about harmonising HPC, HPDA, and AI. The primary objective is to adapt and scale existing CFD codes so they can fully exploit the capabilities of next-generation, heterogeneous supercomputing architectures. Progress toward the 2030 vision is already evident in the successful deployment of these applications across top-tier computing facilities, where codes are achieving unprecedented scalability and uncovering critical bottlenecks in memory and Input/Output (I/O) processes. Furthermore, the constant refinement of Continuous Integration and Continuous Deployment (CI/CD) practices, alongside advanced containerisation strategies, ensures that these extreme-scale simulations remain portable, highly efficient, and fully prepared to meet the massive computational demands of future environmental modelling.

Multidisciplinary Objectives

To accurately model the complex realities of climate change, the multidisciplinary pillar's core goal is to implement robust coupling mechanisms that allow standalone environmental simulations to interact and exchange data dynamically, increasing the

overall precision of the results. The journey toward the 2030 vision is marked by tangible advancements in cross-domain integrations, such as linking urban airflow models with building energy dynamics to study microclimates, or coupling weather forecasting systems with wildfire spread simulators to track smoke dispersion over populated areas. Additionally, the project is heavily utilising ensemble simulations—running multiple scenarios simultaneously with varying parameters—to quantify uncertainties and ensure the high reliability of its predictions. Through the development of sophisticated workflow orchestrators and standardised data management systems, the project is bridging the gap between domain scientists, data analysts, and HPC engineers, enabling a holistic approach to tackling global challenges.

Socio-Scientific Objectives

The objective of the socio-scientific pillar is to push beyond abstract data generation by evolving high-fidelity simulations into interactive, localised digital twins of urban and natural environments. HiDALGO2 tools allow public administrations, urban planners, and emergency responders, to visualise and test various climate resilience and mitigation scenarios before implementing them in the real world. From a socioeconomic perspective, the project's communication and dissemination activities actively target key decision-makers and the public to demonstrate how these technologies can solve critical financial and societal issues. At the same time, through targeted exploitation strategies, the project seeks to commercialise these solutions for large companies, SMEs, and public institutions.

Teamworking and Collaboration Objectives

Recognising that advanced technologies are only as impactful as the people who use them, the teamworking and collaboration pillar provides highly automated, user-friendly platform services that abstract the underlying complexities of supercomputing, thereby empowering non-expert communities, researchers, and SMEs to easily launch and manage complex analytical workflows. Progress is steadily being made through the operational deployment of unified portals, such as the QCG and MathSO interfaces, which streamline everything from data management to job scheduling on major EuroHPC machines. In alignment with the 2030 goals, the project is heavily invested in community building by creating comprehensive open-source training materials. This includes offering specific courses via a dedicated Moodle learning platform and providing interactive Jupyter Notebooks for data analytics. The project is also fostering strategic collaborations with other Centres of Excellence (such as ChEESE, ESiWACE, EXCELLERAT P2, CIRCE, SEVEA and others) and European infrastructure initiatives (like EuroCC 2 and CASTIEL 2) to share best practices, implement joint benchmarking exercises, and integrate software codes. By cultivating an open, collaborative ecosystem and actively disseminating best practices through

hands-on training sessions, online stakeholder awareness workshops, and major initiatives like the HiDALGO2 EU Clustering Event [10] , the project ensures its technological breakthroughs are widely adopted.

7.3 Research & Development Pathways

This section steps into the project's strategic objectives. As HiDALGO2 scales its technologies toward the 2030 horizon, these pathways outline how the individual exploitable results are evolving to meet the immense computational demands of the Exascale era and the rapid rise of AI. Guided by the EuroHPC Joint Undertaking's vision, these tracks focus on advancing foundational technologies, fostering multidisciplinary co-design, delivering tangible socio-scientific impacts, and democratising Exascale access.

To clearly distinguish between the project's current achievements and its long-term Exascale ambitions, we use the Nine Windows framework [11] . This technique is defined as a method for exploring issues and their potential impacts by examining the past, present, and future of both high-level areas and their related subsections. In the Nine Windows framework, analysing a technology requires looking not just at the product itself, but zooming in and out of its complexity. To do this, we split the architecture into three levels: Sub-system, System, and Super-system.

Table 20. Structural Levels of the HiDALGO2 Innovation Framework

Level	Conceptual Meaning	HiDALGO2 Translation	Project Goal
Sub-system	The individual code libraries, mathematical solvers, and algorithms that serve as the foundational building blocks of the software.	Specialized, highly complex physics codes and mathematical solvers, such as RedSim, Feel++, and waLBerla.	Adapt, optimize, and parallelize codes for next-generation accelerated supercomputing architectures to achieve maximum computational efficiency.

System	The integrated platform where discrete software components are coupled to automate workflows and create a cohesive user experience.	Unified, web-based workflow orchestrators (like MathSO and QCG) backed by the central DMS and the mUQSA platform.	Abstract supercomputing complexity through automated, intuitive web interfaces, enabling non-experts to run massive simulations from a browser.
Super-system	The external infrastructure, policy landscape, and societal environment where the coupled system is deployed to deliver real-world value.	Federated EuroHPC networks, European data spaces, and major EU sustainability and digital policy frameworks.	Deliver Local Digital Twins that empower public authorities, grid operators, and emergency services to make swift, life-saving environmental decisions.

The exploitable results are arranged in five solution groups. The grouping follows the way the results are used together. Four groups correspond to the application domains of the pilots. Urban Air and Urban Buildings form one group, because both describe the same urban microclimate and their models are coupled. Visualisation is placed with Wildfires, because this is where it is applied most.

The fifth group, Infrastructure and Orchestration, holds the results that serve all pilots. These are the data management, portal, workflow and monitoring tools. Each result belongs to one group only. A result used by several pilots is assigned to Infrastructure and Orchestration. The first column of Table 21 lists the Key Exploitable Results (KER) and Exploitable Results (ER) of each group, as defined in Table 25 and Table 26.

The following table maps the five core R&D pathways across three developmental horizons. Inspired by the Nine Windows framework, this matrix illustrates the timeline of development from baseline capabilities to the 2030 vision and also the expansion of scope. It demonstrates how individual software components and solvers are currently being optimised (Sub-system level) are integrated into cohesive operational workflows (System level), and how they will ultimately scale to support federated European digital twins and policy-making initiatives (Super-system level) in the future. In the following Sections the reader gets the chance to understand each pathway's development deeper, throughout time.

Table 21. R&D Pathways across developmental horizons

Solution groups and their results	Baseline Pre-HiDALGO2 & Project Start 2023	Present Implementation 2023-2026	Future Post Project 2026-2030
Infrastructure & Orchestration KER1, KER14, ER1, ER2, ER14, ER15, ER18	Disconnected HPC job submission scripts; basic data storage without seamless workflow automation.	System Integration: Deploying MathSO and QCG portals with new graphical templating, built-in execution monitoring, and automated data archiving to CKAN across EuroHPC systems like LUMI and Discoverer.	Super-system (Ecosystem): Deep integration into the EuroHPC Federation Platform and European data spaces; enabling seamless, AI-driven Sovereign Cloud workflows.
Urban Air & Buildings KER2, KER3, KER4, KER8, KER9, ER3, ER4, ER5, ER6, ER7, ER8, ER9, ER10, ER11	High-resolution CFD solvers operating independently; non-watertight city geometries; basic monozone building models.	Sub-system Optimisation: Achieving watertight multi-storey geometry generation, advancing RedSim with MPI+CUDA, and coupling KUB with weather-driven FMUs.	Super-system (Societal): Fully operational, real-time urban digital twins; AI-based surrogate models for instant air-quality predictions to support EU Green Deal city planning.
Renewable Energy Source KER5, KER6, KER7, ER19	Standard deterministic weather prediction (WRF/EULAG) without AI coupling or automated uncertainty quantification.	System Integration: Developing the RES.wind and RES-PV components with AI module trained on real 1MWp PV farm data	Super-system (Societal): Fully operations, providing operational grid stabilization services to DSOs, and accurate electrical energy production from renewable infrastructure

Solution groups and their results	Baseline Pre-HiDALGO2 & Project Start 2023	Present Implementation 2023-2026	Future Post Project 2026-2030
Wildfires & Visualisation KER10, KER11, KER12, ER12, ER13, ER16	PC-scale (4-8 cores) fire spread models limited to hundreds of meters; basic smoke visualization.	Sub-system to System: Coupling WRF-SFIRE with Unreal Engine 5.4 for VR demonstrators, and using LSTM autoencoders/AI for fire similarity retrieval.	Super-system (Societal): Near real-time operational simulation for emergency response; WUI digital twins ported to portable VR devices (e.g., MetaQuest 3) for citizen training.
Material Transport in Water KER13, ER17	Fundamental multiphysics frameworks (waLBerla, HyTeG) developed for generic fluid dynamics.	Sub-system Optimization: Porting codes to GPU architectures, implementing efficient collision operators, and validating conjugate heat transfer.	Super-system (Ecosystem): Scaling to Exascale dimensions (>100 billion cells) and transitioning to AI-driven surrogate models for real-time tracking of water contaminants.

Infrastructure and Orchestration R&D to 2030

Running massive environmental simulations on supercomputers presents a steep barrier to entry, requiring specialized IT expertise to manage data and energy consumption across diverse architectures. To solve this, the project has established a robust DMS, using the CKAN platform as a central data repository, while the Hadoop, HDFS, and YARN frameworks actively drive the HPDA pipelines. Concurrently, the consortium has deployed the BAS to monitor, characterize, and optimize energy usage during computationally intensive tasks. Moving into post-project exploitation, the focus for the DMS is to undergo performance scaling tests to achieve full interoperability with parallel HPC storage, schedulers, and modern cloud APIs. Meanwhile, future development for the BAS will focus on developing custom functionalities for commercial HPC clients, extending support to heterogeneous hardware architectures

(such as Intel, AMD, NVIDIA, and ARM), and finalizing its job energy recommendation and prediction features to help users balance execution speed with power consumption.

Despite these massive computational demands, the core objective remains abstracting supercomputer complexity so that non-expert communities can easily harness Exascale capabilities. Currently, the project achieves this through unified, web-based workflow orchestrators: the MathSO Portal and the QCG middleware ecosystem, which allow users to configure, launch, and monitor jobs via intuitive graphical interfaces. Looking toward the post-project horizon, QCG will be developed to increase platform scalability, improve data processing, and support AI development by integrating with Machine Learning pipelines. The MathSO Portal will execute its documented roadmap to introduce a Parameter Sweep Function, generalized visualization support, and full execution templates for EuroHPC clusters. Finally, the mUQSA platform, which automates uncertainty quantification, will focus on extending its capabilities to support AI models, developing integration libraries for diverse computing environments, and expanding its visualization tools to make result interpretation seamless for policymakers and researchers.

Urban Air and Buildings R&D to 2030

The Urban Air & Buildings Ecosystem simulates urban microclimates by combining outdoor air quality and airflow models with indoor energy efficiency diagnostics. At its core, the building simulation workflow relies on the Ktirio Suite, leveraging Feel++ as its finite element execution core. Users utilize the Ktirio-GUI to configure and deploy cases, while Ktirio Geom handles complex 3D building geometries and meshes, and the Ray Tracing for Solar Mask module calculates facade shading. Relevant environmental data is catalogued via Ktirio Data and processed by Ktirio Models to compute dynamic energy demand, with performance summaries generated by Ktirio Reporting and published to the Ktirio Web Site and the Ktirio Cases dashboard. For microscale atmospheric airflow, the UAP deploys three advanced CFD solvers (UAP-FOAM, RedSim, and Xyst) to simulate urban wind fields at high spatial resolutions. Integrated within the user-friendly MathSO web portal, these workflows enable non-HPC experts to execute faster-than-real-time simulations for urban planning, pedestrian wind comfort, and emergency tracking of toxic gas leaks. These atmospheric computations are currently coupled with building heat fluxes and validated across European demonstration cities, including Győr, Stuttgart, Poznań, Illkirch, and Stockholm.

Moving forward, the post-project research roadmap targets a complete, two-way microclimatic coupling. For the building model, UNISTRA plans to prioritize geometry v2.0 watertight generation focusing on complex roof topologies and harden the

coupling frameworks: Weather Research and Forecasting (WRF) ↔ KUB (for mesoscale meteorological inputs) and UAP ↔ KUB (for bidirectional feedback of building heat emissions and street-canyon airflow). Specifically, UNISTRA is partnering with the Eurométropole de Strasbourg to map summer thermal vulnerability and prioritize district-scale interventions using enriched national databases; with NEPSEN and Espace Habitat to integrate Ktirio into professional regulatory audits and define a scalable renovation strategy for social housing stocks; and with the French transmission system operator RTE to assess the impact of building energy behaviours on electrical load curves and regional energy flexibility. For the UAP, SZE will optimize RedSim for full-machine LUMI runs, develop a splitting advection-diffusion solver for gaseous pollutant dispersion, and reimplement the solver in OpenCL to support heterogeneous AMD GPUs. Concurrently, Xyst's roadmap focuses on testing scalar-transport models, implementing inhomogeneous atmospheric boundary conditions on domain boundaries, and executing 200k-core runs to validate its exascale readiness.

Renewable Energy Sources R&D to 2030

The RES pilot addresses grid stabilization and infrastructure protection by translating high-resolution weather models into precise energy forecasts and damage risk assessments. The core computation relies on the RES-runner orchestrator, which couples the mesoscale WRF model with the local, high-fidelity EULAG fluid solver. This provides three solutions: RES-wind for modelling wind farms and wind turbines, RES-damages to help in prediction of possible damages to the infrastructure due to extreme weather events, and RES-PV for energy production forecasts from photovoltaics.

To make these workflows accessible to non-HPC experts, the entire pipeline is automated using the QCG Portal. The RES-runner, together with QCG stack, automates execution steps and remote job management. The mUQSA platform can be used to performs automated uncertainty quantification and sensitivity analysis on variable weather inputs. The resulting outputs, including the ensembles, can be stored in CKAN repositories and processed further using HPDA pipelines to provide final wind analysis and solar forecasts for in-portal visualization.

Moving into the post-project research roadmap, the consortium is executing a targeted development and commercialization roadmap. On the technical front, PSNC's immediate priority is containerization; having successfully resolved initial deployment blocks by building a layered Docker image containing EULAG and the Python runner, the next step is include more models (such as WRF) into the container. To enhance RES-PV forecasts, the team is finalizing a tight coupling with the KUB, which will directly inject geometric shading and urban shade masks into the forecasting pipeline. Additionally, the first-generation ensemble processing tool will be migrated from ad-

hoc NumPy scripts to a highly scalable software stack based on Hadoop HDFS and Apache Spark to easily process hundreds of daily NetCDF weather ensembles. To validate the RES-wind model for the energy production forecasts, negotiations are underway with a major Polish DSO to acquire real-world wind energy production data. Commercially, the suite is being positioned as a SaaS platform targeting DSOs, renewable operators, and individual producers, with a business model offering subscription access, usage-based exascale scenario billing, and bilateral consultancy agreements for on-premise integration.

Wildfires and Visualisation R&D to 2030

The Wildfires & Immersive Visualisation Ecosystem models wildfire progression and smoke dispersion at both regional landscape and local WUI scales. Large-scale simulations couple the WRF-SFIRE atmospheric model with the Fire Spread Engine (FSE) and the FSE-Ensembles tool to generate Burn Probability Maps. At the microscale, the pilot utilizes OpenFOAM alongside specialized solvers like porousGasificationFoam (PGF), fireFoam, and wildfireFoam to model detailed flame and smoke spread around buildings, using the 3D-VegeFOAM vegetation tool to represent local fuel structures. Additionally, an AI framework using Long Short-Term Memory (LSTM) autoencoders compresses historical datasets, enabling near-instantaneous scenario retrieval.

To convert these complex datasets into intuitive training and awareness tools, simulation outputs are translated via the Software bridge from WRF-SFIRE to Unreal (Bridge-to-VR) into sparse volumes for 3D rendering. These outputs are integrated into high-fidelity immersive environments built with Unreal Engine 5. Finally, these datasets are post-processed and rendered across distributed environments using the Vistle visualization suite.

Moving into the post-project research roadmap, MTG's immediate priority is integrating a smoke dispersion model into FSE, completing the WRF-FSE coupling, and optimizing PGF/OpenFOAM to scale over urbanization domains. The team will also finalize the UAP-WF coupling (sharing data with urban air solvers) and the WF-MTW coupling (injecting ash erosion predictions into aquatic transport solvers). To maintain a competitive edge, the open-source Vistle will be upgraded with GPU acceleration and its packaging will be hardened for Debian and RedHat distributions. Commercially, the wildfire tools will be distributed via web platforms, mobile apps, APIs, and OGC standards targeting risk management authorities at all scales, including European systems like EFFIS, national entities and regional services. The commercial model features periodic or lifetime software licenses, service-based subscriptions, and specialized consultancy (such as pyrocumulus formation risk or multi-scale fire analysis). Conversely, Vistle will remain open-source, securing sustainability through

publicly funded research grants and collaborative public-private R&D projects to develop domain-specific features.

Material Transport in Water and Methods R&D to 2030

The MTW & Fundamental Methods ecosystem addresses the high-fidelity simulation and data-driven surrogate modelling of pollutant transport and thermal dynamics in aquatic systems. At its core, the fluid-particle-scalar simulation is driven by waLBerla, a massively parallel, multi-physics software framework based on the Lattice Boltzmann Method. To model complex multi-phase interactions, waLBerla is coupled with the Mesa-PD submodule for granular particle dynamics, and the HyTeG multigrid finite element solver to compute heat and species transport. Recent breakthroughs include validating a conjugate heat transfer (CHT) model that resolves dynamic temperature evolution inside individual moving particles.

To bypass the extreme computational cost of running full-fidelity simulations for large-scale studies, the team uses ChannelFlow-Tools, an automated end-to-end pipeline that procedurally generates 3D geometries and runs solver automation to export machine-learning-ready CFD datasets. This rich corpus is used to train the 3D U-Net Surrogate Model, an advanced deep-learning emulator with over 500 million parameters that predicts complex turbulent flow fields and contaminant dispersion patterns almost instantaneously.

Moving into the post-project research roadmap, FAU's immediate priority is extending the CHT model to high-Prandtl-number regimes (up to 7, representing water) and initiating large-scale ensemble simulations on upgraded GPU pipelines. On the software integration front, the team plans to package MTW as a modular software suite, resolving build recipes using Spack and EasyBuild by M42 and M44, and collaborating with EESSI and E4S for pre-built distribution across EuroHPC clusters. Future research will also explore multi-scale couplings, such as the -WF coupling to model ash and sediment run-off from wildfires into waterways. Commercially, the software will be distributed under the open-source GNU AGPLv3 license to encourage academic collaboration. FAU will sustain the work through future Horizon Europe grants and monetise the technology by offering highly specialised consultancy—targeting public water administrations, environmental NGOs, and industrial sectors like offshore wind (modelling seabed erosion around suction buckets) and advanced manufacturing.

7.4 Timeline Roadmap to 2030

To transition HiDALGO2's research results from initial software baselines to fully operational exascale services, the consortium has structured its technical, R&D, and deployment roadmap across four distinct chronological phases. This phased

progression establishes clear milestones, marking the transition from code-level refactoring to coupled multi-physics piloting, and ultimately to federated exascale service delivery.

Table 22. Timeline of research results to 2030

Timeline to 2030			
Phase I: Baseline	Phase II: Refactoring	Phase III: Integration	Phase IV: Post-Project
• Exascale Requirements • Profiling & I/O Gaps • Infrastructure Baseline	• GPU Porting & Solvers • LUMI scaling (>190k) • AI Surrogate Prototypes	• Multi-Model Coupling • Ensemble Scenarios • Early-Adopter Validation (UME/Nepsen	• Federated Exascale • Destination Earth • SaaS / DaaS Services

Phase I: Baseline (2023 - Early 2024)

This initial phase established the scientific and technical baselines for the project's applications, moving beyond generic definitions and the HiDALGO project, to map specific physical equations to high-performance computing grids. The consortium conducted comprehensive computational gap analyses on pre-existing pilot codes to identify parallel bottlenecks, memory limits, and I/O constraints on modern heterogeneous architectures. Concurrently, the core computing and brokerage infrastructure was provisioned to establish seamless data-transfer links between distributed HPC centres and cloud environments. On the data front, Phase I laid the groundwork for structured data management, deploying the CKAN metadata platform and initial Hadoop-HDFS stagers to handle the petabytes of environmental data required for subsequent exascale executions.

Phase II: Development and Design (2024 - 2025)

This phase shifted the focus from architectural planning to intensive software engineering and hardware-software co-design. To fully exploit next-generation supercomputing power, partners refactored core physics solvers (such as SZE's RedSim and FAU's waLBerla) to support highly parallel GPU architectures using modern, portable execution frameworks. The success of this co-design approach was proven by the historic scaling of the Xyst solver, which successfully executed runs utilizing nearly 196,000 cores on the LUMI supercomputer. To bypass traditional computational scaling limits, partners developed first-generation AI surrogate models—such as the deep-learning 3D U-Net for sediment transport and LSTM fire spread neural networks—enabling "faster-than-real-time" prediction. Finally, the QCG-

Portal and MathSO were heavily upgraded with new template-based web GUIs to simplify job submission and execution monitoring for non-HPC users.

Phase III: Integration, Piloting and Collaboration (2026)

In the current phase, the Centre's focus has transitioned from optimizing isolated software components to deploying coupled, multi-physics simulation workflows validated on real-world use cases. Rather than executing simple test cases, pilots are running massive, multi-member ensemble scenarios on EuroHPC machines (such as Discoverer and Karolina) to perform rigorous uncertainty quantification and sensitivity analysis. The defining technical milestone of this phase is multi-model coupling, linking mesoscale meteorological forecasts directly with local microscale building models and wildfire smoke spread simulators. These coupled workflows are undergoing operational validation with established early adopters: UNISTRA is validating Ktirio's district energy reporting alongside the national consulting firm Nepsen, SZE is testing urban wind comfort maps with Stockholm city and MeteoGrid is integrating coupled fire-atmosphere forecasting directly into the training workflows of the Spanish Military Emergency Unit (UME).

Phase IV: Post-Project Scaling & Policy Integration (2027 - 2030)

In the post-funding era, HiDALGO2 aims to scale its coupled workflows to run on federated EuroHPC post-exascale architectures, transitioning from a research consortium to an active provider of real-time Local Digital Twins. These digital twins can scale to exceed 100 billion computational cells, integrating directly with emerging European AI Factories and sovereign data spaces like Destination Earth and the European Open Science Cloud. Operationally, the pilot developers want deliver highly localized, actionable, and domain-specific tools, such as immediate toxic gas release tracking for municipal first responders, district-level probabilistic energy efficiency diagnostics for urban planners, and storm-damage risk estimates for electricity grid operators. Sustained by flexible commercial models—such as Simulation-as-a-Service, usage-based exascale billing, and specialized B2B/B2G consultancy—as well as follow-up European funding, the Centre will permanently cement its role in securing Europe’s digital sovereignty and climate resilience.

7.5 Pathways to Market

Demand for environmental simulation is growing. Engineering consultancies already offer conventional environmental studies, and several of them are large and well established, as shown in Section 3.5. The consortium does not compete with them on breadth. Its position rests on coupled, high-resolution simulation with quantified uncertainty, which few providers offer today. HiDALGO2 turns its codes and data systems into consultancy packages and hosted platforms across its five use cases.

The route to market follows the B2B and B2G models described in Section 3. The reference sectors are large. Air quality monitoring is worth about USD 7.2 billion, building information modelling about USD 9.0 billion, wildfire detection about USD 740 million and water quality monitoring about USD 6 billion (Table 8). These totals give context only. The addressable part is much smaller. It consists of simulation studies delivered as consultancy to several hundred cities, utilities and engineering firms in Europe. It is measured in tens of millions of EUR per year (Section 3.4).

A routine engagement is worth about 35 000 to 90 000 EUR. Larger or multi-year engagements reach about 260 000 EUR (Table 9). In the cost model a routine engagement costs about 56 000 EUR and is priced at 78 000 EUR. The contribution of 22 000 EUR goes towards a standing cost of about 135 000 EUR per year. The activity covers this cost at six to seven routine engagements per year across all five pilots (Section 4.4). In the energy sector, the offer targets distribution system operators and renewable operators. It provides tools that protect grid infrastructure and forecast energy yield.

Public procurement takes time. Twelve to eighteen months can pass between the start of business development and the first payment (Section 4.4). The partners bridge this period with publicly funded research projects running in parallel, such as Horizon Europe, EuroHPC JU, LIFE, Interreg and Digital Europe (Table 19). Academic partners keep their research funding in this way, while industrial partners pursue consulting contracts. This mixed model is how the Centre keeps its capability after the project, as described in Section 5.3.

8 Risk assessment and mitigation

This section discusses risks affecting the exploitation of results and project sustainability. The "Description of Action" document details fourteen critical risks for the project as a whole. Two of them are assigned to Work Package 6 (WP6) and several others have implications for exploitation. These risks have been reviewed and re-assessed in light of the project nearing its conclusion. Some have been eliminated, while others have become more significant. Risks that emerge only after the project ends and which were not included in the "Description of Action" have also been added.

The scale used follows the convention adopted in the "Description of Action": probability is defined first, followed by impact, with each parameter rated as low, medium, or high. The column “Now” rates each risk for the period after the project ends.

Risks carried from the Description of Action

Table 23 reassesses the risks that bear on exploitation.

Table 23. Description of Action risks relevant to exploitation, reassessed

DoA	Risk	Original	Now	Comment
13	Failed or insufficient exploitation of results by consortium members	Low / Medium	Medium / Medium	The original assessment assumed exploitation would largely be pursued by individual partners. That remains true, but the joint route now depends on the Exploitation Agreement being signed and on partners choosing to take part. Likelihood is raised accordingly.
14	Outreach to new communities and generated impact lower than expected	Low / High	Low / Medium	Dissemination and clustering activities have been delivered and external organisations are engaged in all five domains. The residual risk is that attention lapses after the project, not that impact fails to materialise.
9	Availability of compute resources does not meet requirements	Low / Medium	Medium / High	Within the project this was mitigated by reserved allocations at PSNC and at HLRS, the computing centre of USTUTT. After the project the question changes, because access schemes are not designed for commercially contracted work. See the entry below.

5	Data management or processing fails to align with data protection obligations	Low / High	Low / High	Unchanged in severity. The Data Management Plan and Ethics Board addressed it during the project. Commercial delivery introduces customer data under contract, which the Exploitation Agreement covers.
1	Partner related risks, including key personnel not being available	Low / Medium	Medium / High	During the project the work plan and its deadlines keep partners engaged, so the risk stayed low. After the project this obligation ends. Each partner then decides how much staff to keep on the topic. The rating is raised for that reason. See risk B below.

Risks specific to the post-project phase

The risks in Table 24 are not in the Description of Action, because they concern the period after the Grant Agreement ends. Several were raised by the Advisory Board.

Table 24. Risks arising after the project, with mitigation

No	Risk	Rating	Mitigation
A	Computing resources are not available for commercially contracted work on the assumed terms. EuroHPC access is allocated on scientific merit and contribution to open science, not for paid consultancy.	Medium / High	Size early engagements so they can be delivered on partner-owned systems, as set out in Section 5.3. Clarify the position on large-scale access before bidding for work that depends on it. Price commercial allocations into the cost model where they are needed, accepting the higher compute line that follows.
B	Technical capability is lost between projects. Staff move on, models cease to be maintained and assets survive as documentation, no longer as something that can be delivered.	Medium / High	Maintain the four functions identified in Section 5.3as a minimum. Concentrate on the use cases ranked highest in Section 3.2 if resources narrow. Preserve remaining assets in a documented and reproducible state, accepting that they cannot then be offered at short notice.
C	Revenue arrives later than the capability can be carried. Twelve to eighteen months pass between starting	Medium / High	Bridge the period from publicly funded research projects held in parallel, as described in Section 5.3. Begin business development before the project ends. Treat the standing cost as a planned commitment by the partners concerned,

	business development and the first payment.		not as something the first contracts will cover.
D	No commercial track record. A first customer has no references to rely on and public procurement often requires evidence of comparable delivery.	High / Medium	Use the organisations already engaged during the project as first reference customers. Offer demonstrations and limited-scope pilots as a lower-risk entry point, as recommended by the Advisory Board. Bid jointly with partners that do hold a delivery record where a tender requires one.
E	The tender win rate is lower than the one bid in three assumed in Section 4.1, which would raise the acquisition cost carried by each won engagement.	Medium / Medium	Track the actual rate from the first submissions and revise the cost model instead of retaining the assumption. Qualify opportunities more strictly before bidding, which is a defined part of the lead generation role in Section 5.2.
F	Cost estimates prove lower than the actual cost of delivery.	Medium / Medium	Replace the first-order figures with rates and tender data collected from the market. Review the model after the first engagements and correct it against what the work actually cost.
G	Public budgets contract further, reducing discretionary spending on environmental modelling.	Medium / Medium	Concentrate on work that discharges a regulatory obligation, not work that depends on discretionary investment, as argued in Section 3.1. Maintain a mix of public and commercial customers so that a downturn in one does not remove all demand.
H	Established competitors respond on price, removing the advantage described in Section 3.5.	Low / Medium	Compete on resolution and treatment of uncertainty as well as price, since these are harder to match quickly. Accept that price advantage alone is not defensible in the long term.
I	Dependence on individuals. For several assets the practical knowledge sits with one or two people.	Medium / High	Document models and workflows to the standard needed for another specialist to run them. Ensure at least two people per pilot theme are able to operate the main workflow, which is the custodianship function in Section 5.3.
J	Intellectual property or licensing obstacles prevent a joint offer being assembled.	Low / Medium	The asset list in Annex I of the Exploitation Agreement records ownership and licensing conditions in advance, so the

			position is known before an opportunity arises and is not negotiated under time pressure.
K	Data needed for an engagement is unavailable or costs more than assumed.	Low / Medium	The cost model carries an explicit data line, as set out in Section 4.1. Where data must be supplied by the customer, make this a condition of the offer, not an assumption.
L	Research on the pilot codes does not continue after the project. Without new research funding the models stop developing and the offer loses its technical lead.	Medium / Medium	Pursue follow-on research funding through the instruments in Table 19. Use the roadmap in Section 7 to set the priorities of new proposals. Keep research and commercial work in the same teams, as described in Section 5.3, so that each supports the other.

Key risks

Three of the above determine whether the plan in Sections 4 and 5F[is executable at all and they are connected. Capability is lost if teams cannot be held together. Teams cannot be held together unless the period before revenue is funded from elsewhere. The work also cannot be delivered at the assumed cost unless computing resources are available on acceptable terms. Risks A, B and C should therefore be treated as one problem instead of three and progress against them is the most useful measure of whether exploitation is on track.

The remaining risks are more limited. They would affect how profitable the activity is, or how fast it develops, but not whether it can exist.

9 Conclusions

The successful execution of the exploitation and sustainability tasks in Work Package 6 has delivered a fully matured, realistic, and commercially viable post-project framework for the HiDALGO2 Centre of Excellence. By achieving a clean single-ownership structure across all 33 technical results and validating a low-risk financial model that requires winning only 6 to 7 routine engagements annually to cover standing operational costs, the consortium has proved that its exascale environmental services can achieve long-term financial self-sufficiency without relying on continuous grant funding. Some strengths of this framework include, that it is supported by a balanced hybrid licensing model that fulfils European Open Science mandates while protecting commercial revenue streams and is legally anchored by the signed Exploitation Agreement (D6.7) and the Exploitation Coordination Committee. This plan ensures that HiDALGO2's technological breakthroughs will sustainably deliver high-impact climate resilience, digital sovereignty, and commercial value across Europe well beyond the project's funding timeline.

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Annexes

Annex 1. List of Exploitable Results

Table 25. Description of Key Exploitable Results

Numbering	Key Exploitable Results	Type of Result	Short Description
KER1	HPC Cloud DMS	Integrated Platform	High-scalable, high-performance data management system, offering data provision and transfer, between Cloud providers and HPC data centres, underpinning the execution of pilot's simulations and the further analytics and visualization of their data outcomes.
KER2	High-resolution urban air comfort maps from simulations	Innovative Solution - SW	The service provides the user with high resolution simulation of urban air and its assessment for urban pedestrian air/wind comfort and safety.
KER3	Software tools for urban planning	Innovative Solution - SW	The service provides urban designers and policymakers with computational tools serving to mitigate or cease the negative effects of urban challenges from an easy-to-use, tailored user interface, and HPC simulations in the background
KER4	Ktirio-Urban-Building Services	Innovative Solution - SW	The Ktirio Urban Building services are a set of services that when used in a workflow allow the simulation of building energy and comfort as well as other use cases
KER5	RES-damages	Innovative Solution - SW	Prediction of the damages to the infrastructure due to extreme weather events
KER6	RES-wind	Innovative Solution - SW	Detailed weather forecast and analysis for wind farms, for later forecast electrical energy production and selection of best spots for new renewables infrastructure
KER7	RES-PV	Innovative Solution - SW	Detailed weather forecasts for photovoltaics, including electrical energy production forecast from photovoltaics

Numbering	Key Exploitable Results	Type of Result	Short Description
KER8	Ktirio-GUI	Innovative Solution - SW	Graphical User Interface that allows to generate the data for the Ktirio Urban Building services
KER9	Ktirio Data - CKAN.Girder	Other Dataset	A robust data management framework built on CKAN and Girder, ensuring secure, scalable storage and efficient cataloguing of building and city datasets, thereby streamlining data sharing across the KUB Pilot.
KER10	Coupled fire spread and smoke dispersion simulator engine / Probabilistic Spread	Innovative Solution - SW	This is a coupled simulation workflow entailing several numerical models (atmosphere, fire spread, smoke spread) aimed at the forecast of fire front spread, fire-atmosphere interaction and smoke production and dispersion over large areas.
KER11	Multi-scale fire analysis tool. Consulting service.	Innovative Solution - SW	Consultancy service to analyse risks in urbanised areas, areas of high environmental value or recreational areas, enabling the analysis of measures to reduce the potential impact on the environment and ensure the protection of people. Take advantage of the use of different tools that allow you to analyse different scales with the tool that best suits the case.
KER12	Pyrocumulus formation, Fire/smoke landscape daily risk. Consulting service.	Innovative Solution - SW	Consultancy service to assess the possibility of pyroconvective movements developing in a fire and the evolution of smoke associated with combustion from an ensemble of equiprobables simulations.
KER13	Material Transport in Water pilot	System/ Model	The scalar transport simulations give an understanding of temperature distribution in particle-laden flows that helps in better studying aquatic systems and other large river bodies.
KER14	HiDALGO2 Dashboard	Integrated Platform	A central hub and landing page for accessing HiDALGO2 services, functioning as an integrated platform available to both guests and registered users.

Table 26. Description of Exploitable Results

Numbering	Exploitable Results	Type of Result	Short Description
ER1	Data Management System	Integrated Platform	High-scalable, high-performance data management system, offering data provision and transfer, between Cloud providers and HPC data centers, underpinning the execution of pilot's simulations and the further analytics and visualization of their data outocomes
ER2	MathSO portal	Integrated Platform	MathSO-portal is a software framework to provide an easy-to-use graphical user interface to define, deploy, execute workflows for HPC applications. The portal is integrated with some pre- and post-processing and integration tools for simulations (e.g. mesh generation, visualization of the results, application image generation).
ER3	CFDR	Innovative Solution - SW	CFDR is a visualization software designed and implemented for the fast visualization of CFD simulation (tailored for CFD applications) results that run on HPC machines and visualized on users servers.
ER4	RedSim	Innovative Solution - SW	RedSim is a native OpenMPI+CUDA code for scalable running CFD on HPC multi-GPU and CPU systems simulations for compressible fluids.
ER5	Ray Tracing for Solar Mask (Open Source)	Algorithm	An open-source tool that uses ray-tracing methods to compute solar masks in urban environments, enabling precise shading analysis and informing energy optimization decisions for building design. it is part of the Feel++ software
ER6	Feel++	Innovative Solution - SW	A high-performance computing framework for solving partial differential equations, providing advanced simulation and modeling capabilities that support advanced numerical methods and numerical building blocks for the Urban building pilot.
ER7	Ktirio Geom	Innovative Solution - SW	A geometry-handling component tailored to complex urban building structures, facilitating accurate 3D model creation from building to cities and integration with other Ktirio modules to improve simulation accuracy.

Numbering	Exploitable Results	Type of Result	Short Description
ER8	Ktirio Cases - https://cases.ktirio.fr	Other Dataset	An online platform where various building and city-related simulation reports are uploaded, managed, and shared, enabling stakeholders to compare and analyze different use cases within the KUB Pilot.
ER9	Ktirio Web Site: https://ktirio.fr	Integrated Platform	The central entry point for the Ktirio ecosystem, offering documentation, user resources, and an overview of available services and tools for managing and analyzing building performance data.
ER10	Ktirio Reporting	Innovative Solution - SW	A reporting module that generates detailed analytics and visual outputs from simulation results, helping stakeholders track and understand building performance metrics over time. It is deployed in ktirio cases site.
ER11	Ktirio Models	Innovative Solution - SW	A collection of validated simulation and data models specifically designed for urban building studies, enabling complex scenario testing and supporting evidence-based decision-making in the KUB Pilot.
ER12	Vegetation descriptor. Analysis of vegetation evolution. Vegetation Tool.	AI & ML Model/ Method	Workflow to enable a detailed description of vegetation by identifying individuals with age and condition characteristics in urban or forest areas. Once the species, age and condition have been characterised, a spatial form is associated with it from a catalogue to facilitate its visualisation in 3D environments and its behaviour in digital twins or simulation environments.
ER13	Local Digital Twins as Demonstrators of assessment capabilities	Innovative Solution - SW	Development of digital twins corresponding to a specific geographical extension for the visualization and exploration of possible climate/weather futures and essay of vegetation (forest fuel) mitigation strategies and policies on wildfire and the effect on the smoke spread and impact in WUI areas.
ER14	mUQSA	Integrated platform	mUQSA is a web platform for automated UQ&SA studies of computational models.
ER15	QCG	System/ Model	QCG is a web protal facilitating and automating remote execution of computational experiments

Numbering	Exploitable Results	Type of Result	Short Description
			on HPC clusters. It provides flexible and highly customisable interface, thus it may be used for many types of jobs ranging from simple serial executions, through parallel jobs and tasks with GUI, and anding with complex workflows.
ER16	Vistle	Innovative Solution - SW	Successor of COVISE with support for parallel post processing, visualization and rendering
ER17	Surrogate Model	Innovative Solution - SW	Prediction of Material Transport in fluids Using a Deep Learning-Based Surrogate Model. The approach involves initially predicting the flow dynamics in fluids, followed by an attempt to predict both the flow and material transport together.
ER18	Bull Argos Suite	Innovative Solution - SW	A suite of energy monitoring and optimization tools integrated into the Bull's Argos Suite. It includes four main modules: a Power and Performance Estimator (PPE) for job behavior prediction, a Job Energy and Performance Comparator (JEPC) for cross-run trade-off analysis and Amdahl's law-based scalability estimation, a Job Energy Predictor (JEP), and a Job Energy Recommender (JER).
ER19	RES-runner	Innovative Solution - SW	Framework to prepare multiscale simulations workflow, from setup, through execution, to post-processing of results.

Annex 2. Intellectual Property Rights

Table 27. Intellectual Property Rights of KERs

Numbering	Key Exploitable Results	Ownership	Name of Owner	Related Tasks	Current TRL	License Of ER	Indicative type of protection	Conditions to use within the project	Conditions to use the result after the end of the project
KER1	HPC Cloud DMS	Single	BULL	T4.1	TRL5	Apache 2.0, AGPL	Open Source	OSS licence, free to use, no restrictions	OSS licence, free to use, no restrictions
KER2	High-resolution urban air comfort maps from simulations	Single	SZE	T.5.1	TRL5	SZE	Copyright SZE	Closed Source, free to use	Upon Agreement
KER3	Software tools for urban planning	Single	SZE	T5.1	TRL5	SZE	Copyright SZE	Closed Source, free to use	Upon Agreement
KER4	Ktirio-Urban-Building Services	Single	UNISTRA	T5.2	TRL4	Closed	Copyright UNISTRA	Closed, free to use on shared EuroHPC resources	Closed, free to use on shared EuroHPC resources
KER5	RES-damages	Single	PSNC	T5.3	TRL 4	AGPLv3, PSNC	Copyright PSNC	AGPLv3, free to use on shared EuroHPC resources	Upon agreement
KER6	RES-wind	Single	PSNC	T5.3	TRL 7	AGPLv3, PSNC	Copyright PSNC	AGPLv3, free to use on shared	Upon agreement

Numbering	Key Exploitable Results	Ownership	Name of Owner	Related Tasks	Current TRL	License Of ER	Indicative type of protection	Conditions to use within the project	Conditions to use the result after the end of the project
								EuroHPC resources	
KER7	RES-PV	Single	PSNC	T5.3	TRL 8	AGPLv3, PSNC	Copyright PSNC	AGPLv3, free to use on shared EuroHPC resources	Upon agreement
KER8	Ktirio-GUI	Single	UNISTRA	T5.2	TRL4	Closed	Copyright UNISTRA	Closed, free to use on shared EuroHPC resources	Closed, free to use on shared EuroHPC resources
KER9	Ktirio Data - CKAN.Girder	Single	UNISTRA	T5.2	TRL 7	GPL	Copyright UNISTRA	Closed, free to use	Closed, open to discussions on the exploitation, NDA, licensing
KER10	Coupled fire spread and smoke dispersion simulator engine / Probabilistic Spread	Single	MTG	T5.4	TRL6	Open GPL/ MTG	Copyright MTG	Free to use	Software - Free to use / Simulation Service Open to discussion on the explotation NDA licencing
KER11	Multi-scale fire analysis tool. Consulting service.	Single	MTG	T5.4	TRL9	Open GPL/ MTG	Copyright MTG	Free to use	Software - Free to use / Simulation Service Open to discussion on the

Numbering	Key Exploitable Results	Ownership	Name of Owner	Related Tasks	Current TRL	License Of ER	Indicative type of protection	Conditions to use within the project	Conditions to use the result after the end of the project
									explotation NDA licencing
KER12	Pyrocumulus formatio, Fire/smoke landscape daily risk. Consulting service.	Single	MTG	T5.4	TRL3	Open GPL	Copyright MTG	Free to use	Software - Free to use / Simulation Service Open to discussion on the explotation NDA licencing
KER13	Material Transport in Water pilot	Single	FAU	T5.5, T3.4	TRL4	GNU AGPLv3	AGPLv3 FSF	Free to use	free to use
KER14	HiDALGO2 Dashboard	Single	SZE	T2.3	TRL6	SZE	Copyright SZE	Closed	Upon Agreement

Table 28. Intellectual Property Rights of ERs

Numbering	Exploitable Results	Ownership	Name of Owner	Related Tasks	Current TRL	License Of ER	Indicative type of protection	Conditions to use within the project	Conditions to use the result after the end of the project
ER1	Data Management System	Single	PSNC	T4.1	TRL5	AGPL v3.0, APLv2.0	Open Source	OSS licence, free to use, no restrictions	OSS licence, free to use, no restrictions
ER2	MathSO portal	Single	SZE	T.5.1	TRL5	SZE	Copyright SZE	Closed Source, free to use	Upon Agreement
ER3	CFDR	Single	SZE	T5.1	TRL5	SZE	Copyright SZE	Closed Source, free to use	Upon Agreement
ER4	RedSim	Single	UNISTRA	T5.1	TRL5	SZE	Copyright SZE	Closed Source, free to use	Upon Agreement
ER5	Ray Tracing for Solar Mask	Single	UNISTRA	T5.2	TRL 4	GPL	Copyright UNISTRA	Open, free to use	Open, free to use
ER6	Feel++	Single	UNISTRA	T5.2	TRL 5	LGPL & GPL	Copyright UNISTRA	Open, free to use	Open, free to use
ER7	Ktirio Geom	Single	UNISTRA	T5.2	TRL 5	GPL	Copyright UNISTRA	Open, free to use	Open, free to use, double licensing under study

Numbering	Exploitable Results	Ownership	Name of Owner	Related Tasks	Current TRL	License Of ER	Indicative type of protection	Conditions to use within the project	Conditions to use the result after the end of the project
ER8	Ktirio Cases	Single	UNISTRA	T5.2	TRL 7	N/A	Copyright UNISTRA	free to use	free to use
ER9	Ktirio Web Site	Single	UNISTRA	T5.2	TRL 7	N/A	Copyright UNISTRA	free to use	free to use
ER10	Ktirio Reporting	Single	UNISTRA	T5.2	TRL 7	GPL and commercial licencing	Copyright UNISTRA	free to use	Open, free to use
ER11	Ktirio Models	Single	UNISTRA	T4.6, T2.4	TRL 4	GPL	Copyright UNISTRA	Closed	Closed, open to discussions on the exploitation, NDA, licensing
ER12	Vegetation descriptor. Analysis of vegetation evolution. Vegetation Tool.	Single	MTG	T5.4	TRL 5	Free to use / Open GPL	Copyright MTG	Free to use	Software - Free to use / Simulation Service Open to discussion on the explotation NDA licencing
ER13	Local Digital Twins as Demonstrators of assessment capabilities	Single	MTG	T5.4	TRL6	Free to use / Open GPL	Copyright MTG	Free to use	Software - Free to use / Simulation Service Open to discussion on the explotation NDA licencing

Numbering	Exploitable Results	Ownership	Name of Owner	Related Tasks	Current TRL	License Of ER	Indicative type of protection	Conditions to use within the project	Conditions to use the result after the end of the project
ER14	mUQSA	Single	PSNC	T4.6, T2.4	TRL7	AGPLv3	open source	free to use	free to use
ER15	QCG	Single	PSNC	T2.4	TRL7	AGPLv3	open source	free to use	free to use
ER16	Vistle	Single	USTUTT	T4.4	TRL7	LGPL v2.1	N/A	free to use	free to use
ER17	Surrogate Model	Single	FAU	T4.3, T3.3	TRL4	AGPLv3	AGPLv3 FSF	free to use	free to use
ER18	Bull Argos Suite	Single	BULL	T2.4	TRL4	BullSequana Source-Available License (BSSAL)	Copyright	Closed	Restrictions / Licence required
ER19	RES-runner	Single	PSNC	T5.3	TRL9	AGPLv3	Copyright PSNC	Free to use	Free to use