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Hydrogen Valley in the Province of Mantova

Hymantovalley

PLANNING RESEARCH ACTIVITIES

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Project Partners

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A EXECUTIVE SUMMARY

The deliverable titled "HYMANTOVALLEY - Planning Research activities" outlines the establishment of a Hydrogen Research Hub in Mantova, Italy. This hub aims to position itself as a national and European leader in hydrogen technologies, focusing on both local and European needs. The executive summary details the hub's purpose, vision, mission, strategic goals, organisational structure, facilities, and business plan.

- Purpose of the Hydrogen Research Hub

The Hydrogen Research Hub is designed to create a premier centre dedicated to advancing hydrogen technologies. It aims to provide a collaborative environment for companies and research institutions interested in hydrogen applications, particularly those that promote decarbonisation and sustainability in energy-intensive sectors. By establishing itself as a leader in hydrogen research and innovation, the hub will enhance Mantova's significance on both national and international scales, aligning with Europe's green energy objectives.

- Vision and Mission

The vision of the Hydrogen Research Hub is to foster innovation in hydrogen technologies through a flexible research environment that adapts to industry demands. Its mission encompasses fostering partnerships between industry and academia to ensure that research outputs translate into practical, deployable hydrogen solutions. By prioritising collaboration and real-world applications, the hub aspires to become a vital contributor to the hydrogen economy, promoting sustainable development and technological advancements.

- Strategic Goals

Key strategic goals of the Hydrogen Research Hub include:

  - **Collaborative Environment for Innovation**. The hub aims to provide a space where industry experts and academic researchers can work together on hydrogen projects, encompassing experimental studies and applied technologies such as fuel cell development and hydrogen storage solutions.
  - **Enhanced Research Capabilities**. It will focus on developing advanced laboratories, testing facilities, and data-sharing platforms that facilitate breakthrough research in hydrogen technologies.
  - **Support for Sustainability in Energy**. Aligning with global sustainability targets, the hub will advocate for hydrogen applications in sectors that are challenging to decarbonise. This goal underscores hydrogen's potential in reducing greenhouse gas emissions while advancing the European Union's climate objectives.

By pursuing these strategic goals, the Hydrogen Research Hub will significantly impact the European energy landscape, driving technological progress while addressing critical environmental challenges.

- Organisational Structure

The organisational structure of the Hydrogen Research Hub is designed to facilitate effective governance and operational efficiency. It incorporates a governance model that ensures accountability and strategic direction. The management overview highlights key roles within the hub:

- **Executive Board**. Comprising representatives from industry partners, academic institutions, and government entities, this board will oversee strategic decision-making processes.
- **Research Management Team**. Responsible for coordinating research activities, this team will ensure alignment with industry needs while managing collaborations between researchers and industrial partners.
- **Administrative Support**. This team will handle logistical aspects of operations including budgeting, compliance with regulations, and stakeholder communication.

- Laboratories and Facilities

The Hydrogen Research Hub will feature state-of-the-art laboratories designed for flexibility and efficiency. Key aspects include:

- **Flexible Laboratory Design**. Laboratories will be modular in setup to accommodate various research projects. This design allows for quick reconfiguration based on evolving project needs.
- **State-of-the-Art Equipment**. The hub will be equipped with advanced technology essential for conducting cutting-edge research in hydrogen production, storage, and utilisation.
- **Office Spaces**. Dedicated office spaces for researchers and administrative staff will facilitate collaboration while ensuring a conducive working environment.
- **Safety and Environmental Considerations**. Safety protocols will be integrated into all laboratory designs to protect personnel while adhering to environmental standards.

- Business Plan

The business plan outlines potential revenue sources and sustainability initiatives that will underpin the financial viability of the Hydrogen Research Hub:

- **Cost Sharing Model**. The hub will implement a cost-sharing model among partners to distribute operational expenses fairly while encouraging investment from various stakeholders.
- **Potential Revenue Sources**. Revenue may be generated through grant funding from governmental bodies, partnerships with private sector companies for joint research projects, consultancy services offered to industries seeking expertise in hydrogen technologies, and training programs aimed at upskilling personnel in relevant fields.

- **Sustainability Initiatives**. The hub is committed to sustainability not only through its research focus but also by implementing green practices within its operations. This includes energy-efficient building designs and waste reduction strategies.

In conclusion, the establishment of the Hydrogen Research Hub in Mantova represents a strategic opportunity to address contemporary energy challenges while fostering technological innovation. By focusing on targeted research efforts tailored to industrial needs within a robust organisational framework, this hub aims not only to accelerate the adoption of hydrogen technologies but also to ensure they meet rigorous industrial demands. Ultimately, this initiative seeks to bridge the gap between research outputs and practical applications while strengthening Mantova's role in shaping a sustainable energy future within Europe.

B BACKGROUND AND IMPORTANCE OF HYDROGEN

The current energy system is crucial for global economic and social development. However, its heavy reliance on fossil fuels and foreign energy supplies has made economies around the world vulnerable to various risks [1]. The depletion of valuable natural resources and growing environmental challenges, such as pollution and climate change, highlight the need for a deep rethinking of energy technologies [2]. From sourcing raw materials to the final disposal of products, there is an urgent call for a more efficient and sustainable approach that ensures accessibility and resilience [3].

In this context, hydrogen, the most abundant element in the universe, emerges as a key solution in the future energy transition, offering significant environmental benefits while supporting sustainable development [4]. Hydrogen can be integrated into the global energy system alongside other energy sources, helping to diversify and strengthen available options, rather than completely replacing them [5]. The hydrogen value chain (Figure 1) begins with the generation of energy, which can either be sourced from fossil fuels or renewable sources. Petroleum-based energy produces gray hydrogen, which emits carbon dioxide, and blue hydrogen, which incorporates carbon capture to reduce emissions. In contrast, green hydrogen is generated entirely from renewable energy sources, such as wind or solar, through a process called electrolysis, ensuring no harmful emissions are released.

Once generated, hydrogen technology enables its conversion and use in various sectors. Fuel cells, such as Proton Exchange Membrane Fuel Cells (PEMFC) and Solid Oxide Fuel Cells (SOFC), play a central role in transforming hydrogen into electricity, making it viable for applications across diverse fields. Additionally, hydrogen can be directly burned through combustion for particular uses where direct fuel is preferred.

Hydrogen's versatility allows it to serve crucial roles in sectors where decarbonization is challenging. It powers passenger cars, commercial vehicles, rail, and even maritime and aerial applications, providing a clean alternative to traditional fuel sources. In practical applications, hydrogen infrastructure supports refueling stations, transportation, and fleet management. This multi-stage process showcases hydrogen's potential as a sustainable energy source capable of reducing emissions across high-impact industries.

Hydrogen is also valuable in sectors that are difficult to decarbonize, such as heavy industry, long-distance transportation, and energy storage. Unlike fossil fuels, hydrogen can be produced from renewable sources, resulting in "green hydrogen" that does not release harmful emissions [7], [8] . This makes hydrogen not just an environmentally friendly alternative, but also a driving force for new energy technologies and infrastructure [9].

By including hydrogen in the energy mix, the system becomes more flexible and sustainable, especially when paired with renewable sources like solar and wind [10]. Hydrogen can store and transport energy, making it available when needed. Its growing popularity, particularly in Europe, Asia, and North America, shows its potential to become a major part of future energy strategies. The move towards hydrogen is part of a global push for sustainability, energy security, and innovation . Hydrogen offers a way to reduce dependence on fossil fuels while developing cleaner, more resilient energy systems . Investment in hydrogen technologies and infrastructure will be critical in realising its full potential, both for economic growth and in addressing climate change [11].

Figura 1 - Hydrogen Value Chain [6]

Based on these premises, the creation of a Hydrogen Research Hub in Mantova presents a strategic opportunity to address current and future energy challenges. With hydrogen increasingly recognized as a key element in the global energy transition, this research hub can become a centre of excellence, promoting technological innovation, developing sustainable solutions, and fostering collaboration between industry and academy.

The Hydrogen Research Hub in Mantova aims to position itself as a national and European leader, with a dual focus. On one hand, it will meet the needs of companies interested in developing hydrogen-related technologies; on the other, it will establish itself as a leading hub for advanced research in this field. This dual role will make the centre a key site for technological experimentation and development, supporting the shift toward hydrogen as a crucial energy carrier for the future.

The establishment of the centre will allow for the exploration of innovative solutions for the production, storage, and application of hydrogen in critical sectors such as heavy industry and transportation, contributing to the reduction of carbon emissions. Furthermore, the hub will promote economic growth by attracting investment, generating new technologies, and creating a collaborative environment that bridges the gap between research and practical applications. In doing so, it will strengthen Mantova's role in the energy landscape both nationally and across Europe.

Focusing on the industrial side, there is an urgent need for dedicated research into hydrogen technologies to meet the specific requirements of various industries. Hydrogen has the potential to revolutionise sectors such as manufacturing, transportation, and energy production, but to unlock its full potential, targeted research and development efforts are essential.

Industries require scalable, efficient, and cost-effective hydrogen solutions to replace fossil fuels in high-energy-demand processes. For instance, in heavy industries such as steel production and chemical manufacturing, hydrogen can serve as a cleaner alternative to carbon-intensive fuels. However, adapting these industries to hydrogen requires advancements in production methods, storage solutions, and the integration of hydrogen into existing processes.

Research must focus on developing industrial-grade hydrogen technologies that are both economically viable and environmentally sustainable. This includes improving electrolysis methods to produce green hydrogen at a lower cost, enhancing fuel cell efficiency for industrial applications, and creating reliable storage and transportation systems to facilitate large-scale hydrogen use.

Moreover, industrial research needs to address the safety, infrastructure, and regulatory challenges associated with hydrogen deployment. The hub must be able to carry out certified tests and issue the related certificates for the companies' products related to the use of this gas. Establishing robust standards and safety protocols will be crucial to gaining the trust of industries and regulators alike. By focusing on these areas, the research conducted at the Research Hub will not only accelerate the adoption of hydrogen technologies but will also ensure that they meet the rigorous demands of industrial-scale operations. Collaboration between industrial players and research institutions is key to this effort. The diagram in Figure 2 illustrates the full hydrogen ecosystem, from supply sources (such as renewables, natural gas, and nuclear energy) to demand applications in transportation, buildings, and industry.

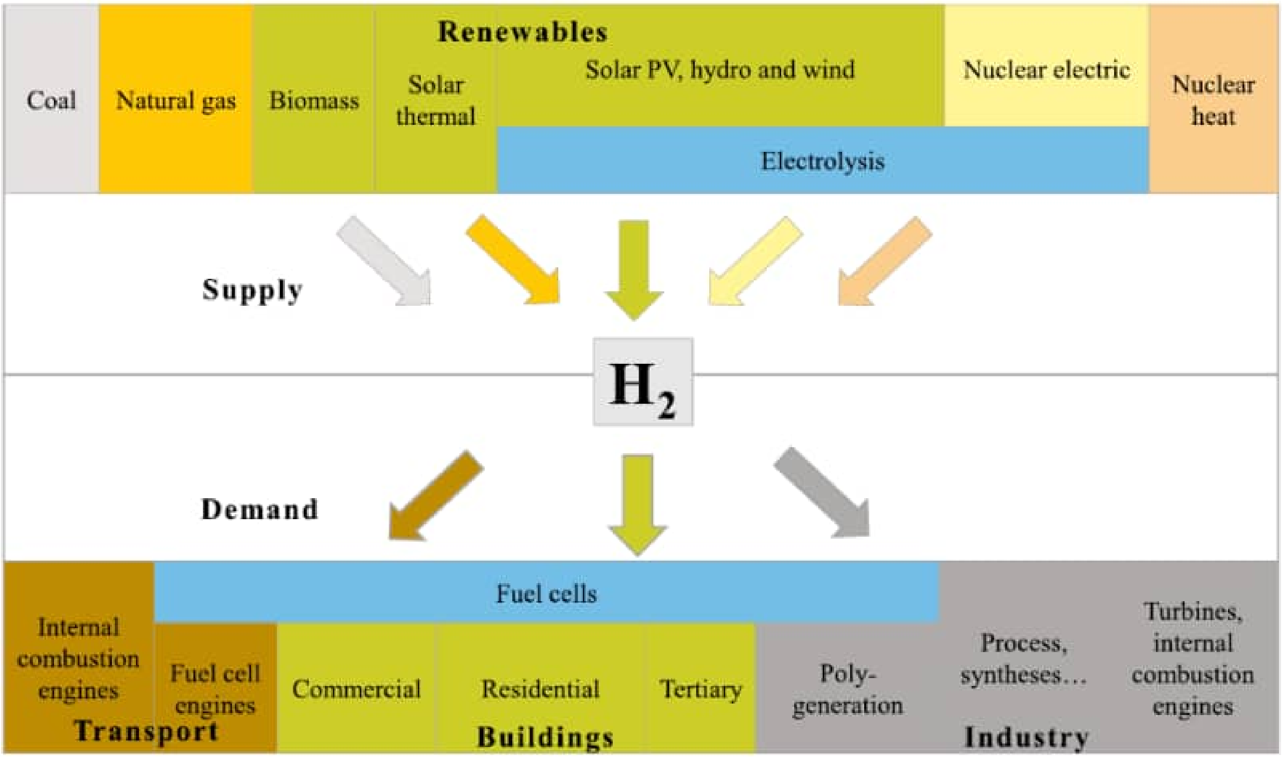

Figure 2 - [12]

The Hydrogen Research Hub will act as the bridge within this ecosystem, facilitating partnerships that are essential for advancing and testing hydrogen technologies. By leveraging the supply options (shown in the diagram) and targeting the needs of each demand sector, the hub can develop, prototype, and implement hydrogen solutions tailored to industry requirements. This collaborative approach ensures that hydrogen technologies align with industries' decarbonization goals, helping them maintain competitiveness while transitioning to cleaner energy options.

The following sectors can gain the most from hydrogen:

1. Heavy Industry (Steel, Cement, and Chemicals)

In the steel production field, hydrogen can replace coal in steel manufacturing, particularly through the direct reduction of iron (DRI) process, significantly reducing carbon emissions. This is critical for decarbonizing one of the largest emitters of CO_2 globally. The cement industry faces challenges in reducing emissions because of the chemical process involved in production. Hydrogen can be used both as a heat source and as part of the chemical processes to lower the carbon footprint. In the chemical Industry, hydrogen is already used extensively in the production of ammonia and methanol, or in the plastics industry. Shifting from fossil-fuel-derived hydrogen to green hydrogen can dramatically cut emissions in this sector [13].

2. Transportation

For heavy-duty transport, fuel cells are well-suited for heavy vehicles such as trucks, buses, and trains, where battery technology struggles with weight and range limitations. Hydrogen's energy density makes it ideal for long-haul transportation. The maritime industry is exploring hydrogen and ammonia as alternative fuels to meet stringent emissions regulations while maintaining long-range travel capabilities.In the Hymantovalley project, river transport of goods on boats using hydrogen as fuel will be tested. This could lead to a decrease in road and rail traffic, thus reducing some of the air pollution. While still in the experimental stages, hydrogen is a promising solution for decarbonizing aviation, either through hydrogen combustion engines or fuel cells, which could be integrated into aircraft to reduce the industry's substantial carbon emissions [14], [15]. By 2050, 400 million automobiles and 20 million trucks might run on hydrogen, according to the Global Hydrogen Council [16], [17].

3. Energy Storage and Grid Management

Hydrogen can store surplus energy generated from renewable sources like solar and wind. This stored energy can be converted back into electricity during periods of low renewable generation, ensuring a stable and flexible power grid. Moreover, fuel cells offer reliable and clean backup power for industries, data centres, hospitals, and even residential areas, replacing traditional diesel generators [9]. The advancement of hydrogen storage infrastructure and sophisticated electrolysis technologies will support the future expansion of hydrogen in energy storage and grid balancing. By 2050, hydrogen is expected to provide 3.6 exajoules of energy storage capacity, according to the International Renewable Energy Agency (IRENA). By 2030, 40 gigawatts of electrolyzers are expected to be installed as part of the European Commission's Hydrogen Strategy to produce hydrogen [18].

4. Oil Refining and Petrochemicals

Hydrogen is currently used in oil refining for desulfurization processes. Replacing grey hydrogen (produced from fossil fuels) with green hydrogen can help the sector transition towards cleaner processes while meeting existing industrial needs [19]. The Hydrogen Council calculates that 10% of the world's oil refining process uses hydrogen, generating a market value of more than $20 billion annually. According to the International Energy Agency, hydrogen might contribute to an 80% reduction in carbon dioxide emissions from the refining of oil [1].

5. Residential and Commercial Heating

Hydrogen can be used for residential and commercial heating, especially in regions where it is difficult to transition to electric heating. Blending hydrogen with natural gas or using it as a standalone fuel can significantly reduce emissions in this sector [20].

6. Power Generation

Hydrogen can be burned in turbines or used in fuel cells to generate electricity, offering a flexible, zero-carbon alternative to natural gas in power generation. This is particularly important for countries and regions heavily reliant on fossil fuel power plants [21].

7. Agriculture

Hydrogen can power agricultural machinery, contribute to ammonia-based fertiliser production, and serve as an energy storage solution for farms using renewable energy systems. This can reduce the carbon footprint of farming operations while improving energy independence.

In summary, industries that rely on high energy inputs, have difficulties with direct electrification, or produce significant carbon emissions, such as heavy industry, transportation, and energy storage, can benefit the most from hydrogen technologies. As research and development progress, hydrogen is expected to become a cornerstone in the decarbonization strategies of these sectors [7].

Hydrogen industry faces a variety of challenges related to cost, infrastructure, safety, efficiency, regulatory support, and competition from other technologies. These challenges must be addressed for the widespread adoption and integration of hydrogen technologies. An Hydrogen Research Hub, could represent the answer to the following areas:

- High Production Costs → producing green hydrogen via electrolysis (using renewable energy) is significantly more expensive than producing grey hydrogen (from natural gas) or blue hydrogen (from natural gas with carbon capture) (Figure 3). The cost of renewable electricity, electrolyzer technology, and scaling up production are major barriers to making green hydrogen cost-competitive. In addition, electrolysis technology is still in the early stages of development, and scaling it up to industrial levels while maintaining efficiency and reducing costs is a major challenge. Advances in technology and greater investment are needed to achieve economies of scale.

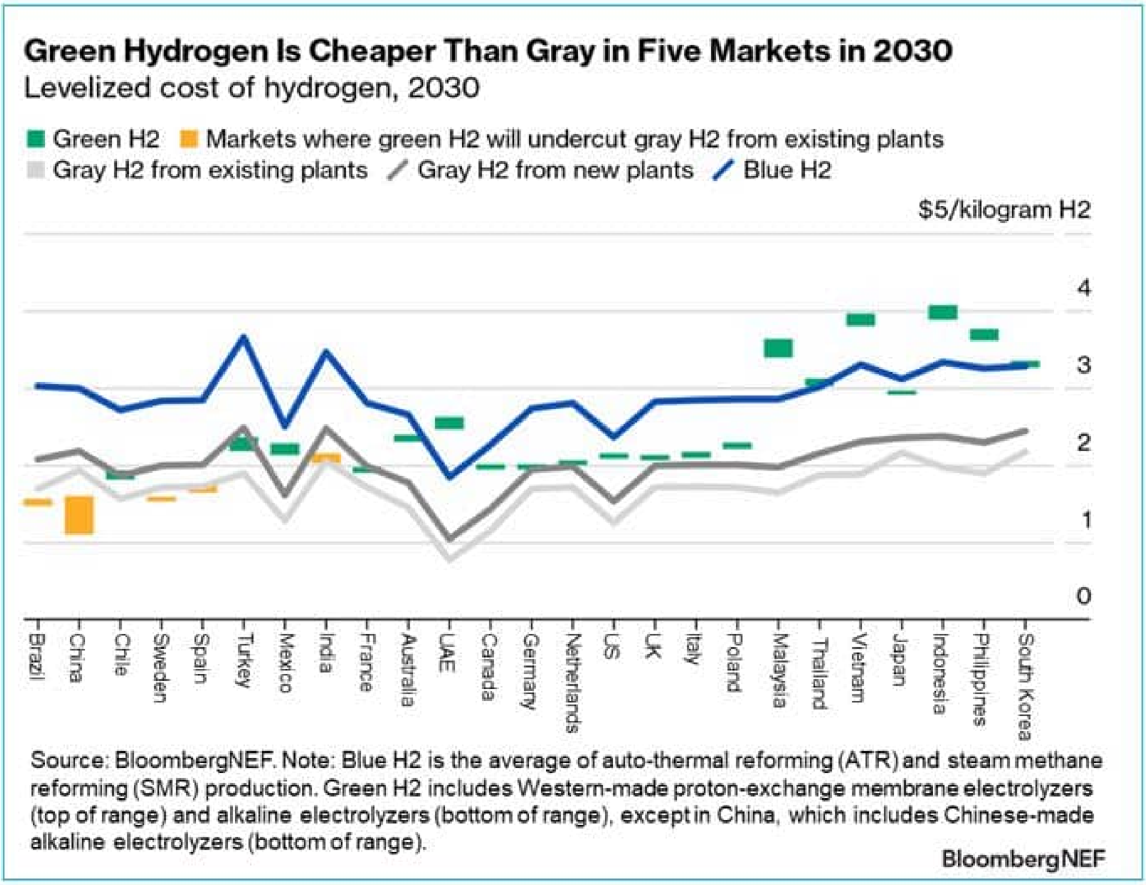

Figure 3 - projected levelized cost of hydrogen in 2030 [22]

- Infrastructure Development → Hydrogen is difficult to store and transport due to its low energy density by volume and the need for high-pressure or cryogenic storage solutions. Developing safe, cost-effective, and efficient infrastructure for hydrogen storage, pipelines, and transport (e.g., for shipping) is critical for scaling the hydrogen economy. Most existing infrastructure, such as natural gas pipelines, cannot be easily converted to handle hydrogen without significant modifications due to hydrogen's small molecule size and tendency to cause embrittlement in metals. A widespread network for hydrogen delivery does not yet exist, which limits its availability.
- Energy Loss and Efficiency → actually, the process of producing, storing, and using hydrogen involves several energy conversion steps, each with inherent energy losses. Electrolysis, compression, storage, and fuel cell conversion result in efficiency losses, meaning more renewable electricity is needed to produce usable hydrogen energy compared to direct electrification. While fuel cells are a promising technology for converting hydrogen into electricity, they are not as efficient as batteries when it comes to energy conversion. Improving the efficiency of hydrogen fuel cells is critical for their competitiveness, particularly in transportation and power generation.
- Safety Concerns → The flammability and explosiveness of hydrogen require the implementation of strict safety regulations. Educating the public and building trust around hydrogen safety protocols are crucial for its widespread adoption. Currently, there is a general public perception that hydrogen is too dangerous to handle,

largely due to its association with a few high-profile accidents. Addressing these concerns through clear communication, rigorous safety standards, and proven technological advancements will help dispel misconceptions and foster greater confidence in hydrogen technologies.

- Competition from Other Technologies → in some sectors, particularly light transportation and small-scale energy storage, hydrogen faces competition from battery technology, which is advancing rapidly in terms of energy density and cost reduction. Hydrogen's role must be clearly defined, particularly in areas where electrification is more efficient or practical. Many hydrogen technologies, including those related to storage, fuel cells, and hydrogen production, are still in development and this immaturity makes hydrogen less attractive in the short term compared to other more established low-carbon technologies, such as wind, solar, and batteries.
- Environmental Impact of Hydrogen Production → most hydrogen today is produced using fossil fuels, which generate significant CO_2 emissions (grey hydrogen). While blue hydrogen uses carbon capture and storage (CCS) to reduce emissions (Figure 3), it is not entirely carbon-free. Moving towards green hydrogen production is essential to make hydrogen a truly sustainable energy solution, but this transition requires significant investment and development.

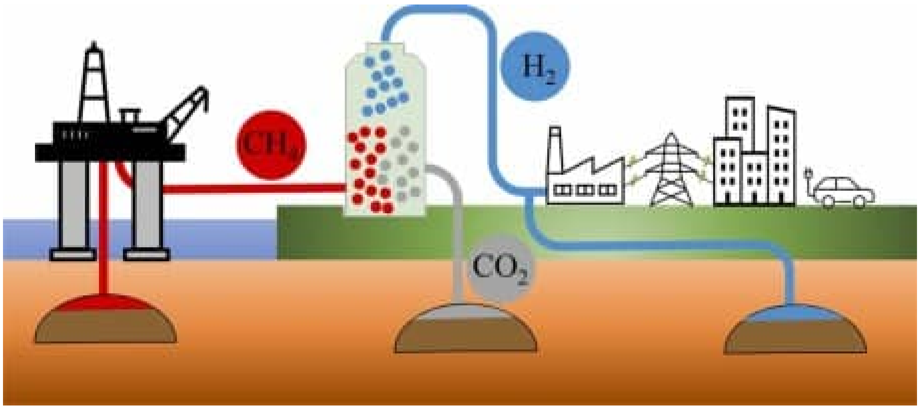

Figure 3 - Blue hydrogen production process [12]

In conclusion, the potential of hydrogen as an energy carrier is unmistakable, offering promising solutions to some of the most pressing challenges of our time, from energy security to environmental sustainability. This part of the deliverable has highlighted hydrogen's critical role in sectors difficult to decarbonize, such as heavy industry, transportation, and energy storage. Focusing on the development of PEM fuel cells and advancing the methodologies to optimise electrode production, particularly through 3D inkjet printing, contributes directly to improving efficiency and scalability in hydrogen technologies.

The establishment of a Hydrogen Research Hub in Mantova represents a strategic opportunity to propel Italy and Europe forward in the green energy transition. By facilitating collaboration between academia and industry, the hub can foster innovation, support sustainable economic growth, and create pathways for the practical application of hydrogen technologies across various sectors.

Subsequent Chapters

The Hydrogen Research Hub project for Mantua is founded on two principal pillars: the organisational structure and the physical infrastructure of the centre. These aspects are crucial for ensuring the efficiency and collaborative nature of the research environment, which will be discussed in further detail in the following chapters.

Organisation of the Centre: The organisational framework is designed to foster a high degree of efficiency and collaboration among researchers, technicians, and administrative staff. This includes streamlined processes, clear communication channels, and a supportive management structure that encourages innovation and teamwork.

Infrastructure of the Centre: The centre's physical structure will encompass well-equipped laboratories, offices, meeting rooms, a dedicated space for social interactions among staff, and a small conference hall. Flexibility is a key feature, with spaces designed to expand or contract based on needs. This will be achieved by minimising fixed walls and using movable partitions. Additionally, utilities will be routed through the upper sections of the building, allowing for easy modification and adaptation. Modular units for offices and laboratories can be stacked vertically to make the most of available space.

These two elements will be elaborated upon in the subsequent chapters, detailing the intricacies of their design and implementation.

C ORGANISATIONAL STRUCTURE

An effective governance structure for a hydrogen research hub must facilitate collaboration, enhance efficiency and encourage innovation, while mitigating the potential for conflicts and redundancies. An agile organisational framework, comprising clearly delineated roles and responsibilities, can ensure the smooth operation and strategic alignment of all stakeholders. This section presents a streamlined management structure that unifies advisory functions, research leadership, and industry engagement into coherent entities.

By organising governance through distinct, yet interconnected bodies the hub can facilitate effective decision-making and foster an environment of collaboration. Such a structure will not only advance hydrogen-related technologies but will also ensure that the hub's research outputs are impactful, relevant, and aligned with the broader societal goal of achieving a sustainable energy transition.

C.1 MANAGEMENT OVERVIEW

The governance model is organised into four primary bodies: the Executive Board, the Advisory Board, the Research Directorate, and the Industry Engagement, as illustrated in Figure 4. Each entity has distinct yet interconnected roles in supporting, guiding, and overseeing the hub's activities, thereby promoting fair cooperation and efficient decision-making.

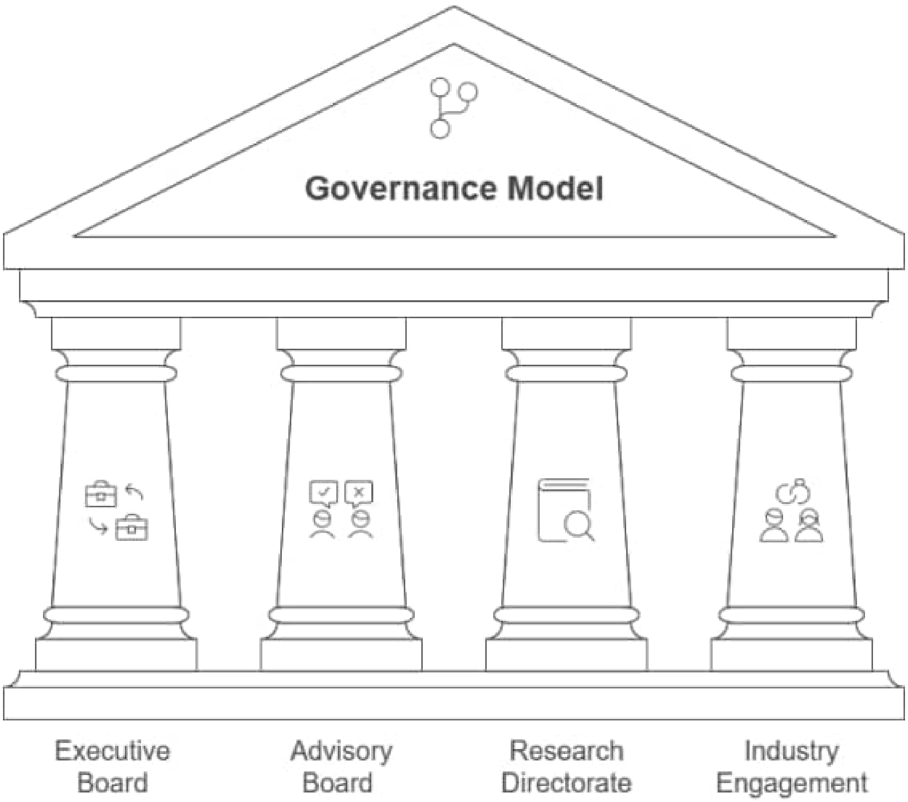

Figure 4 - Organisational structure of the hydrogen research hub proposed for Mantua

C.1.1 EXECUTIVE BOARD

The Executive Board is the top-level decision-making body, responsible for overall strategic management, financial oversight, and compliance with legal and regulatory standards. It comprises representatives from the universities, partner institutions, government officials, and key industry players; the board ensures balanced representation and alignment of interests. A Director, selected among stakeholders, facilitates resolutions during impasses.

Responsibilities of the Executive Board include:

- Defining the strategic vision and long-term goals of the research hub.
- Overseeing the allocation of resources, including funding, personnel, and infrastructure.
- Ensuring compliance with ethical guidelines, legal requirements, and financial accountability.
- Approving annual operational plans and research strategies.
- Resolving divergences and setting definitive courses of action when consensus cannot be achieved.

The Executive Board meets quarterly to review progress, evaluate initiatives, and address emerging opportunities in the hydrogen research sector.

C.1.2 ADVISORY BOARD

The Advisory Board provides comprehensive strategic and scientific guidance, ensuring that the hub's activities are aligned with both global trends and cutting-edge research in hydrogen technologies. The board comprises experts with diverse backgrounds, including hydrogen technology researchers, industry professionals, economists, policymakers, and representatives from international research bodies.

The Advisory Board is responsible for:

- Offering external perspectives on the hub's goals and alignment with global hydrogen research trends.
- Evaluating the scientific quality and relevance of ongoing and proposed research projects.
- Advising on grant acquisition, strategic partnerships, and technology transfer opportunities.
- Reviewing the research portfolio to ensure its relevance to industry needs and national/international policy objectives.
- Facilitating connections with international scientific and industrial communities to foster collaborative research opportunities.

The Advisory Board convenes biannually, with additional meetings as required to address specific strategic or scientific challenges.

C.1.3 RESEARCH DIRECTORATE

The Research Directorate is at the heart of the hydrogen hub, coordinating research activities and ensuring that the hub's scientific mission is achieved. The Research Directorate is led by a Chief Research Director, supported by Deputy Directors who are responsible for specific thematic areas, such as hydrogen production, storage, distribution, fuel cell technologies, and hydrogen safety.

The Chief Research Director is an academic of international standing, whose role involves:

- Leading the research agenda and ensuring alignment with the hub's broader mission.
- Coordinating interdisciplinary research programmes.
- Facilitating communication between different research teams to enhance collaboration.

Deputy Directors oversee research groups and have direct responsibility for day-to-day research activities within their respective themes. They ensure that research projects are progressing according to their milestones and are directly involved in mentoring younger researchers and post-doctoral fellows. Moreover, each Deputy Director is responsible for maintaining partnerships with relevant industry stakeholders.

C.1.3.1 Integration of Cross-Cutting Themes

The hub must address cross-cutting themes relevant to hydrogen research, such as sustainability, regulatory frameworks, and public acceptance.To manage them, cross-theme co-ordinators are needed within the Research Directorate. They are responsible for integrating issues like environmental sustainability, economic viability, and policy alignment across the various research themes.

These cross-cutting theme coordinators report directly to the Chief Research Director and play a role in ensuring that research outputs align with the overarching mission of creating sustainable, safe, and economically feasible hydrogen technologies.

C.1.3.2 Research Groups and Thematic Clusters

Within the Research Directorate, research activities are organised into thematic clusters. Each cluster consists of multiple research groups that focus on specific topics within the broader hydrogen theme. Examples include:

- **Hydrogen Production and Electrolysis Technologies**. This cluster focuses on optimising methods for hydrogen production, such as electrolysis, and improving efficiency.

- **Hydrogen Storage and Distribution**. A dedicated cluster to overcome challenges related to hydrogen storage and the development of infrastructure for distribution.

- **Fuel Cells and End-Use Applications**. This cluster looks at advancements in fuel cell technology, focusing on improving efficiency and reducing costs.

- **Safety and Environmental Impact**. A cluster addressing the safety implications and environmental impacts of hydrogen production and utilisation.
- **Materials Group**. This group studies new materials capable of functioning as catalysts, developing new materials for hydrogen storage, or enhancing resistance to embrittlement caused by hydrogen exposure.
- **Economic Aspects Group**. This group investigates the economic dimensions of hydrogen technologies, including cost analysis, market readiness, and economic impacts.
- **Training and Societal Aspects Group**. This group focuses on preparing skilled technicians, developing educational initiatives, and raising public awareness about hydrogen technologies.
- **Mechanisation and AI Optimisation Group**. This group studies the mechanisation of hydrogen-related systems, including the optimisation of hydrogen production processes through artificial intelligence.
- **Quality Group**. This group is responsible for ensuring the quality of processes and products, focusing on standards, quality control, and continuous improvement.

Each cluster is led by a senior researcher who collaborates closely with the Deputy Directors. Research group leaders within the clusters are responsible for driving the day-to-day work, supervising students, and ensuring adherence to project timelines. While the number of researchers directly employed by the Centre may be exceeded by the number of those affiliated with it, it should be noted that this figure includes not only those affiliated with the Centre itself but also those from the universities participating in the Centre and, potentially, those from collaborating companies.

C.1.3.3 Capacity Building and Training

To ensure long-term sustainability, the hub should focus on capacity building and training the next generation of hydrogen researchers, while also contributing to the preparation of graduates and post-diploma technicians, and creating training courses for industry personnel. A Training and Capacity Building Office (TCBO) could be established, operating under the Research Directorate, with a mandate to develop training modules, workshops, and fellowships. The TCBO works closely with both academic institutions and industry partners to ensure the relevance of training programmes to real-world challenges.

C.1.3.4 INDUSTRY ENGAGEMENT

To streamline interactions with industry stakeholders and prevent duplication of efforts, industry engagement is centralised within the Research Directorate, in coordination with the Advisory Board. This approach ensures consistent communication, aligns research activities with industry needs, and facilitates the commercialisation of technologies developed within the hub. The primary roles in industry engagement are:

- Providing input on research topics of immediate interest to the industry, ensuring the relevance of the hub's activities.

- Facilitating the commercialisation of technologies through partnerships, licensing agreements, and the establishment of spin-off companies.
- Acting as a forum for open dialogue, where industry partners can articulate their needs and provide constructive feedback on research activities.

Regular meetings with industry stakeholders are organised as needed, with a minimum of one annual meeting to discuss progress and emerging opportunities.

C.1.5 COLLABORATION AND DECISION-MAKING PROCESS

The hub's management structure encourages collaboration through an interconnected decision-making framework that combines input from different governance bodies. Decision-making processes within the hub follow a collaborative approach to ensure that diverse perspectives are taken into consideration.

- Strategic Decisions: Strategic decisions, such as the research hub's focus areas, are made by the Executive Board after receiving input from the Advisory Board, Research Directorate, and Industry Engagement. Such decisions are informed by international developments in hydrogen research and are evaluated for alignment with regional, national, and global needs.

- Operational Decisions: The Chief Research Director, along with the Deputy Directors, handles operational decisions. Their responsibilities include resource allocation for research activities, the establishment of working groups, and project approvals. Deputy Directors have the authority to form collaborative teams across the research hub to tackle specific projects or challenges.

- Feedback Loops: To ensure continuous improvement, the governance model features formal feedback loops, such as annual stakeholder reviews, which allow all key players—researchers, industry partners, and policy advisors—to assess the hub's progress and recalibrate its activities.

In any complex organisational structure, conflicts may arise due to the existence of different visions or needs. Even if every attempt to find a solution that suits all the relevant parties is unsuccessful, it is still important to find a way of removing the centre from any potential impasse that might block its activities.

An analysis of the proposed governance structure of the hydrogen research cluster reveals the existence of potential overlaps and reasons for conflict between the various bodies, which could have an adverse effect on its operational effectiveness.

The following table (Table I) presents a summary of the potential conflicts, the governance bodies involved, and the proposed solutions for the organisational structure.

Table I - Conflicts, Governance Bodies Involved, and Proposed Solutions

Potential Conflict	Governance Bodies Involved	Proposed Solution
Residual overlap in strategic and scientific guidance, leading to conflicting priorities	- Executive Board - Advisory Board	- Clearly define the scope of each body's responsibilities to prevent overlap. - Establish effective communication channels to align strategic and scientific priorities. - In cases of unresolved conflict, the Executive Board should make the final decision to set the definitive course of action.
Tensions between administrative objectives and research priorities in resource allocation	- Executive Board - Research Directorate	- Define clear boundaries between the Executive Board's strategic management and the Research Directorate's leadership of the research agenda. - Foster collaboration through regular joint meetings to discuss resource allocation. - The Executive Board resolves divergences decisively when consensus cannot be reached.
Potential for inconsistent communication with industry stakeholders, risking confusion and duplication	- Research Directorate - Advisory Board	- Implement an unified protocol for industry engagement to ensure consistent communication. - Assign specific roles in industry interactions to each body, providing clarity for external partners. - Enhance internal communication to synchronise efforts and prevent duplication.

Divergent interests among Executive Board members, potentially slowing decision-making	- Executive Board (includes university representatives, partner institutions, government officials, and industry players)	- Establish a shared vision and common goals to align all stakeholders from the outset. - Promote a culture of fair cooperation and open dialogue during meetings. - The Chairperson facilitates resolutions during impasses, ensuring efficient decision-making. - It is required that the number of votes be always an odd number. In the event that the number of members is even, the vote of the Director of the Executive Board shall be counted as double in the event of a tie.This prevents decisions from being blocked
Different frequencies of meetings among governance bodies, leading to delays and coordination issues	- Executive Board - Advisory Board - Research Directorate	- Synchronise key meetings and planning cycles where possible to facilitate timely decision-making. - Implement effective communication strategies, including interim updates and virtual meetings as needed. - Utilise collaborative tools to share real-time information across all governance bodies.
Unclear delineation of responsibilities, leading to confusion and inefficiencies	- All governance bodies	- Develop comprehensive governance documentation outlining specific roles and responsibilities for each body. - Provide orientation and training sessions for members of each governance body to ensure understanding. - Ensure transparency in operations and decision-making processes to build trust and clarity among all stakeholders.

By implementing this organisational structure and addressing potential conflicts proactively, the hydrogen research hub can promote fair cooperation among its various elements. Clear delineation of responsibilities, effective communication channels, and decisive intervention by the Executive Board when necessary will ensure that the hub functions efficiently and cohesively towards its strategic goals.

C.1.6 INCLUSIVITY AND STAKEHOLDER ENGAGEMENT

Inclusivity is a crucial aspect of governance in a hydrogen research hub. The governance structure must ensure broad stakeholder engagement, particularly in decision-making and strategic planning. Mechanisms to facilitate stakeholder engagement include:

- Stakeholder Forums: Annual forums that bring together all stakeholders—academics, industry, policymakers, and the public—to discuss the hub's progress, societal impact, and upcoming challenges.
- Open Call Workshops: These workshops, open to all partners and even the public, aim to identify emerging research questions and challenges within the hydrogen domain.
- Diversity Initiatives: The hub should also have initiatives to promote diversity within its workforce and leadership teams, ensuring an inclusive environment that values different perspectives.

C.1.7 REPORTING AND ACCOUNTABILITY

Transparency would be essential for the success of a research hub of this scale. Therefore, a robust reporting mechanism should be in place. Each year, the Chief Research Director, in collaboration with the Deputy Directors, would prepare an Annual Report summarising research progress, financial statements, and strategic initiatives for the upcoming year. This report would be reviewed by the Executive Board and could also be made publicly available to demonstrate the hub's commitment to transparency, while ensuring that confidentiality regarding research conducted with industry partners is maintained.

To maintain accountability, an independent review panel may also be formed to evaluate the hub's activities periodically. This panel would provide an unbiased assessment of research quality, industry impact, and socio-economic relevance, thereby ensuring that the research hub remains on track to meet its objectives.

D LABORATORIES AND FACILITIES

Flexible laboratory design represents a transformative approach to creating research environments that can respond to the rapidly changing landscape of modern science. By emphasising modularity, scalability, and versatility, adaptable laboratories support both short-term, industry-driven projects and long-term academic studies, fostering an environment that is conducive to innovation and collaboration. The ability to reconfigure laboratories efficiently not only saves time and reduces costs but also enhances sustainability by minimising waste and resource consumption. However, the successful implementation of flexible laboratories requires careful planning, a willingness to invest in specialised infrastructure, and a shift in mindset for those working within these dynamic environments. As the demands on scientific research continue to evolve, the adaptability offered by flexible laboratory design will be crucial in ensuring that research spaces remain at the forefront of innovation.

D.1 FLEXIBLE LABORATORY DESIGN

The dynamic nature of scientific and industrial research requires an environment that is capable of responding swiftly to evolving needs, especially as objectives shift and diversify over time. The concept of flexible laboratory design has emerged as a response to these requirements, emphasising adaptability, scalability, and efficiency. This approach has gained traction in both academia and industry as the demand for laboratories that can accommodate varying research demands has increased. This proposed model for the Mantua research hub will examine the characteristics, advantages and challenges of flexible laboratory design, with a particular focus on their ability to be reconfigured in accordance with the specific requirements of research projects.

D.1.1 MODULAR SETUP

Adaptable research laboratories are based on a few key principles:

- modularity;
- scalability;
- versatility.

Modularity involves the creation of laboratory components that can be easily moved, replaced or reconfigured. This includes the use of containerised labs (Figure 5), mobile screens, modular cabinets, mobile benches and equipment that can be moved as required. The configuration of containerised laboratories allows for the placement of multiple units in a vertical arrangement (Figure 6), thereby optimising the utilisation of available space. The ability to reconfigure a laboratory in a relatively short time without the need for major refurbishment is crucial to optimising research workflows.
Scalability refers to the ability to expand or reduce laboratory capacity according to the requirements of a project. For example, if a research group needs additional space to conduct experiments with more personnel or larger equipment, a well-designed flexible laboratory can accommodate expansion with minimal effort.

Versatility allows laboratories to support different types of research, providing a basic infrastructure that can be quickly adapted to specific needs. Flexible laboratories are designed with infrastructure that is prepared for change. For instance, plug-and-play utilities like overhead service carriers allow researchers to quickly add or modify gas, electricity, or data services without extensive rewiring or reconstruction. The floors, ceilings, and walls in flexible labs often feature tracks or mounts that facilitate reconfiguration, making it easy to reposition utility connections and fixtures. This setup enables researchers to rearrange their workspaces with minimal disruption.

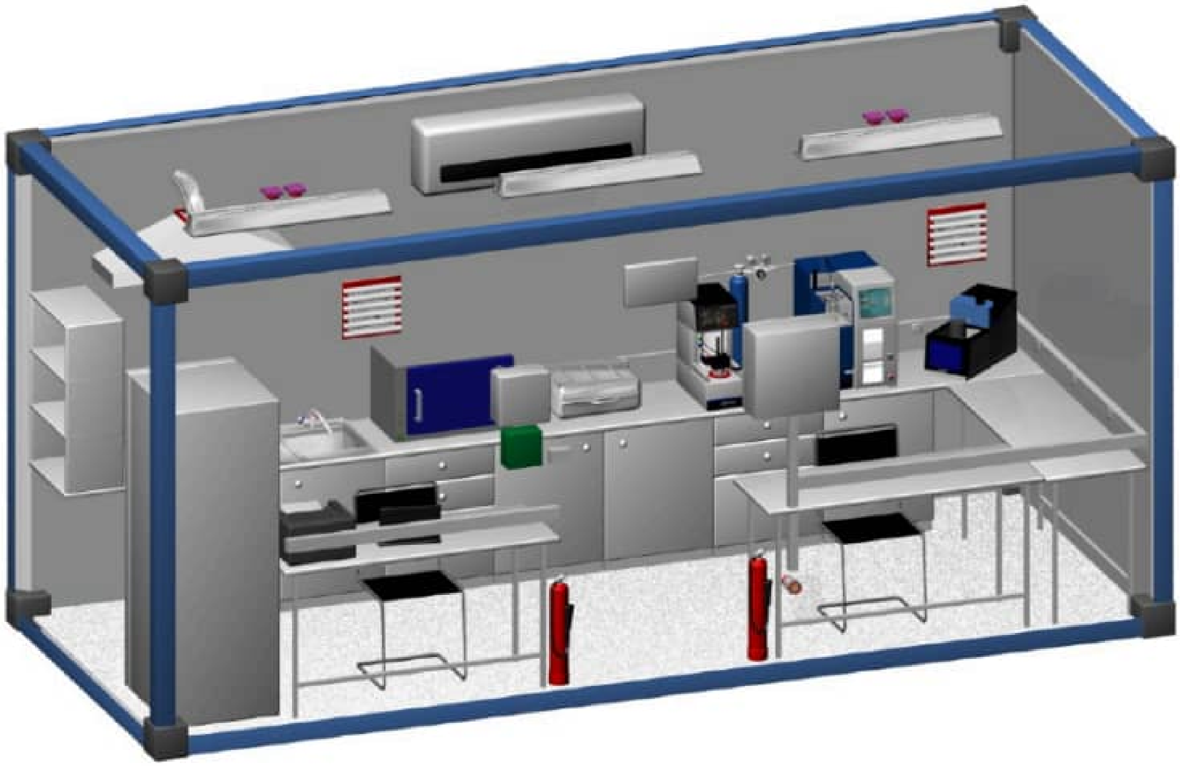

Fig.5 - Example of containerised lab [23]

One of the principal advantages of adaptable laboratory design is its capacity to accommodate both short-term, industry-oriented projects and long-term academic research. The nature of short-term projects is such that they typically involve fast-paced workflows with frequent changes in objectives. The ability of flexible laboratories to be rapidly reconfigured to meet these changing needs is therefore of great benefit. To exemplify, an electrolyser manufacturing company may collaborate with a university to assess novel materials for hydrogen production, which may require the utilisation of specialised equipment and infrastructure for a limited period of time. A flexible laboratory can be readily adapted to create the requisite research environment without significant disruption.

In contrast, long-term academic studies typically involve more consistent research goals that might extend over several years. Such projects may benefit from a stable laboratory environment, but periodic adjustments may also be required as the research progresses. To illustrate, a laboratory engaged in the investigation of hydrogen production and storage might initially focus on the development of materials to do that, subsequently transitioning to the assessment of electrolyser efficiency. This necessitates adaptations to the infrastructure to accommodate disparate experimental configurations. The flexibility of the design allows for these transitions to be made without requiring the researchers to relocate to an entirely new facility or undergo a lengthy period of renovation.

Fig.6 - Example of containerised lab [24]

The versatility of adaptable laboratories also makes them suitable for multidisciplinary research, which is increasingly the norm in both industry and academia. Complex challenges, such as those related to hydrogen production, storage, and fuel cell technology, often require expertise from multiple disciplines. Flexible laboratory spaces can be reconfigured to accommodate the tools, personnel, and experimental setups necessary for research, facilitating collaboration and innovation. A laboratory that can swiftly transition from material synthesis for hydrogen storage to testing electrolyser performance supports the type of integrative research that is essential for advancing technologies.

D.1.1.1 BENEFITS OF FLEXIBLE LABORATORY DESIGN

The benefits of adaptable laboratory design are multifaceted, impacting not only the efficiency and functionality of research spaces but also the financial and environmental aspects of laboratory operation. One of the most significant advantages is the cost efficiency. Traditional laboratory renovations are both time-consuming and costly, often requiring weeks or even months of downtime. With flexible design, reconfiguration can be carried out in a matter of days or even hours, reducing the costs associated with labour, materials, and lost productivity. This means that institutions can allocate more of their budget toward actual research activities rather than infrastructure changes.

Enhanced collaboration is another key benefit of flexible laboratories. Research environments that can be reconfigured to suit different projects promote better communication and cooperation among researchers. Movable benches, adaptable workstations, and shared spaces make it easy for different teams to work alongside each other, promoting knowledge transfer and collaboration. This kind of adaptable environment is particularly important for encouraging the creativity and cross-pollination of ideas that lead to breakthroughs.

From an environmental perspective, flexible laboratories contribute to sustainability. Laboratories are typically resource-intensive spaces, consuming large amounts of energy and water and generating considerable waste. By allowing for incremental changes rather than large-scale renovations, flexible labs reduce the amount of construction waste produced. Moreover, adaptable infrastructure that can be reused and reconfigured helps minimise the need for new materials, supporting a more sustainable approach to laboratory management.

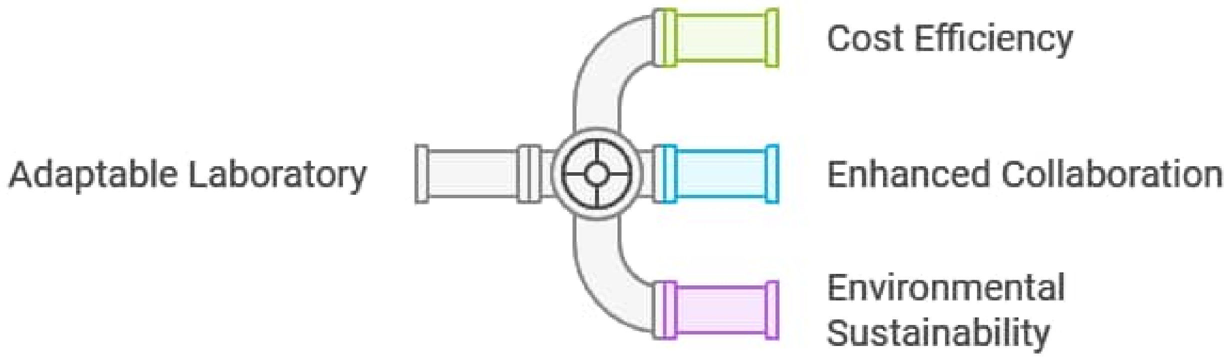

Figure 7 - Characteristics of adaptable laboratories

D.1.1.2 CHALLENGES IN IMPLEMENTING FLEXIBLE LABORATORIES

Another challenge is the complexity of designing for multiple uses. A laboratory focused on hydrogen technologies must accommodate various types of research, including chemical experiments, engineering tests, and materials science studies. For example, chemical research may require fume hoods for safe handling of reactive gases, while engineering research on electrolyser components may need specialised testing stations, and materials science might require controlled environments for developing and analysing hydrogen storage materials. Ensuring that the laboratory can safely and effectively transition between these different setups requires careful integration of safety infrastructure and adaptable facilities.

Moreover, the successful implementation of flexible laboratory design requires a shift in mindset for both researchers and facility managers. Traditional laboratories are often designed with a specific purpose in mind, and researchers can become accustomed to static work environments. Training and adjustment are necessary to help researchers fully utilise the potential of adaptable spaces. Facility managers also need to be adept at coordinating the reconfiguration of laboratory spaces, ensuring that the infrastructure remains aligned with the researchers' needs. Additionally, it is crucial to establish a shared regulation for the use of laboratory spaces to prevent researchers from occupying areas without effectively using them, while others may need space but cannot access it. This regulation should consider the real-time needs, include planning and monitoring of actual usage, and define a contribution rule where those using the space contribute to maintaining its efficiency. Such a rule discourages occupying space without proper use. While none of this is impossible to achieve, it requires a collectively agreed-upon regulation.

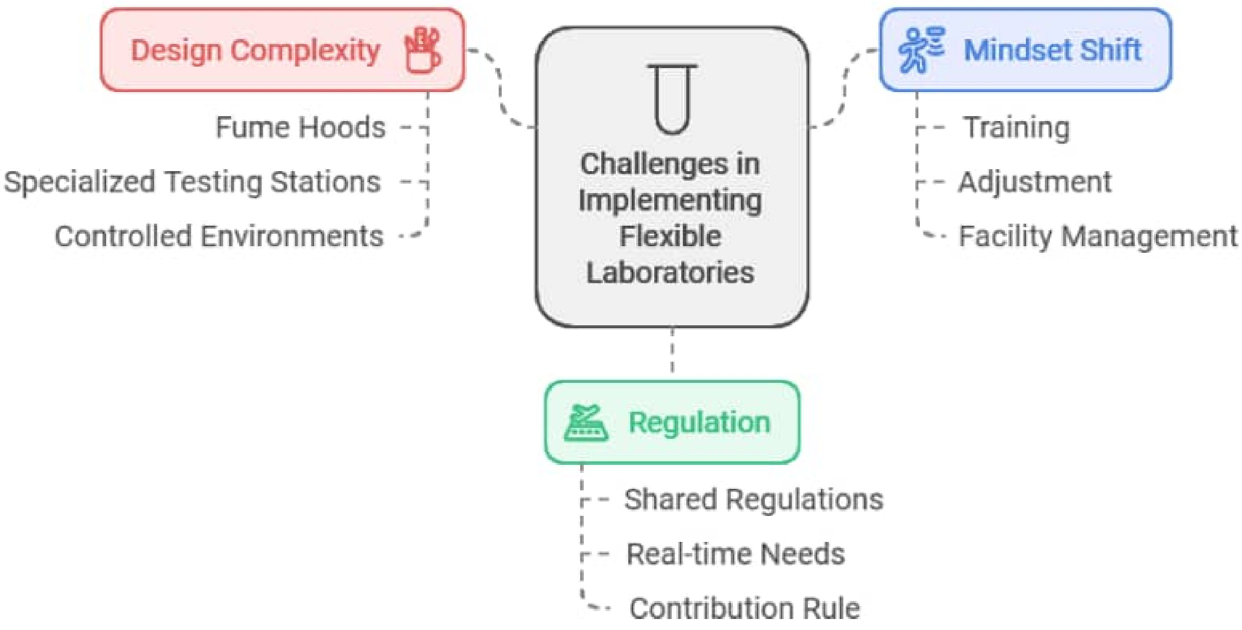

Figure 8 - Challenges of adaptable laboratories

D.1.3 OFFICE SPACES

The design of office spaces plays a crucial role in fostering productivity, collaboration, and innovation within research environments. In the context of a hydrogen technologies research hub, it is essential to create spaces that are versatile and facilitate interactions between researchers, visiting academics, and industry partners. The concept proposed here revolves around the use of modular, prefabricated office spaces that can be stacked vertically to maximise available land area while providing dynamic and adaptable solutions for a diverse set of users.

D.1.3.1 PREFABRICATED MODULAR UNITS: VERSATILITY IN OFFICE DESIGN

The proposed layout is centred around the idea of using prefabricated modular units that can be also stacked vertically to create an efficient use of space. These modules are not assigned to individual researchers on a permanent basis. Instead, they can be booked according to individual needs, ensuring that every office space is actively used throughout the day. This booking system ensures a fluid and efficient use of resources, eliminating the common problem of vacant or underutilised office spaces.

By making the modules reservable, the hub can better accommodate the varying schedules of researchers, visiting academics, and industry collaborators. This flexibility is particularly important in a research environment where personnel often work in the laboratory or spend time off-site for meetings and collaborations. The modular units can easily be configured for different purposes—from individual work to small group meetings—depending on the requirements of the occupant at a given time.

Fig.9 - Example of commercial modular spaces for offices [25]

D.1.3.2 MULTI-PURPOSE MEETING ROOMS

In addition to individual office modules, the design includes several multi-purpose meeting rooms that can also be booked through a centralised app. These meeting rooms are essential for hosting formal meetings, brainstorming sessions, or collaborative project discussions involving researchers, visiting academics, and industry partners.

The multi-purpose aspect of these rooms means that they are not restricted to a single function. They can be reconfigured depending on the nature of the meeting or event. For example, they can accommodate formal presentations with industry stakeholders, small group discussions, or even workshops for hands-on activities. Equipped with state-of-the-art audiovisual tools and communication technologies, these rooms enable seamless remote participation, ensuring that collaborators from different locations can easily contribute.

Fig.10 - Example of Multi-Purpose Meeting Rooms with different sizes [26, 27]

D.1.3.3 SECURE STORAGE FOR PERSONAL MATERIALS

Given the shared nature of these office spaces, a practical solution for storing personal materials is essential. Each researcher is provided with a secure, lockable cabinet where they can store physical documents, books, and any other necessary materials. These cabinets are accessible via a personalised combination lock, offering peace of mind regarding the safety of personal items.

The design of these secure cabinets also promotes a clean and organised workspace. Since the offices themselves are shared and booked on an as-needed basis, it is important to avoid leaving personal belongings in the office overnight. The cabinets are conveniently located to allow quick and easy access, encouraging researchers to adopt a minimalist approach while using the shared office spaces.

Fig.11 - Example of commercial locker boxes for offices (*Lockers*, n.d.)[28]

D.1.3.4 DIGITAL SOLUTIONS FOR DATA STORAGE

To reduce the reliance on physical storage, the hub promotes the use of digital solutions for storing and managing research materials. Most of the documentation, research outputs, and reference materials are digitalised, reducing the need for bulky filing cabinets and freeing up valuable workspace. This approach aligns well with modern research needs, where data security, accessibility, and ease of sharing are paramount. The digital-first approach not only saves physical space but also facilitates remote collaboration. Researchers can access their work securely from anywhere, allowing greater flexibility and supporting the hybrid work culture that has become increasingly common in academia and industry partnerships. The hub utilises in-house and/or external rented servers to store research data and digitalised materials. These servers are designed to be highly secure, protecting against cyberattacks and ensuring that sensitive information remains confidential. Authorised personnel can access the servers remotely via password protection, ensuring data is available when needed while maintaining strict security protocols. By using cloud storage solutions, the hub ensures that data is both secure and easily shareable, fostering an environment where collaboration is effortless and efficient.

D.1.3.5 BOOKING OFFICE SPACES

To ensure that the shared office spaces are used efficiently, a comprehensive booking system is employed. Researchers, visiting academics, and industry partners can book office modules via an intuitive app available on both mobile devices and PCs. Once a booking is confirmed, the user receives a unique access code that changes with each reservation. This code is used to unlock the office module, which is secured by a combination lock system and enables the use of electricity, telephone and Internet connections within it. This approach not only ensures that the space is accessible only to the person who has booked it but also enhances security and prevents unauthorised access. The flexibility of booking via an app allows users to easily reserve and access office spaces as needed, streamlining the process and maximising the utility of the available resources.

Fig.12 - Example of commercial app for office reservation

D.1.3.6 ENSURING PROPER SANITATION OF SHARED SPACES

Given the shared nature of these office modules, maintaining a high standard of hygiene is crucial. Practical solutions for sanitising the spaces include providing easily accessible disinfectant wipes and hand sanitiser stations throughout the hub. After each use, occupants are encouraged to sanitise their workspace, and a professional cleaning service is scheduled regularly to deep-clean the offices and shared areas. The use of antimicrobial surfaces and air purification systems can further help reduce the spread of germs, ensuring a safe and healthy environment for all users. The booking app could also include an option to request additional cleaning after particularly intensive use, adding an extra layer of flexibility and safety.

D.1.3.7 CREATING OPPORTUNITIES FOR INFORMAL INTERACTIONS

While formal meetings are crucial for structured collaboration, informal interactions often lead to the most creative ideas and breakthroughs. To facilitate these informal exchanges, the design of the research hub includes dedicated social spaces where researchers, academics, and industry partners can gather, relax, and exchange ideas.

These social spaces include areas where individuals can have lunch, grab a coffee, or simply take a break from their work. The layout is designed to be inviting, with comfortable seating, natural light, and greenery to create a pleasant and relaxed atmosphere. Such spaces are strategically located to encourage spontaneous conversations and interactions between individuals who might not otherwise cross paths during their daily routines.

The importance of these informal spaces cannot be overstated, as they contribute significantly to building a sense of community within the hub. By providing opportunities for individuals from different disciplines and backgrounds to interact, the hub fosters interdisciplinary collaboration, which is often essential for tackling complex challenges in hydrogen research and technology development.

Fig.13 - Solutions for space sanitising

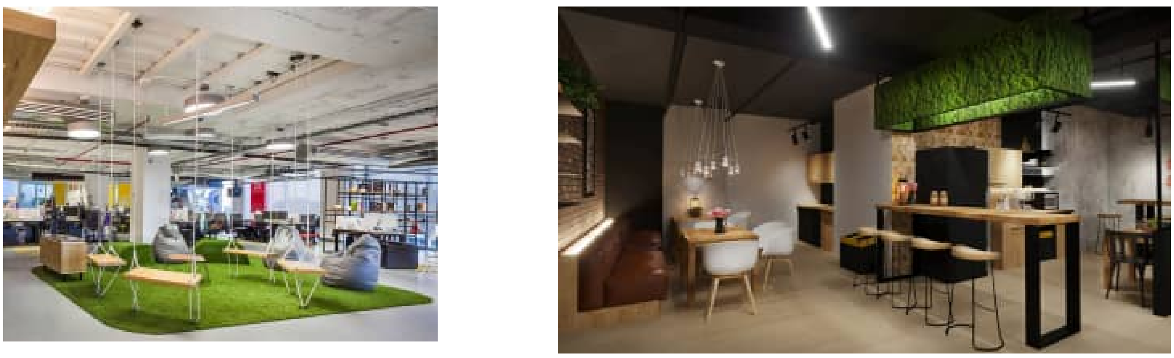

Fig.14 - Examples of two social spaces [29]

D.1.3.8 SUSTAINABILITY AND FUTURE EXPANSION

The use of prefabricated modular units also offers significant advantages in terms of sustainability and future expansion. Prefabrication allows for greater control over construction materials and processes, resulting in reduced waste and improved energy efficiency. This approach aligns with the overarching goal of the research hub—to advance hydrogen technologies and contribute to a more sustainable future.

Furthermore, the modular design makes future expansion straightforward. As the research hub grows and the need for more office or meeting spaces arises, additional modules can be added either horizontally or vertically, depending on the available land. This scalability ensures that the hub can adapt to changing needs over time without requiring significant reconstruction or disruption to ongoing research activities.

In selecting module suppliers, it is advisable to give preference to those who offer modules composed of environmentally friendly materials, potentially including recycled and natural components. This decision not only has an environmentally beneficial impact but also conveys to the external community a message of active dedication to environmental stewardship.

E RESEARCH FOCUS AREAS

The Hydrogen Research Hub in Mantua is dedicated to both fundamental research and practical applications that support the local economy and sustain Mantuan businesses. This chapter provides a brief overview of Mantua's economic landscape and explores the potential benefits of introducing a hydrogen-based economy. The aim is to highlight how this innovative approach can bolster regional industries and create new opportunities.

Furthermore, the chapter will outline the strategic importance of expanding hydrogen initiatives to Northern Italy, illustrating the broader regional benefits. By leveraging Mantua's pioneering efforts, the region can become a leader in the hydrogen economy, setting an example for other areas to follow.

This comprehensive approach underscores the dual focus of the research hub: advancing scientific knowledge while delivering tangible economic benefits to Mantua and beyond .

E.1 ECONOMIC SECTORS IN MANTOVA

Mantua's economy is characterised by a diverse mix of agricultural, industrial, and service sectors. Integrating hydrogen technologies can drive growth, enhance competitiveness, and foster sustainability across these economical areas. The research hub aims to facilitate this transition by developing cutting-edge solutions that meet local needs and promote economic resilience.

E.1.1 AGRICULTURE.

Agriculture remains a vital sector in Mantova. The area is known for its high-quality agricultural products. It is closely linked to food processing industries, which utilise local products effectively.

E.1.2 INDUSTRY

Mantova's industrial sector is characterised by a blend of traditional manufacturing practices and modern innovations, making it a crucial part of the local economy while also facing challenges such as market fluctuations and competition. Here are the key components

- Manufacturing.
  Manufacturing includes a variety of industries, with a strong emphasis on textiles, particularly women's hosiery, where Mantova is a leading producer. Additionally, mechanical engineering and metalworking are vital components of the industrial landscape.

- Food Processing.
  Mantova is renowned for its agro-food transformation industry, which includes significant operations in meat processing (especially pork and beef) and dairy production. The region is known for producing high-quality products, including two major DOP (Protected Designation of Origin) cheeses.

- Construction.

  Although it represents a smaller portion of the industrial sector, construction remains an essential area, contributing to local employment and infrastructure development.

- Innovation and Technology

  There is an increasing focus on innovation within the industrial sector, with investments in research and development aimed at enhancing productivity and competitiveness. The integration of hydrogen technology in Mantova's innovation and technology sector can significantly boost local economic growth. Establishing a hydrogen industry could create numerous jobs, fostering a skilled workforce while contributing to the province's GDP. By developing hydrogen-based solutions, Mantova can position itself as a leader in sustainable technology, attracting investments and partnerships. Furthermore, products and services derived from hydrogen technologies can be marketed as environmentally friendly, appealing to consumers in markets increasingly focused on sustainability. This competitive advantage could offset higher energy costs, making Mantova an attractive destination for eco-conscious businesses and tourists alike.

- Services

  The services sector is the largest contributor to Mantova's economy, making up 57.9% of the GDP. This includes retail, logistics, and public services. The province benefits from a strong logistics network, particularly through the Port of Mantova, which enhances its connectivity to international markets.

- Craftsmanship and Small Enterprises

  Mantova has a vibrant landscape of small and medium-sized enterprises (SMEs), which dominate the local economy. These businesses operate in agriculture and commerce, with many being family-run or employing fewer than five workers. This structure allows for flexibility and innovation within the local economy.

- Tourism

  While not as dominant as other sectors, tourism plays an essential role in Mantova's economy due to its rich cultural heritage and historical significance. The province attracts visitors interested in art, history, and gastronomy, contributing to local businesses.[30]

E.2 ECONOMIC SECTORS IN LOMBARDY AND NORTH ITALY

The development of a hydrogen (H_2) sector in Mantua has the potential to expand significantly in northern Italy, particularly in regions with strong industrial bases that align with Mantua's manufacturing realities. The following examples illustrate the potential for the H2 technology developed in Mantua to find a market in neighbouring regions.

- Lombardy

Milan: It is a prominent financial and technological hub, and is witnessing an increase in demand for sustainable energy solutions. The utilisation of hydrogen in public transport systems, such as buses and trains, would serve to reinforce the city's commitment to the reduction of carbon emissions.
Bergamo and Brescia: The manufacturing sector, particularly the machinery and construction industry, could benefit from hydrogen as a clean energy source for production processes, thereby facilitating the adoption of more sustainable production practices.

- Emilia-Romagna:
  Bologna: The automotive industry in Bologna and Modena is well established. The integration of hydrogen fuel cells into vehicles could facilitate the adoption of cleaner alternatives, aligning with the region's efforts to promote innovative transport solutions.
  Modena and Parma are renowned for their food and packaging industries. Modena could potentially adopt hydrogen technologies to power its operations, thereby reducing the carbon footprint of food production and processing.

- Veneto
  Verona: The agricultural sector in Verona has the potential to utilise hydrogen as an energy source for irrigation and processing activities, thereby enhancing the sustainability of food production and attracting environmentally conscious consumers.
  Vicenza: With a focus on the textile and clothing sector, Vicenza could utilise hydrogen to power machinery, thereby establishing itself as a leader in sustainable textile production.

- Trentino-South Tyrol
  Bolzano: This region's emphasis on green tourism can be complemented by the use of hydrogen vehicles for transport services, promoting green travel options that attract environmentally conscious tourists.

By creating a strong H2 industry in Mantua, local companies can tap into these interconnected markets across Northern Italy, fostering job creation and contributing positively to regional GDP while promoting sustainable industrial practices.

E.3 FUNDAMENTAL RESEARCH

The establishment of the H2 Research Hub in Mantua presents a significant opportunity to advance fundamental research in hydrogen technologies within the province of Mantua and the broader Lombardy region. Given the economic landscape of Mantua, characterised by a strong industrial base and a commitment to sustainable development, the Hub could focus on several key themes that align with regional priorities and global sustainability goals. This paragraph explores the most pertinent research areas that could be pursued at the H2 Research Hub, including innovative hydrogen production methods, advanced storage solutions, fuel cell technologies, and the integration of hydrogen into existing energy systems.

E.3.1 INNOVATIVE HYDROGEN PRODUCTION METHODS

A primary research theme for the Hub could be the development of efficient and cost-effective hydrogen production techniques. Mantua's proximity to agricultural activities provides a unique opportunity to explore biomass conversion technologies and production of H2 by biogas without the production of CO2. Fundamental research could investigate thermochemical processes, such as gasification and pyrolysis of agricultural residues, to produce hydrogen. Additionally, the Hub could delve into electrolysis powered by renewable energy sources, such as solar, aiming to enhance the efficiency and reduce the costs associated with green hydrogen production.

E.3.2 ADVANCED HYDROGEN STORAGE SOLUTIONS

Effective storage of hydrogen remains a critical challenge for its widespread adoption. Research at the Hub could focus on developing advanced materials and methods for hydrogen storage. This includes exploring metal hydrides, high-pressure tanks, and novel nanostructured materials that offer higher storage densities and improved safety profiles. Fundamental studies on the thermodynamics and kinetics of hydrogen absorption and desorption in these materials would be essential. Such advancements could have significant implications for both stationary and mobile energy applications in Lombardy.

E.3.3 FUEL CELL TECHNOLOGIES

Fuel cells are integral to utilising hydrogen as a clean energy source. The Hub could engage in fundamental research on next-generation fuel cell technologies, aiming to improve their efficiency, durability, and cost-effectiveness. Investigations could include the development of new catalyst materials, membrane technologies, and system architectures. Given Lombardy's strong automotive and machinery sectors, research on fuel cells for transportation applications could be particularly relevant, contributing to the decarbonisation of the region's transport infrastructure.

E.3.4 INTEGRATION INTO EXISTING ENERGY SYSTEMS

Integrating hydrogen into existing energy systems is vital for its practical utilisation. Fundamental research could explore the blending of hydrogen with natural gas in pipeline networks, assessing the impacts on materials integrity and combustion characteristics. Studies on the role of hydrogen in energy storage, particularly in balancing the intermittency of renewable energy sources, would also be pertinent. Modelling and simulation of hydrogen's integration into the regional energy grid could provide valuable insights into the scalability and economic viability of such initiatives.

E.3.5 ENVIRONMENTAL IMPACT AND SUSTAINABILITY ASSESSMENTS

Assessing the environmental implications of hydrogen technologies is crucial for ensuring their sustainability. The Hub could conduct life cycle assessments (LCAs) of various hydrogen production and utilisation pathways to quantify their environmental footprints. Research could focus on greenhouse gas emissions, resource use, and ecological impacts, providing a comprehensive understanding of the sustainability of hydrogen technologies. Such assessments would inform policymakers and stakeholders in Mantua and Lombardy, guiding strategic decisions on energy investments.

E.3.6 SAFETY AND PUBLIC ACCEPTANCE

Addressing safety concerns and fostering public acceptance are essential for the successful deployment of hydrogen technologies. Fundamental research on hydrogen safety, including leak detection, mitigation strategies, and emergency response protocols, would be invaluable. Additionally, social science research could examine public perceptions of hydrogen technologies in the region, identifying barriers to acceptance and developing outreach programmes to educate and engage the community.

E.3.7 ECONOMIC ANALYSIS AND POLICY DEVELOPMENT

Understanding the economic implications of hydrogen technologies is key to their adoption. The Hub could conduct economic analyses of hydrogen supply chains, exploring cost reduction pathways and market potentials. Research could inform policy development, providing evidence-based recommendations on incentives, regulations, and infrastructure investments needed to support the hydrogen economy in Mantua and Lombardy

E.3.8 EDUCATIONAL RESEARCH AND DEVELOPMENT

Advancing the pedagogy of hydrogen technologies is essential for fostering a knowledgeable and skilled workforce. The Hub could undertake educational research aimed at developing innovative teaching methodologies tailored to hydrogen technology. This could include integrating interdisciplinary approaches, employing digital tools, and creating hands-on learning experiences. Research outcomes could guide curriculum design and teacher training programmes, ensuring that educational institutions at various levels are equipped to deliver high-quality, relevant education. These initiatives would support the dissemination of hydrogen technology knowledge, thus promoting its widespread adoption and integration into the regional economy of Mantua and Lombardy. Moreover, creating interactive software, augmented reality applications, and video courses can be marketed internationally, providing a valuable product for global markets. This approach not only improves technical education but also opens up new commercial opportunities.

E.4 APPLIED RESEARCH AND INDUSTRY COLLABORATION

To bridge the gap between fundamental research and practical implementation, the H2 Research Hub in Mantua could engage in applied research in collaboration with industry partners. Such partnerships would not only accelerate the development of hydrogen technologies but also stimulate economic growth within the province and the wider Lombardy region. The focus could encompass hydrogen fuel cells, infrastructure development, and emerging use cases, particularly in the transportation sector.

Collaborative efforts with local industries could drive the advancement of hydrogen fuel cell technologies. By working alongside manufacturers and energy companies, the Hub could facilitate the design and optimisation of fuel cells for various applications, enhancing their efficiency, durability, and cost-effectiveness. Applied research could involve the development of new catalyst materials, membrane technologies, and system architectures tailored to specific industrial needs.

Infrastructure is a critical component for the widespread adoption of hydrogen technologies. The Hub could partner with utility companies and infrastructure providers to develop efficient hydrogen production facilities, storage solutions, and distribution networks. This includes the establishment of refuelling stations strategically located to support emerging hydrogen-powered vehicles and machinery. Research could address logistical challenges, safety protocols, and regulatory compliance, ensuring that the infrastructure is robust, scalable, and sustainable.

E.4.1 EMERGING USE CASES IN TRANSPORTATION

Transportation offers significant opportunities for the application of hydrogen technologies, particularly in areas where electrification is challenging. The H2 Research Hub could focus on applied research in road transport, rail systems, and maritime applications, leveraging Mantua's strategic position and existing transportation networks.

- Road Transport

  In collaboration with automotive manufacturers, the Hub could develop hydrogen fuel cell vehicles, including cars, buses, and heavy-duty trucks. Research could aim to improve fuel cell performance, extend vehicle range, and reduce costs. Pilot projects could demonstrate the viability of hydrogen-powered fleets for public transport and logistics, contributing to reduced emissions and enhanced energy efficiency in road transport.

- Rail Transport

  Hydrogen trains represent a promising solution for non-electrified rail lines. The Hub could work with railway companies to design and test hydrogen-powered locomotives and multiple units. Applied research could focus on integrating fuel cells into rolling stock, developing onboard hydrogen storage systems, and establishing refuelling infrastructure along rail corridors. Such initiatives would support the decarbonisation of regional rail services without the need for costly electrification.

- Maritime Transport on the River Mincio

  Mantua's access to the River Mincio, which connects to the Adriatic Sea via the Po River, presents unique opportunities for hydrogen applications in maritime transport. The Hub could explore the development of hydrogen-powered vessels, including cargo ships and passenger ferries, suitable for inland waterways and coastal shipping. Research could address the challenges of maritime fuel cell integration, hydrogen storage solutions adapted to marine environments, and compliance with maritime safety standards.

E.4.1.1 ADVANTAGES OF HYDROGEN APPLICATIONS IN TRANSPORTATION

The adoption of hydrogen technologies in transportation offers numerous benefits:

- Environmental Impact.

Hydrogen-powered vehicles produce zero emissions, emitting only water vapour. This significantly reduces air pollution and greenhouse gas emissions, contributing to improved air quality and helping Lombardy meet its environmental targets.

- Operational Efficiency.
  Hydrogen vehicles can offer longer ranges and shorter refuelling times compared to battery-electric counterparts, particularly advantageous for heavy-duty and long-distance applications. This enhances operational efficiency in sectors such as freight transport and public transit.

- Utilisation of Existing Infrastructure.
  For maritime transport, leveraging the River Mincio allows for the utilisation of existing waterways, reducing the need for new infrastructure. Hydrogen-powered ships could revitalise river transport, offering an environmentally friendly alternative to road haulage.

Finally, by producing hydrogen locally, the region reduces its dependence on imported fossil fuels, enhancing energy security. Utilising renewable energy sources for hydrogen production further aligns with sustainable energy policies.

E.4.2 AGRICULTURE AND AGRO-FOOD PROCESSING

In agriculture, hydrogen can play a vital role in decarbonising farming operations by developing hydrogen-powered machinery, such as tractors and harvesters, which reduces reliance on diesel fuel and lowers greenhouse gas emissions. Hydrogen-derived ammonia, produced through green hydrogen processes, can serve as a sustainable fertiliser. In agro-food processing, hydrogen can provide a clean energy source for heat and power, enhancing energy efficiency and reducing carbon footprints. Hydrogen fuel cells can be integrated into processing plants, refrigeration, and logistics to further these benefits.

Mantua's agricultural sector, known for high-quality products, is closely linked to food processing industries. By integrating hydrogen technologies, the sector can improve energy efficiency and resilience. The energy needed to produce hydrogen could come from agro voltaic systems, which combine agricultural production with photovoltaic power generation. These systems optimise land use and generate excess energy that can be converted to hydrogen through electrolysis. This stored hydrogen ensures a constant energy supply for agricultural operations, even during periods of low solar or wind power production. Environmentally sustainable agriculture based on hydrogen can be a significant advantage in markets that value planetary health.

E.4.3 HYDROGEN APPLICATIONS IN KEY INDUSTRIAL SECTORS

The utilisation of hydrogen extends beyond transportation and energy systems, offering transformative potential across various industrial sectors prominent in Mantua and Lombardy. The H2 Research Hub could focus on applied research to explore and enhance hydrogen applications in industrial sectors as: rubber-plastics and non-metallic minerals, steel industry, mechanical engineering and transportation equipment, textiles, and the food industry. This section examines how hydrogen technologies can be integrated into these sectors, highlighting the advantages and research opportunities.

E.4.3.1 RUBBER-PLASTICS AND NON-METALLIC MINERALS

The rubber and plastics industry could benefit from hydrogen as a feedstock for producing sustainable polymers. Research could delve into hydrogenation processes to create bio-based plastics, reducing dependence on fossil fuels. In the non-metallic minerals sector, hydrogen can be used as a reducing agent or as a clean fuel in high-temperature processes, such as glass and ceramics manufacturing. The Hub could explore innovative methods to incorporate hydrogen into production processes, aiming to lower emissions and enhance product sustainability.

E.4.3.2 STEEL INDUSTRY

The steel industry is one of the largest emitters of carbon dioxide due to traditional coal-based production methods. Hydrogen presents an opportunity to revolutionise steel manufacturing through the direct reduction of iron ore using hydrogen gas, producing water vapour instead of carbon dioxide. The H2 Research Hub could collaborate with steel producers to develop and optimise hydrogen-based steelmaking technologies, conducting pilot projects to assess feasibility and scalability. This transition could significantly reduce emissions and position Lombardy as a leader in green steel production.

E.4.3.3 MECHANICAL ENGINEERING AND TRANSPORTATION EQUIPMENT

Mechanical engineering and the production of transportation equipment are vital sectors in Lombardy. Hydrogen can be integrated into manufacturing processes as a clean energy source for machinery and equipment operation. The Hub could research the use of hydrogen-powered tools and robotic systems, improving energy efficiency and reducing emissions in factories. Furthermore, developing hydrogen fuel cells for use in various transportation equipment, including buses, trucks, and industrial vehicles, could enhance product offerings and meet emerging market demands for sustainable solutions.

E.4.3.4 FOOD INDUSTRY

The food industry encompasses processing, packaging, and distribution, all of which have substantial energy requirements. Hydrogen can serve as a clean energy source for heating, cooling, and power generation within food processing facilities. Research initiatives could investigate the implementation of hydrogen technologies to enhance energy efficiency, reduce emissions, as a feedstock for certain chemical processes, and maintain product quality. Additionally, hydrogen fuel cells could be used in logistics, powering refrigerated transport vehicles and warehouses, ensuring a sustainable cold chain. Products labelled as sustainably produced through hydrogen usage could attract premium pricing in international markets, particularly in regions with strong sustainability mandates.

E.4.3.5 CONSTRUCTION

The construction industry can benefit from hydrogen by using it to power machinery and equipment, thus reducing the carbon footprint of construction projects. Sustainable building practices are increasingly favoured in many countries, providing a competitive advantage for firms that adopt hydrogen solutions.

E.4.3.6 SERVICES

Hydrogen fuel cell technology can enhance logistics operations by providing clean energy for transportation vehicles. This shift not only reduces emissions but also aligns with global trends towards decarbonization in logistics, making Mantova's products more attractive in markets that value sustainability.

E.4.3.7 CRAFTSMANSHIP AND SMALL ENTERPRISES

Small and medium-sized enterprises (SMEs) can leverage hydrogen technologies to innovate their production processes. By adopting sustainable practices, these businesses can differentiate themselves in niche markets where consumers are willing to pay more for environmentally friendly products.

E.4.3.8 TOURISM

The tourism industry in Mantua has the potential to flourish by adopting environmentally friendly practices. The use of renewable energy sources, such as hydrogen, in sustainable accommodation facilities is an attractive proposition for eco-conscious tourists. The implementation of green certifications, waste reduction strategies, and water conservation measures serves to enhance the appeal of the destination. The development of eco-compatible services, such as cultural and nature tours with minimal impact, has the potential to attract tourists seeking authentic experiences. The services offered include bicycle rentals, walking tours, and partnerships with local sustainable businesses.

E.5 ADVANTAGES AND RESEARCH OPPORTUNITIES

Integrating hydrogen into these key industrial sectors offers several advantages:

- Emission Reduction
  Transitioning to hydrogen reduces carbon emissions, helping industries meet environmental regulations and contributing to regional sustainability goals.
- Energy Efficiency
  Hydrogen technologies can improve energy efficiency in industrial processes, leading to cost savings and enhanced competitiveness.
- Innovation and Leadership
  By adopting hydrogen solutions, industries in Mantua and Lombardy can position themselves at the forefront of technological innovation, opening new markets and opportunities.

- Economic Growth
  Developing hydrogen applications stimulates investment, job creation, and economic diversification within the region.

The H2 Research Hub can play a pivotal role by conducting applied research to overcome technical challenges, optimise processes, and develop industry-specific hydrogen solutions. Collaboration with industry partners will be essential to tailor research efforts to practical needs, facilitate technology transfer, and accelerate the adoption of hydrogen technologies across these sectors.

F SPACE USAGE AND SCHEDULING PROGRAM

In research institutions, the judicious allocation of both laboratory and office space is paramount for fostering an environment that supports innovation, productivity, and collaboration. Space is a finite and valuable resource, and its allocation must be managed with a transparent, equitable, and efficient approach to ensure all stakeholders have fair access to the necessary facilities.

The allocation requires careful planning, transparent procedures, and a commitment to shared principles. By establishing a framework that prioritises equity, efficiency, accountability, and sustainability, the institution can ensure that its limited physical resources are used effectively to support high-quality research.

This section of the document aims to establish a systematic method for allocating laboratory spaces, drawing parallels to the shared office spaces, with the intention of preventing exclusivity and promoting a flexible, shared-use model.

F.1 LAB SPACE ALLOCATION

The fundamental principle underpinning this allocation policy is that laboratory spaces are not to be perceived as the exclusive property of any single research team but are instead to be temporarily assigned for the specific duration of a given project. Upon the conclusion of the project, the space must be vacated to allow for reassignment to other ongoing or future projects.. By ensuring that laboratory spaces are used temporarily, without any team having exclusive rights, the institution can maximise the availability of facilities for all stakeholders and promote an environment where all research teams have the opportunity to succeed. Ultimately, the effective management of laboratory space is essential for the ongoing success of the research centre, enabling it to support cutting-edge research and maintain its position at the forefront of scientific discovery.

F.1.1 PRINCIPLES OF SPACE ALLOCATION

The principles that govern the allocation of laboratory spaces include equity, efficiency, accountability, and sustainability. These principles aim to promote an environment where research activities are not impeded by undue resource constraints and where all research teams have equitable opportunities to access space as required.

1. **Equity**. All research teams must be given equal consideration for space allocation based on their research needs and the institutional priorities. The allocation process must be free from bias, ensuring that all teams, regardless of their seniority or the perceived prestige of their research, have fair access to the laboratory resources.

2. **Efficiency**. Laboratory space must be used efficiently, with the goal of maximising the value that the institution derives from its physical resources. This principle encourages shared use, minimisation of idle space, and the optimal scheduling of laboratory activities to avoid conflicts or periods of underutilisation.

3. **Accountability**. Research teams occupying laboratory space must be accountable for its use. To this end, they are required to make a financial contribution from their research funds. This contribution serves two functions:

firstly, to contribute to the economic running of the research centre, covering costs such as utilities, maintenance, and administrative support; secondly, to discourage long-term occupation of space without a valid, active project.

4. **Sustainability**. Laboratory space allocation must also align with the broader goals of sustainability, both in terms of environmental stewardship and resource management. This includes ensuring that laboratory activities are conducted in a manner that minimises environmental impact and that space allocation decisions consider the long-term sustainability of research initiatives.

5. **Safety of Research Experiments**. Ensuring the safety of all researchers is a fundamental aspect of laboratory space allocation and usage. All research teams must adhere strictly to established safety protocols and best practices. This includes conducting thorough risk assessments for each experiment, ensuring that all personnel are trained in emergency procedures, and that appropriate safety measures are in place, such as the availability of personal protective equipment (PPE), safety data sheets (SDS) for all chemicals, and the implementation of regular safety audits. The research centre will also provide necessary support for compliance with safety standards, including training sessions and access to safety officers for consultation. Additionally, a designated Safety Officer, with sufficiently high technical skills on the subject, will be appointed. The Safety Officer will have the authority to intervene and stop experiments or address potentially dangerous situations. They will report directly to the director of the research centre. By prioritising safety, the institution aims to create a secure working environment that mitigates risks and protects the well-being of all individuals involved in research activities.

F.1.2 ALLOCATION PROCEDURES

The process for laboratory space allocation consists of several key steps designed to ensure transparency, fairness, and efficiency. The executive board of the research centre is responsible for making final decisions on space allocation, following consultation with relevant stakeholders and committees.

1. **Submission of Space Request**: Research teams must formally apply for laboratory space by submitting a request to the executive board. This request must include a detailed description of the proposed project, including the duration, the specific facilities required, the anticipated benefits to the research centre, and any special considerations regarding safety, equipment, or collaborations.

2. **Evaluation and Prioritisation**: The executive board, after consulting the Research Directorate, will evaluate all submitted requests based on a set of criteria that prioritises projects according to their alignment with the institution's strategic objectives, the potential impact of the research, the feasibility of the proposed activities, and the level of funding available. Priority may be given to projects that are highly collaborative, have significant external funding, or are expected to yield high-impact outcomes. The executive board has the ultimate authority

to decide how laboratory space is allocated; it acts as arbiter; it is responsible for monitoring the use of laboratory space.

3. **Allocation and Scheduling**: Once projects are prioritised, the executive board will allocate laboratory space accordingly. The allocation will specify the duration for which the space is assigned, with a clear start and end date, and will outline any specific terms and conditions for use. Flexibility will be key in ensuring that space can be reallocated as projects evolve or conclude ahead of schedule.

4. **Contribution to Operational Costs**: As part of the allocation agreement, each research team must commit a financial contribution from their research funds. This contribution is intended to cover a portion of the operational costs associated with the laboratory space, including utilities, consumables, and general upkeep. By requiring a financial commitment, the research centre aims to promote accountability and discourage the occupation of laboratory space without active, meaningful research.

5. **Periodic Review and Reallocation**: The executive board will conduct periodic reviews of laboratory space usage to ensure that allocated spaces are being used efficiently and in line with the original project goals. If a project is concluded early or if space is being underutilised, the board reserves the right to reallocate the space to other projects that may have a more immediate need.

6. **Space Allocation for Basic Research**. A portion of the laboratory space will be allocated specifically for basic research activities. For such basic research projects, no financial contribution will be required if the research is not funded by public or private sources. This provision aims to support non-competitive research with low Technology Readiness Levels (TRL), fostering innovation at the foundational level. The availability of free space for basic research encourages exploratory projects that may not yet have significant funding but hold potential for groundbreaking discoveries. These free spaces provide an environment for researchers to engage in creative and fundamental scientific inquiry without the pressure of immediate financial burdens, thereby contributing to the long-term advancement of scientific knowledge.

F.2 FACILITY ACCESS FOR PARTNERS

In an increasingly interconnected research environment, effective collaboration between a public research hub and private partners is crucial for the success of joint projects and the advancement of innovation. To foster such partnerships while safeguarding sensitive information, it is essential to establish a structured process for facility access for private partners. This ensures that all parties involved can work together seamlessly, while also maintaining strict controls over intellectual property and proprietary data. This section outlines the protocols and policies related to facility access for private partners, providing a clear understanding of the procedures, responsibilities, and guidelines necessary to ensure both efficient collaboration and the security of valuable research assets.

F.2.1 DEFINING FACILITY ACCESS AND ITS IMPORTANCE

Facility access for private partners refers to the controlled permission granted to external stakeholders, including vendors, collaborators, and clients, allowing them to enter a research hub's premises to carry out specific, predefined activities. These activities may range from project meetings, technical evaluations, training, to operational integration and collaboration in operational research. While collaboration is vital to the hub’s competitiveness and growth, facility access introduces inherent risks—primarily concerning the protection of intellectual property (IP), sensitive research processes, ensuring that partners comply with organisational protocols, and managing the safety and responsibility of receiving external personnel in the building. Additionally, controlling access effectively is crucial to prevent unauthorised entry and mitigate potential security threats.

Ensuring seamless collaboration while simultaneously securing intellectual property requires a fine balance of transparent and efficient processes. These processes must reflect the hub's values, regulatory requirements, and operational demands. Consequently, this paragraph aims to provide a clear and precise understanding of the requirements, responsibilities, and mechanisms involved in partner facility access.

F.2.1.2 THE FACILITY ACCESS PROCESS FOR PARTNERS

The following procedure outlines the process by which external partners may request access to and use of the centre's laboratories and offices for the purpose of conducting research activities in collaboration with the hub's researchers. A more efficient and straightforward process is proposed for those visiting on a day-to-day basis.

F.2.1.2.1 INITIAL REQUIREMENTS AND APPLICATION

The first step towards facilitating partner access to research hub facilities involves the private partner organisation submitting a formal request. This application should outline the scope and objectives of the visit, details regarding the personnel involved, and the specific areas or departments that need to be accessed. It is imperative that these details are clearly defined to ensure that the partner's presence aligns with the hub’s goals and the nature of the partnership.

The application process includes the following essential components

- **Scope and Purpose**. The partner must provide a comprehensive statement of the purpose of their visit. This can include project descriptions, intended collaboration areas, and the specific role of each participant.

- **Personnel Verification**. The list of visiting personnel must include identification details, qualifications, and security clearance levels. The hub will perform a verification process to ensure that the individuals listed are suitably qualified and authorised to access the specified areas.

- **Approval Workflow**. The application must be approved by the Executive Board, after consulting: the Research Directorate; the security personnel, and the relevant project manager. Each level of approval ensures that the visit serves a valid purpose, aligns with strategic priorities, and that adequate security measures are in place.

Before access is granted, private partners are required to sign a legally binding non-disclosure agreement (NDA). This ensures that all sensitive information accessed during their visit is treated with the utmost confidentiality. NDAs are an essential component of IP protection and provide the hub with legal recourse should any breach occur.
Additionally, compliance documentation is required to ensure that the partner adheres to all relevant safety, data protectIn addition, compliance documentation is required to ensure that the partner adheres to all operational, safety and insurance standards for its workers.

F.2.1.2.2 ONBOARDING AND ACCESS PRIVILEGES

Once the access request has been approved and the necessary documentation is in place, the onboarding process commences. This process serves to familiarise partners with the facility, providing them with information on security protocols, safety procedures, and emergency measures.
The following key activities are carried out during onboarding.

- **Security Briefing**. Partners are briefed on the security protocols relevant to the areas they will access. This includes guidelines on restricted areas, data handling, and the proper use of hub equipment.
- **Identification and Access Cards**. Each visiting member is issued a temporary identification badge or access card, which is programmed to allow entry only to the authorised sections of the facility. Access cards are time-limited and monitored to prevent unauthorised extension of access privileges.
- **Digital Access Rights**. Where applicable, digital access rights are assigned to ensure that partners can access necessary systems and data during their visit. These rights are strictly controlled, and access is granted based on the principle of least privilege—partners are provided with the minimum level of access necessary to fulfil their tasks.

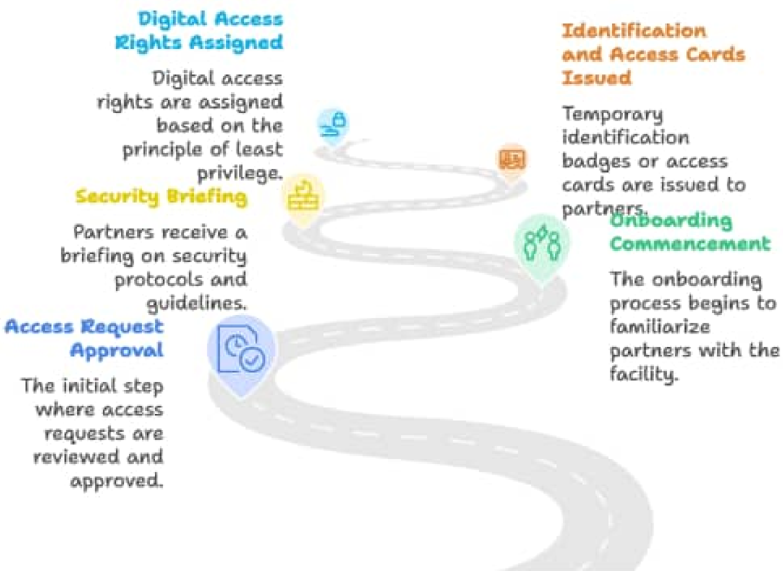

Fig.15 - Onboarding process for facility access

Upon the conclusion of the collaboration period, external personnel will no longer be granted access, and their identification badges will be deactivated. Furthermore, they will no longer be able to utilise the IT services. However, a request for an extension may be submitted by the internal research manager and must be endorsed by the executive board.

F.2.1.2.3 Daily visitor regulations

The following simplified regulations outline the procedure for daily visitor access. The aim is to ensure a smooth and secure experience for all visitors while maintaining high standards of safety and efficiency within the facility.

Responsibility. The researcher who invites the visitor is responsible for their conduct and adherence to the Centre's policies. It is their duty to ensure the visitor is aware of and complies with all relevant guidelines.

Arrival Procedure. All visitors must report to the reception upon arrival. The reception desk will issue a visitor badge, which includes:

  - Designated areas the visitor is permitted to access.
  - Key safety procedures and emergency information.

Badge and Identification. Visitors must wear their badge visibly at all times within the Centre. The badge grants access only to the specified areas mentioned during registration.

The researcher in charge must ensure the visitor understands these guidelines.

Visitor Log. A record of all visitors will be maintained at the reception.

The log will include:

  - Visitor's full name.
  - Date and time of entry and exit.
  - Name of the hosting researcher.

By adhering to these regulations, the Centre ensures a safe, efficient, and productive environment for both visitors and staff.

F.2.1.3 PHYSICAL AND DIGITAL SECURITY MEASURES

One of the most significant challenges associated with facility access for partners is ensuring that both physical and digital assets are adequately protected. To achieve this, the following security measures are implemented:

- **Surveillance and Monitoring**. All areas accessed by partners are subject to surveillance via CCTV systems. This provides an audit trail that can be reviewed in the event of any incident.

- **Restricted Areas**. Workspaces designated for private partners are clearly marked and closed to public view. Signage is used to indicate that these areas are restricted, and access is limited to authorised personnel only. This ensures that sensitive activities are not visible to unauthorised individuals.

- **Device Control and Data Management**. Partners are not permitted to bring unauthorised electronic devices into the facility. Hub-owned devices may be provided to facilitate collaboration, but strict controls are in place to prevent data leakage or the installation of unauthorised software.
- **Network Segregation**. If digital access to hub systems is required, partners are provided access via a segregated network. This measure minimises the risk of unauthorised access to core IT systems and protects against potential cyber threats.

F.2.2 ENSURING THE PROTECTION OF INTELLECTUAL PROPERTY

Intellectual property is a hub's most valuable asset, and its protection must be a top priority during any collaboration. The following strategies are used to ensure that IP remains secure while partners are on-site:

F.2.2.1 ACCESS LIMITATIONS

Access to sensitive information is restricted based on the need-to-know principle. Partners are only provided with the information required for their specific tasks, and access is strictly time-bound. Digital access is logged, and all interactions with sensitive data are monitored to ensure compliance.

F.2.3.2 CONFIDENTIAL WORKSPACES

Where partners require dedicated workspaces within the facility, confidential workspaces are provided. These areas are designed to prevent unauthorised personnel from overhearing or viewing sensitive information. Additionally, all workspaces are cleared of confidential documents at the end of each day, in line with the hub's clean desk policy.

Fig.16 - Example of confidential workspaces[31]

F.2.3.3 TRAINING AND AWARENESS

Partners are required to undergo training on intellectual property protection. This includes understanding their responsibilities under the NDA, recognising the importance of safeguarding proprietary information, and being aware of potential threats such as social engineering attacks. By raising awareness and providing education, the hub ensures that partners understand the critical role they play in protecting IP.

The hub is responsible for establishing clear protocols, providing adequate security, and ensuring that partners are well-informed of their obligations. Additionally, the hub must monitor partner activities and take prompt action in the event of any breach.

Partner Responsibilities: Partners are responsible for adhering to the terms of their access, ensuring that their personnel follow all guidelines, and promptly reporting any incidents or security concerns. Partners must respect the boundaries established by the hub and refrain from engaging in any activities beyond the authorised scope of their visit.

Striking the right balance between facilitating partner collaboration and ensuring robust security is a challenging task. On the one hand, excessive restrictions can hinder the collaborative process, stifling innovation and reducing the effectiveness of joint projects. On the other hand, inadequate controls can expose the hub to significant risks, including the loss of intellectual property, regulatory breaches, and reputational damage.

To achieve this balance, the hub adopts a risk-based approach. Security measures are scaled according to the sensitivity of the project and the areas being accessed. Low-risk collaborations may involve more straightforward access procedures, while high-risk engagements require comprehensive security protocols. Regular reviews are conducted to assess the effectiveness of these measures, and adjustments are made as necessary to address emerging risks.

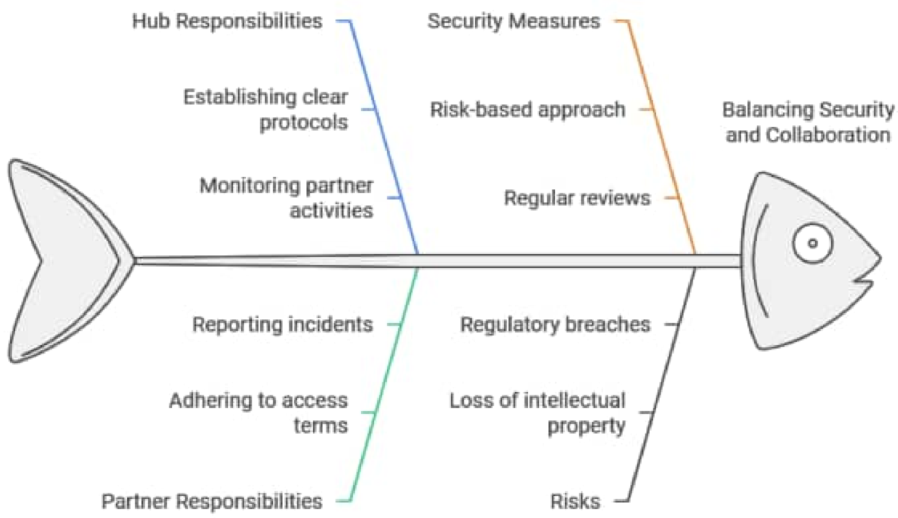

Fig.17 - Challenges in facility access management

G SUSTAINABILITY AND MAINTENANCE PROGRAM

This chapter presents the projected costs and revenues for the H2 Research Centre over a five-year period. The figures provided are reasonable estimates based on current market conditions and operational assumptions. However, it is important to note that actual values may vary due to fluctuations in costs and other unforeseen factors.

The financial projections aim to demonstrate the economic sustainability of the Centre, highlighting a robust business model that supports ongoing research and development activities. By carefully balancing expenses and revenue streams, the Centre can ensure its long-term viability and contribution to the advancement of hydrogen technologies.

This financial overview includes a detailed analysis of major cost components, such as staffing, equipment, and facilities, as well as anticipated revenue sources from grants, partnerships, and other funding opportunities. Through this analysis, it is intended to provide a comprehensive understanding of the Centre's economic foundation and its potential for growth and success.

G.1 COST MODEL

This five-year business plan outlines the primary expenditure categories required to establish and operate a hydrogen research laboratory. In order to ensure a balanced budget, expenditure values have been adjusted to prevent years of significant losses compared to revenue. It is important to highlight that the costs related to the construction of the infrastructure and all internal facilities are not included in these estimates. The structure is provided free of charge, already ready for use. The Centre will allocate funds towards the maintenance and improvement of its facilities and equipment.

The Table II below presents the anticipated costs, with an accompanying explanation and illustration of their evolution.

Table II - Cost five-year business plan

Category	Year 1	Year 2	Year 3	Year 4	Year 5
Research Staff Salaries (5 PhD)	€ 180.000,00	€ 183.600,00	€ 307.272,00	€ 313.417,44	€ 379.685,79
Lab Technicians Salaries (5 Technicians)	€ 120.000,00	€ 122.400,00	€ 204.848,00	€ 208.944,96	€ 253.123,86
Admin Staff Salaries (3 person)	€ 105.000,00	€ 107.100,00	€ 109.242,00	€ 111.426,84	€ 113.655,38
Laboratory Equipment	€ 300.000,00	€ 300.000,00	€ 320.000,00	€ 350.000,00	€ 350.000,00
Consumables and Supplies	€ 50.000,00	€ 55.000,00	€ 60.000,00	€ 65.000,00	€ 70.000,00
Utilities (Electricity, Water, etc.)	€ 30.000,00	€ 32.000,00	€ 35.000,00	€ 35.000,00	€ 38.000,00

IT Infrastructure and Maintenance	€ 50.000,00	€ 20.000,00	€ 20.000,00	€ 30.000,00	€ 30.000,00
Insurance	€ 20.000,00	€ 22.000,00	€ 24.200,00	€ 26.620,00	€ 29.282,00
Training and Development	€ 15.000,00	€ 17.000,00	€ 18.000,00	€ 19.000,00	€ 20.000,00
Travel and Conferences	€ 10.000,00	€ 20.000,00	€ 25.000,00	€ 30.000,00	€ 35.000,00
Marketing and Outreach	€ 10.000,00	€ 12.000,00	€ 13.000,00	€ 13.500,00	€ 14.000,00
Miscellaneous	€ 5.000,00	€ 5.000,00	€ 5.500,00	€ 6.500,00	€ 7.000,00
Attendance fees	€ 10.000,00	€ 10.000,00	€ 10.000,00	€ 10.000,00	€ 10.000,00
Total	€ 905.000,00	€ 896.100,00	€ 1.142.062,00	€ 1.209.409,24	€ 1.339.747,02

G.1.1 POTENTIAL COST SOURCES

- **Research Staff Salaries (PhD)**
  This budget covers the salaries of the five PhD-qualified researchers who will form the core of the scientific team, conducting pivotal work in hydrogen technology. Salary increases each year account for a 2% annual inflation and ensure competitive compensation, fostering staff retention and continuity within the research team. In order to maintain a balanced budget, it was planned to hire the figures gradually: three PhDs in the first and second year; four in the third and fourth year and then only five at the end of the five-year period. This is in line with the idea that, initially, the demand for research also from external parties will be lower and then increase.

- **Lab Technicians' Salaries**
  The contribution of laboratory technicians to the smooth functioning of the laboratory is invaluable. They are responsible for the maintenance of equipment, the preparation of samples and the monitoring of quality standards. The provision of incremental annual salary increases is intended to ensure the retention of experienced technicians, who are a vital component of the laboratory's operational efficiency and the success of ongoing projects. By the end of the five-year period, the budget will cover the salaries of the five laboratory technicians. As with the PhD staff, the decision was taken to adopt a gradual approach to the recruitment of technicians. The salary increase has been designed to offset the impact of inflation, with a target of recovering 2% of the cost of living.

- **Admin Staff Salaries**
  Administrative staff will manage fundamental support functions, including accounting, human resources, and general office administration, allowing the scientific team to focus solely on research. A staff unit will also be assigned to reception. Salaries are adjusted yearly to reflect inflation and ensure stability within the support team. A total of three people were considered: an administrative manager; two co-workers, one of whom is also a receptionist. The salary increase has been designed to offset the impact of inflation, with a target of recovering 2% of the cost of living.

- **Laboratory Equipment**
  A substantial initial investment is allocated for state-of-the-art lab equipment required for foundational research. This expenditure will gradually increase in subsequent years due to both the maintenance costs of the instruments, the possible purchase of parts to improve the instrument, and the purchase of new equipment.

- **Consumables and Supplies**
  This category covers essential daily materials, including chemicals, gases, safety equipment, and other laboratory supplies. These costs are expected to increase gradually as research activities intensify, and new projects begin.

- **Utilities (Electricity, Water, etc.)**
  Laboratories require substantial utility consumption, particularly for specialised equipment and climate control. Utility costs are anticipated to increase modestly each year as the lab becomes fully operational.

- **IT Infrastructure and Maintenance**
  This budget covers the setup and ongoing maintenance of computers, specialised software, and data storage systems. Higher initial costs cover the setup of essential IT resources, while subsequent years focus on routine maintenance and minor upgrades.

- **Insurance**
  Insurance is vital to protect the laboratory from potential liabilities, including equipment damage and employee safety. The budget allows for a 10% annual increase to accommodate the additional risks associated with the expansion of research activities at the laboratory.

- **Training and Development**
  Continuous professional development ensures staff remain current with the latest research methodologies and safety practices. The budget is projected to increase by 10% annually, facilitating the provision of training for newly-hired personnel and facilitating the dissemination of updated knowledge throughout the team.

- **Travel and Conferences**
  Attendance at conferences and scientific events is crucial for networking and sharing research findings. This category’s allocation grows slightly over time to support increased participation in international events and collaborations. Expenditure is expected to increase with the recruitment of new staff.

- **Marketing and Outreach**
  To promote the lab’s research, attract potential funding, and foster collaborations, a modest marketing budget is included. This covers promotional activities and maintaining an online presence, crucial for visibility within the research community.

- **Miscellaneous**

This category provides a reserve for unforeseen expenses and minor purchases that may arise. It includes a slight annual increase to cover potential new requirements as the laboratory evolves.

- **Attendance fees**
  The salaries of university researchers and external participants from various governing bodies associated with the Centre are not included in the costs. These individuals are compensated by their respective institutions. Only an attendance fee is recognised.

G.2 REVENUE MODEL

This part forms a comprehensive financial plan to ensure the lab has the necessary resources, infrastructure, and expertise to achieve its research goals in hydrogen technology over the next five years.

Revenue will likely stem from diverse streams, including government grants, private sector collaborations, and intellectual property (IP) royalties. A well-rounded revenue model is critical for ensuring long-term financial stability and enabling the lab to continuously expand its research capabilities. Below is a breakdown of anticipated revenue sources and their justifications.

A reserve fund has been established on the revenue side to reserve resources in the event that expenditure exceeds revenue in a given year.

The Table III below presents the expected revenues, with an accompanying explanation and evolution.

Table III - Revenue five-year business plan

Revenue Source	Year 1	Year 2	Year 3	Year 4	Year 5
Government Grants	€ 430.000,00	€ 300.000,00	€ 250.000,00	€ 250.000,00	€ 150.000,00
University Partnerships	€ 50.000,00	€ 55.000,00	€ 60.000,00	€ 65.000,00	€ 70.000,00
Corporate Sponsorships and Collaborations	€ 100.000,00	€ 200.000,00	€ 250.000,00	€ 250.000,00	€ 300.000,00
Intellectual Property Licensing	€ 0,00	€ 0,00	€ 20.000,00	€ 20.000,00	€ 20.000,00
Consulting Services	€ 40.000,00	€ 50.000,00	€ 60.000,00	€ 70.000,00	€ 70.000,00
Public-Private Research Funding	€ 100.000,00	€ 110.000,00	€ 150.000,00	€ 200.000,00	€ 250.000,00
Hydrogen Technology Sales or Pilot Projects	€ 50.000,00	€ 70.000,00	€ 80.000,00	€ 100.000,00	€ 150.000,00
EU or International Grants	€ 100.000,00	€ 120.000,00	€ 150.000,00	€ 170.000,00	€ 200.000,00
Fee-Based Training and Workshops	€ 20.000,00	€ 40.000,00	€ 50.000,00	€ 60.000,00	€ 70.000,00

Publications and Sponsored Research Papers	€ 15.000,00	€ 20.000,00	€ 25.000,00	€ 30.000,00	€ 35.000,00
Reserve funds	€ 0,00	€ 0,00	€ 68.900,00	€ 21.838,00	€ 27.428,76
Total	€ 905.000,00	€ 965.000,00	€ 1.163.900,00	€ 1.236.838,00	€ 1.342.428,76

G.2.1 POTENTIAL REVENUE SOURCES

- **Government Grants and Research Funding**
  Government support, in particular from the Lombardy region and the province of Mantua, for hydrogen technology and renewable energy initiatives is substantial and necessary if ambitious goals are to be achieved. These can cover a substantial part of the research costs, especially in the early stages of the laboratory, and are generally allocated on the basis of competitive research proposals that align with national priorities. Funds are expected to decrease over the years until they reach zero within a decade.

- **Academic Partnerships and Funding from Universities**.
  Partnering with universities may provide research funding, researchers, PhD students, and shared facilities, reducing overhead costs. Additionally, academic partnerships may open avenues for grant applications and collaborative projects, adding both financial and intellectual value. The value of this item is not very high and is growing slowly.

- **Corporate Sponsorships and Collaborations**
  Private companies in energy, transport, and manufacturing sectors are actively investing in hydrogen solutions, providing substantial revenue opportunities through sponsorships and collaborations. Sponsorships could cover specific projects that align with corporate goals. Collaborative agreements may include shared IP rights, joint funding of research personnel, or the use of company-owned testing facilities. These partnerships also offer the lab real-world testing opportunities for its research outputs, enhancing the lab's reputation in applied hydrogen technology. The value of this item is important and constantly growing because it is one of the main purposes of the research hub.

- **Licensing of Intellectual Property (IP)**
  As the lab develops unique processes, materials, or devices, IP licensing agreements could serve as a valuable revenue stream. Patents and IP rights can be licensed to private companies, allowing them to use the lab's innovations while providing the lab with royalties or licensing fees. This model can offer consistent revenue, particularly if the lab's research yields high-demand technologies. In the initial two-year period, the contribution is set at zero, reflecting the expectation that it will represent the culmination of at least two years of research. Subsequently, the income remains constant. Given the inherently uncertain nature of the item in question, it has not been set at a particularly high level.

- **Consultancy Services**

  The lab can provide expert consulting services for companies seeking technical guidance on hydrogen technology adoption, environmental assessments, or infrastructure development. Consulting services could include feasibility studies, environmental impact analyses, technology selection advice, and custom design of hydrogen systems. As hydrogen adoption grows, more sectors will need expertise in integrating hydrogen technology within their operations, creating a steady demand for consulting services and reinforcing the lab's reputation as a knowledge leader. The value of this item is constantly growing.

- **Public-Private Research Funding**

  Public-private research funding initiatives bring together resources from government and industry, offering substantial project-based funding. These collaborations are often aimed at high-impact projects with clear commercial applications, such as developing hydrogen-fuelled transport or green hydrogen production facilities. Public-private partnerships typically have well-defined objectives and timelines, with companies providing capital and market insights while the lab contributes research expertise. Such funding arrangements can significantly advance the lab's work while ensuring alignment with industry needs. The value of this item is important and constantly growing because it is one of the main purposes of the research hub.

- **Hydrogen Technology Sales or Pilot Projects**

  As the lab develops market-ready solutions, it may conduct pilot projects or technology demonstrations, which can attract funding from stakeholders interested in validating hydrogen solutions on a larger scale. This could include working with municipalities, energy companies, or transportation sectors eager to adopt green hydrogen. Pilot projects enable the lab to demonstrate its technology in real-world applications. Upon successful demonstration, these pilots may lead to full-scale commercial applications and even direct sales of lab-developed hydrogen solutions, establishing the lab as a key player in practical hydrogen deployment. The value of this item is constantly growing.

- **EU or International Grants**

  Joining consortia focused on hydrogen technology can lead to funding opportunities and resource-sharing arrangements. Many consortia distribute pooled research funds across participants, which can supplement the lab's funding while providing access to shared knowledge and technology. Programs like Horizon Europe offer grants for hydrogen research, often aimed at collaborative projects involving multiple countries and research institutions. By participating in these grant programmes, the lab can receive substantial funding while engaging in high-profile, internationally recognised research initiatives. Such involvement also broadens the lab's network and positions it as a leader in global hydrogen research. The value of this contribution is considered gradually increasing in line with the growing availability of personnel and equipment, which will enabling the submission of an increasing number of projects and participation in an expanding number of consortia.

- **Fee-Based Training and Workshops**

The growing demand for hydrogen expertise offers opportunities to host training sessions, workshops, and certification programmes. Targeting professionals, students, and companies interested in adopting hydrogen technology, these programmes can provide a steady revenue stream while positioning the lab as an educational leader in the field. Tailoring courses to industry needs (e.g., safe handling of hydrogen, hydrogen system design) will maximise appeal and expand the lab's influence in workforce development. This item is considered to be growing steadily due to the hiring of new staff.

- **Workshops, Training, and Certification Courses**
  With an increasing demand for skilled professionals in hydrogen technology, the lab could offer workshops, training sessions, and certification courses. Revenue from such programmes could not only provide additional income but also position the lab as a leader in hydrogen education. This item is considered to be growing steadily due to the hiring of new staff.

- **Reserve Funds**
  They provide essential financial stability and resilience for the hydrogen research lab, serving as a financial cushion for unforeseen circumstances and cash flow fluctuations. Key purposes include:

  - Emergency Management: Covers unexpected equipment repairs or replacements, minimising downtime and ensuring continuity.
  - Cash Flow Support: Maintains liquidity during delays in funding, avoiding the need for short-term financing.
  - Strategic Project Development: Enables the lab to pursue promising research opportunities or strategic collaborations before securing dedicated external funds.
  - Economic Risk Mitigation: Protects against economic fluctuations, such as inflation or unexpected operational cost increases.

  A well-managed Reserve Fund is not only a safeguard but a strategic asset that enables the lab to remain adaptable and seize growth opportunities in the dynamic hydrogen sector.

G.3 SUSTAINABILITY INITIATIVES

When discussing sustainability initiatives for a research hydrogen hub, it's important to highlight the measures that minimise the carbon footprint, encompassing renewable energy use, waste management protocols, and energy-efficient design. These three pillars work in tandem to significantly reduce the carbon footprint of a hydrogen research hub. The hub should be designed with a holistic approach to sustainability, where each element complements the others, ensuring that the environmental impact of hydrogen research and production is minimised.
In addition, the use of self-generated renewable energy through photovoltaics, while representing a higher initial cost, allows for savings in future years, which is very important for an arguably energy-intensive business.These elements

together form the backbone of an effective strategy to build a truly green hydrogen hub. Let's explore each aspect in greater detail.

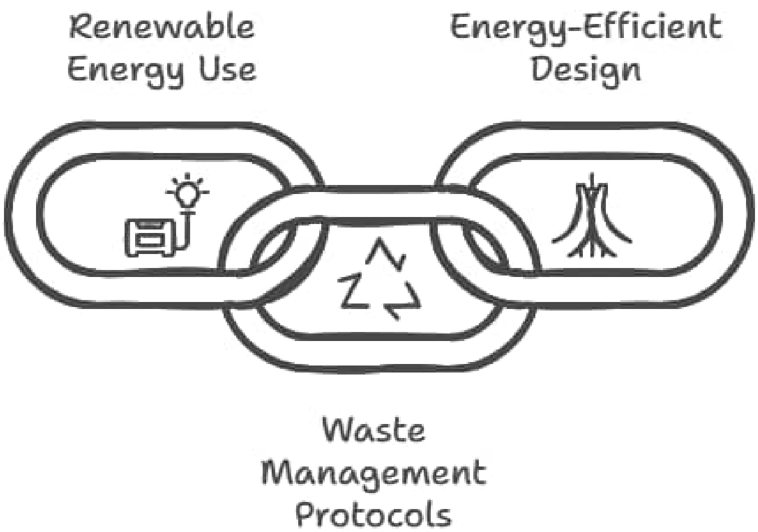

Fig.18 - Sustainability initiatives

G.3.1 RENEWABLE ENERGY USE

The use of renewable energy is one of the most critical measures for minimising the carbon footprint of a hydrogen research hub. As a first step, renewable energies can be used to produce the hydrogen needed for basic and applied research. Hydrogen can be produced with electrolysis using renewable electricity being among the cleanest ways to generate hydrogen without greenhouse gas emissions.

Beyond hydrogen production, renewable energy can also be used to power the general operations of the facility, including lighting, heating, and cooling. Adopting renewable-powered technologies and systems at every level of the hub helps make its operations as carbon-neutral as possible. Incorporating energy storage solutions like batteries can also improve reliability, storing surplus energy generated during peak production and using it when renewable sources are not actively producing, thus reducing dependency on the grid and maintaining sustainable operation. This approach can turn the hub itself into a useful case study for other contexts

G.3.2 WASTE MANAGEMENT PROTOCOLS

Effective waste management is another key aspect of minimising the carbon footprint of the hydrogen research hub. Research activities often generate waste in various forms, including chemical by-products, water effluents, and general operational waste. A sustainable hydrogen hub needs to implement a robust waste management strategy that prioritises minimising waste production and maximising recycling and reuse wherever possible.

For hydrogen production through electrolysis, managing water resources is crucial. Ensuring that the water used is sourced sustainably and exploring ways to purify and recycle wastewater can significantly reduce the environmental impact. Using treated water from municipal or industrial wastewater systems, rather than drawing on fresh potable supplies, can further contribute to sustainability goals. Any wastewater generated during the process should be carefully treated before disposal to minimise environmental damage.

For solid waste, a comprehensive recycling system should be set up to sort and manage materials used in research, including metals, plastics, and other laboratory consumables. Additionally, by implementing processes to capture and recycle chemicals used during research and experimentation, the hub can significantly reduce hazardous waste production.

To further improve sustainability, the hydrogen hub could explore partnerships with local waste management facilities and other research institutions to collaboratively develop innovative waste treatment or recycling technologies. These initiatives can help reduce the volume of waste sent to landfills while contributing to broader sustainability efforts in the community.

G.3.3 ENERGY-EFFICIENT DESIGN

Energy-efficient design is the third essential component for minimising the carbon footprint of a hydrogen research hub. From the outset, careful consideration should be given to designing the facility in a way that reduces energy consumption and promotes efficiency. This starts with the architecture of the buildings—employing passive design principles that reduce the need for artificial heating, cooling, and lighting can significantly cut down energy usage.

Examples of such design principles include incorporating high-quality insulation, optimising natural ventilation, and maximising the use of natural light through strategic window placement. Green roofs, which provide natural insulation while reducing stormwater runoff, could also be a valuable feature. Utilising building materials that have a lower embodied carbon footprint, such as recycled or sustainably sourced materials, further helps minimise the environmental impact.

Another major aspect of energy-efficient design is the integration of smart energy management systems throughout the facility. Smart systems, including sensors, automation, and building management software, can optimise energy usage by automatically adjusting lighting, temperature, and equipment power based on real-time needs. For instance, automated systems can turn off lights and equipment in unused areas, reducing unnecessary energy consumption. Heating, ventilation, and air conditioning (HVAC) systems could be equipped with intelligent controls to ensure that energy is used efficiently without compromising comfort.

Moreover, integrating energy-efficient laboratory equipment plays an essential role in minimising the hub's carbon footprint. Labs are traditionally energy-intensive due to the equipment they require, so opting for energy-efficient alternatives and ensuring that equipment is well-maintained to operate at peak efficiency can lead to substantial energy savings over time. Research hubs could also encourage behavioural changes among researchers and staff to adopt energy-saving practices, such as turning off unused equipment and consolidating experimental runs to minimise idle time.

H IMPLEMENTATION PLAN

Establishing a hydrogen research hub is a complex endeavour that demands meticulous planning and coordination of various activities over an extended period. A phased, two-year timeline ensures the successful implementation of all necessary components, minimises delays, and optimised resource allocation.

This chapter outlines a suggested two-year timeline for the establishment of the hydrogen research hub, highlighting key milestones such as construction, equipment procurement, hiring, and the launch of initial projects. The timeline is divided into two main phases: Year 1, focused on planning, construction, and initial setup, and Year 2, centred on facility completion, team expansion, and project launch.

Effective planning and execution during these phases will set the foundation for a state-of-the-art hydrogen research hub that prioritises sustainability, safety, and community engagement. This structured approach aims to achieve operational readiness and ensure the hub's long-term success in contributing to hydrogen technology advancements and regional economic growth.

H.1 TIMELINE

The establishment of a hydrogen research hub is a complex undertaking that requires careful planning and the coordination of multiple activities over an extended period. A phased, two-year timeline helps to ensure that all necessary components are successfully implemented, minimising delays and optimising resource allocation. Below is a suggested two-year timeline for the establishment of the hydrogen research hub, highlighting key milestones such as construction, equipment procurement, hiring, and initial project launches.

H.1.1 YEAR 1: PLANNING, CONSTRUCTION, AND INITIAL SETUP

Initial Planning and Permitting

- **Project Planning and Feasibility Studies**: Conduct detailed feasibility studies, including site selection, risk assessments, and environmental impact assessments. Finalise project scope, objectives, and timeline.
- **Permitting and Regulatory Approvals**: Obtain necessary permits and approvals from local authorities, environmental regulators, and safety inspectors.
- **Partnership Development**: Engage with potential industry and academic partners to establish collaborations and secure initial funding commitments.

Design and Procurement

- **Architectural Design**: Finalise architectural and engineering designs for the research hub, incorporating energy-efficient and safety-focused features.
- **Procurement Planning**: Develop procurement plans for construction materials, laboratory equipment, and renewable energy infrastructure. Issue requests for proposals (RFPs) and secure contracts with suppliers.

Construction Kick-off

- **Groundbreaking and Construction Initiation**: Begin construction of the research facility, including site preparation, foundation work, and initial building phases.
- **Utilities Installation**: Ensure that utilities, including electricity, water, and renewable energy systems, are installed in parallel with the main construction efforts.

Recruitment and Equipment Procurement

- **Key Personnel Hiring**: Begin recruiting key personnel, including PhD researchers, lab technicians, and administrative staff. Prioritise personnel with expertise in hydrogen technologies and related research fields.
- **Equipment Procurement**: Finalise procurement and initiate delivery of essential laboratory equipment, including electrolysers, hydrogen storage systems, and safety monitoring tools.

H.1.2 YEAR 2: FACILITY COMPLETION, TEAM EXPANSION, AND PROJECT LAUNCH

Construction Completion and Internal Setup

- **Facility Completion**: Complete the main construction activities, including laboratories, offices, and storage areas. Perform final inspections to ensure compliance with safety and building regulations.
- **Internal Setup**: Install laboratory equipment, renewable energy systems (e.g., solar panels or wind turbines), and hydrogen production and storage infrastructure.

Staff Expansion and Training

- **Training Programmes**: Conduct comprehensive training programmes for all staff, focusing on safety procedures, equipment operation, and emergency response protocols related to hydrogen handling.

Testing and Calibration

- **System Testing**: Perform testing and calibration of all equipment and systems, including hydrogen production units, monitoring sensors, and safety protocols. Identify and resolve any technical issues before full-scale operations begin.
- **Safety Drills**: Conduct safety drills to prepare staff for emergency situations, ensuring familiarity with emergency shutdown procedures and evacuation routes.

Initial Project Launch and Public Engagement

- **Launch of Initial Research Projects**: Officially launch initial research projects focusing on hydrogen production, storage, and utilisation. Begin collaborative projects with academic and industrial partners.

- **Public Engagement and Outreach**: Host an open house event or public information session to introduce the hydrogen hub to the community. Highlight the benefits of hydrogen technology and demonstrate the hub's commitment to sustainability and safety.
- **Monitoring and Review**: Establish a monitoring framework to assess the hub's performance against key performance indicators (KPIs) and conduct a review to identify potential improvements in future phases.

This phased, two-year timeline provides a structured approach to the establishment of the hydrogen research hub, ensuring that key milestones are met efficiently and effectively. By prioritising planning, recruitment, construction, equipment procurement, and initial research activities, the hydrogen hub can achieve operational readiness while maintaining a focus on sustainability, safety, and community engagement.

Table IV - Gannt chart for hydrogen research hub

	Months																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Initial Planning and Permitting	■	■	■																					
Design and Procurement			■	■	■																			
Construction Kick-off					■	■																		
Recruitment and Equipment Procurement			■	■	■	■																		
Construction Completion and Internal Setup							■	■	■	■	■	■	■	■	■	■	■	■						
Staff Expansion and Training						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Testing and Calibration																		■	■	■	■	■	■	■
Initial Project Launch and Public Engagement																						■	■	■

H.2 RISK MANAGEMENT

Describe potential risks and the mitigation strategies that will be put in place to ensure the project progresses as planned.

Risk management is an essential component of establishing and operating a research hydrogen hub. Given the innovative nature of hydrogen technologies and their associated infrastructure, identifying potential risks and implementing effective mitigation strategies is crucial to ensure the project progresses as planned. This detailed exploration will cover various types of risks—including: community perception, operational, technical, regulatory, financial, environmental, and safety risks—and provide the corresponding mitigation strategies that can help maintain stability, reliability, and safety in the hydrogen hub.

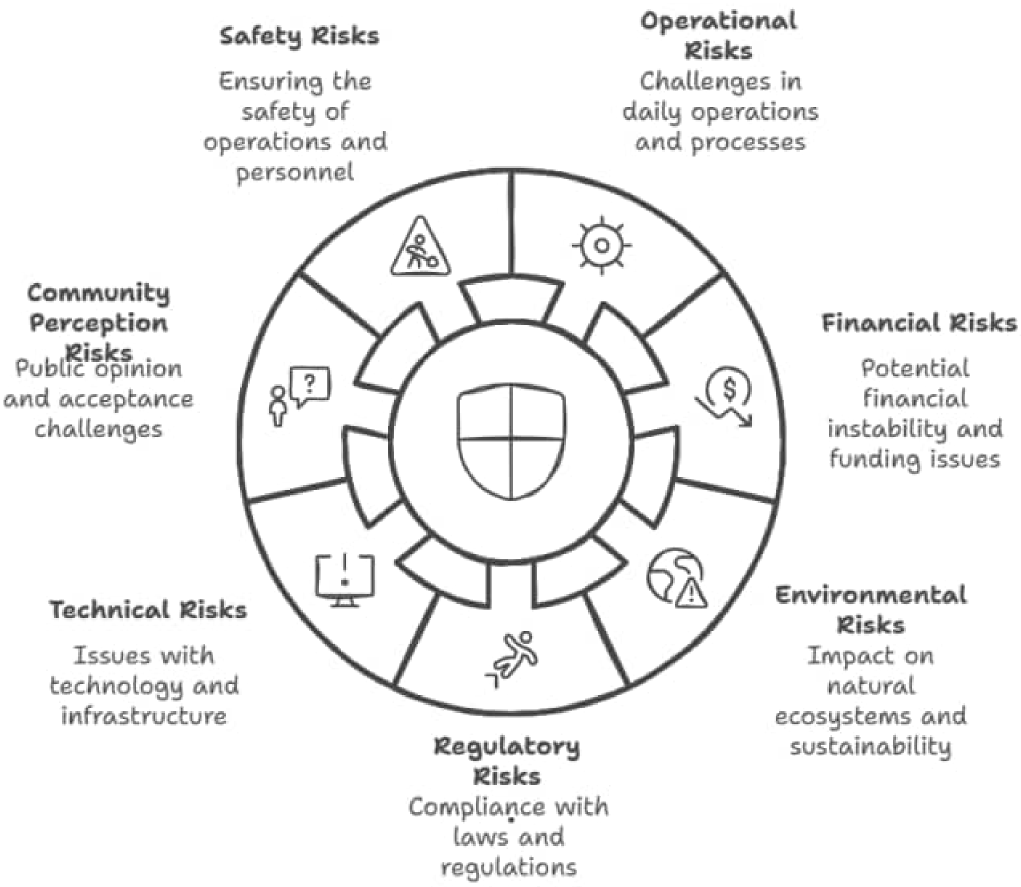

Fig.19 - Hydrogen hub risk management

H.2.1 FINANCIAL RISKS

Financial risks include the possibility of cost overruns, budget cuts, and insufficient funding to complete the project. This is particularly important for hydrogen hubs, which often require significant upfront investment and ongoing financial support.

- Mitigation Strategies.
    - Budget Monitoring and Cost Controls. Regular monitoring of the budget and implementing cost controls will help to identify deviations from financial plans early on. Employing dedicated financial management teams can ensure that spending is kept under control and resources are allocated efficiently.
    - Securing Multiple Funding Streams. Diversifying funding sources can provide greater financial security. This approach is what was adopted in the business plan: in addition to securing government grants, partnerships with private industry and academic institutions can help stabilise the funding base. Applying for additional research grants or incentives can also provide financial buffers during uncertain times.

- Phased Development Approach. Implementing the hydrogen hub in phases can reduce financial risk by allowing time to reassess funding and adapt project goals at each stage. This approach provides the flexibility to adjust investments depending on funding availability and progress.
- Industry Collaboration Risks: There is also the risk that industries may not seek collaboration with the hydrogen hub, which could lead to financial difficulties due to a lack of industrial partnerships and funding support. To mitigate this, the hub should actively engage with potential industrial partners, demonstrating the value and potential returns of collaboration. Establishing a dedicated business development team that fosters relationships with industry stakeholders, organises joint workshops, and tailors research outcomes to industry needs can make collaboration more attractive.It is also important to have a strong and constant visibility on social networks and discussion groups, especially those on which companies most often use (e.g. Linkedin). Additionally, maintaining a portfolio of successful case studies and practical demonstrations can help to showcase the benefits of partnering with the hub, thereby encouraging industry involvement.

H.2.2 OPERATIONAL RISKS

Operational risks involve challenges related to the day-to-day functioning of the hydrogen research hub. These risks can include equipment failure, supply chain disruptions, delays in project timelines, and human resource constraints. Effective management of these risks is vital to keep the hydrogen hub on track and ensure the successful development of hydrogen technologies.

- Mitigation Strategies.
    - Redundancy and Maintenance Plans. One key strategy is to incorporate redundancy in critical systems, meaning that backup components are available if a failure occurs. Additionally, establishing a proactive maintenance schedule will help reduce the risk of unexpected equipment failures by ensuring that all infrastructure is kept in good working order.
    - Supplier Diversification. The supply chain should be diversified by working with multiple suppliers for key materials, reducing the risk of disruption if one supplier fails to meet its obligations. Establishing strong relationships with suppliers and maintaining adequate inventory can further mitigate this risk.
    - Contingency Planning and Timeline Flexibility. Building in flexibility to project timelines and developing contingency plans allows the research hub to adapt to unforeseen delays or disruptions. Regular risk assessments and periodic project reviews can help identify potential bottlenecks before they become significant issues.
    - Training and Workforce Development. Human resource constraints can be minimised through continuous training and workforce development initiatives. Ensuring that staff are adequately trained to operate specialised equipment and conduct hydrogen research will reduce the likelihood of human error and promote efficient operations.

H.2.3 SAFETY RISKS

Safety is a primary concern for a hydrogen research hub, given the risks associated with handling and storing hydrogen, which is a highly flammable gas. Potential safety risks include hydrogen leaks, fires, and explosions, as well as risks to workers during the operation of high-pressure systems.

- Mitigation Strategies
  - Comprehensive Safety Protocols. Developing and implementing comprehensive safety protocols is essential to minimise safety risks. These protocols should include guidelines for safely handling hydrogen, regular safety drills, and emergency response plans.
  - Hydrogen Detection and Monitoring Systems. Hydrogen is colourless and odourless, making leaks difficult to detect. Installing hydrogen detection sensors throughout the facility ensures that any leaks are quickly identified, allowing prompt response to prevent escalation. These systems should be integrated with automatic shutdown features that isolate affected areas.
  - Ventilation and Explosion-Proof Design. Proper ventilation is crucial for preventing the buildup of hydrogen gas in enclosed spaces. Facility design should incorporate adequate ventilation systems, explosion-proof components, and safety barriers to reduce the risk of fires or explosions. Ensuring that storage areas are appropriately designed and separated from other parts of the facility also helps to minimise risk.
  - Workforce Training and Safety Culture. Establishing a culture of safety within the research hub is vital. Training staff in hydrogen safety, providing personal protective equipment (PPE), and promoting adherence to safety procedures all contribute to a safer working environment. Regular safety audits and reviews help to identify any areas for improvement and ensure compliance with established safety standards.

H.2.4 ENVIRONMENTAL RISKS

Environmental risks pertain to potential negative impacts that the hydrogen research hub could have on the surrounding environment. The primary concerns include greenhouse gas emissions from non-renewable energy use, water consumption, and potential contamination of soil and water during hydrogen production.

- Mitigation Strategies
  - Environmental Impact Assessments (EIA). Conducting comprehensive EIAs before construction and periodically during operation helps identify potential environmental risks. These assessments provide crucial information to guide decision-making and design processes to minimise ecological impact.
  - Use of Renewable Energy. To mitigate greenhouse gas emissions, the hydrogen hub should prioritise the use of renewable energy sources for both hydrogen production and general facility operations. Using renewable electricity for electrolysis significantly lowers the overall carbon footprint of hydrogen production.

- Efficient Water Management. Electrolysis requires significant amounts of water. Implementing water conservation measures and recycling wastewater helps minimise the impact on local water resources. Sourcing water from treated municipal or industrial wastewater systems rather than using fresh potable supplies can further reduce the environmental footprint.
- Monitoring and Compliance. Environmental monitoring should be an ongoing process throughout the hydrogen hub's lifecycle to ensure compliance with regulatory standards. This will help identify any emerging environmental risks and ensure that corrective actions are taken before significant issues arise.

H.2.5 REGULATORY AND COMPLIANCE RISKS

Hydrogen research hubs must navigate a complex regulatory landscape, encompassing health and safety standards, environmental laws, and industry-specific regulations. Failure to comply with regulations could result in fines, project delays, or reputational damage.

- Mitigation Strategies
    - Staying Informed on Regulatory Changes.
      Establishing a dedicated regulatory affairs team can help the hydrogen hub stay informed about regulatory developments and ensure ongoing compliance. This team should work closely with government agencies to understand regulatory requirements and incorporate them into the project's planning and operations. The team should consist of researchers from the research centre
    - Engagement with Stakeholders.
      Engaging with regulators, community members, and industry stakeholders during the project development phase ensures that the hub aligns with expectations and regulations. This proactive approach reduces the likelihood of facing opposition or regulatory hurdles once the project is underway.
    - Compliance Audits.
      Regular internal and third-party compliance audits are crucial for identifying potential gaps in regulatory adherence and implementing corrective actions. These audits provide a structured way to ensure all aspects of the facility remain in line with relevant laws and standards.

H.2.6 TECHNICAL AND TECHNOLOGICAL RISKS

Hydrogen research is at the cutting edge of technology, and as such, there is an inherent risk associated with technology failures or limitations. Technical risks include equipment malfunctions, failures of experimental technologies, and the inability to achieve desired performance targets.

- Mitigation Strategies.
    - Research and Development (R&D) Partnerships.

Establishing partnerships with universities, research institutions, and technology providers can provide access to a broader knowledge base and mitigate technical risks. Collaboration can accelerate problem-solving when technical issues arise.

- Prototype Testing and Pilot Projects.

  Conducting small-scale prototype testing or pilot projects before full-scale implementation allows for identification of technical flaws early in the process. These pilot projects provide invaluable insights and allow adjustments to be made to ensure that technology is viable for large-scale deployment.
- Continuous Monitoring and Improvement.

  A system for continuously monitoring the performance of technologies used in the hydrogen hub helps identify emerging problems early. This monitoring, combined with a commitment to continuous improvement, ensures that technical risks are actively managed throughout the project lifecycle.

H.2.7 COMMUNITY AND PUBLIC PERCEPTION RISKS

Public perception is an important risk factor for any hydrogen research hub. Negative public perception, community opposition, or misinformation about hydrogen safety can create challenges for project development and acceptance.

- Mitigation Strategies:
  - Community Engagement and Education.

    Engaging with the local community through workshops, open house events, and public information sessions helps build trust and understanding. Explaining the benefits of hydrogen technology, its safety measures, and its contribution to sustainability can alleviate fears and garner community support.
  - Transparency and Communication.

    Maintaining transparency about project goals, potential risks, and mitigation efforts ensures that the public remains well-informed. Creating an open channel of communication with community members and stakeholders builds credibility and helps address any concerns before they escalate.
  - Media and Outreach Campaigns.

    Positive media coverage and outreach campaigns can help shape public perception. Highlighting the environmental benefits of hydrogen research and the hub's role in driving innovation and sustainability can foster public support and mitigate perception risks.

REFERENCES

[1] International Energy Agency, «World Energy Outlook 2022».
[2] Intergovernmental Panel On Climate Change (Ipcc), *Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 1ª ed. Cambridge University Press, 2023. doi: 10.1017/9781009157896.
[3] «The-Sustainable-Development-Goals-Report-2022».
[4] I. Staffell *et al.*, «The role of hydrogen and fuel cells in the global energy system», *Energy Environ. Sci.*, vol. 12, fasc. 2, pp. 463–491, 2019, doi: 10.1039/C8EE01157E.
[5] «Hydrogen-Scaling-up_Hydrogen-Council_2017.compressed».
[6] https://www.marketsandmarkets.com/, «Which industries need hydrogen?» [Online]. Disponibile su: https://www.marketsandmarkets.com/industry-practice/hydrogen/hydrogen-industries
[7] European commission, «A hydrogen strategy for a climate-neutral Europe», 2020.
[8] «BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020».
[9] I. Dincer e M. I. Aydin, «New paradigms in sustainable energy systems with hydrogen», *Energy Convers. Manag.*, vol. 283, p. 116950, mag. 2023, doi: 10.1016/j.enconman.2023.116950.
[10] S. M. M. Ehteshami e S. H. Chan, «The role of hydrogen and fuel cells to store renewable energy in the future energy network – potentials and challenges», *Energy Policy*, vol. 73, pp. 103–109, ott. 2014, doi: 10.1016/j.enpol.2014.04.046.
[11] S. Griffiths, B. K. Sovacool, J. Kim, M. Bazilian, e J. M. Uratani, «Industrial decarbonization via hydrogen: A critical and systematic review of developments, socio-technical systems and policy options», *Energy Res. Soc. Sci.*, vol. 80, p. 102208, ott. 2021, doi: 10.1016/j.erss.2021.102208.
[12] O. Massarweh, «Blue hydrogen production from natural gas reservoirs: A review of application and feasibility», 2023.
[13] V. Vogl, M. Åhman, e L. J. Nilsson, «Assessment of hydrogen direct reduction for fossil-free steelmaking», *J. Clean. Prod.*, vol. 203, pp. 736–745, dic. 2018, doi: 10.1016/j.jclepro.2018.08.279.
[14] Y. Bicer e I. Dincer, «Clean fuel options with hydrogen for sea transportation: A life cycle approach», *Int. J. Hydrog. Energy*, vol. 43, fasc. 2, pp. 1179–1193, gen. 2018, doi: 10.1016/j.ijhydene.2017.10.157.
[15] U. Eberle, B. Müller, e R. Von Helmolt, «Fuel cell electric vehicles and hydrogen infrastructure: status 2012», *Energy Environ. Sci.*, vol. 5, fasc. 10, p. 8780, 2012, doi: 10.1039/c2ee22596d.
[16] hydrogencouncil, «Hydrogen Insights 2024», 2024.
[17] uropean Hydrogen Observatory, «The hydrogen landscape at a glance». [Online]. Disponibile su: https://observatory.clean-hydrogen.europa.eu/
[18] International Renewable Energy Agency (IRENA, «Global hydrogen trade».
[19] X. Shi, G. Wang, X. Wang, e B. Chen, «A Study on the Promoting Role of Renewable Hydrogen in the Transformation of Petroleum Refining Pathways», *Processes*, vol. 12, fasc. 7, p. 1317, giu. 2024, doi: 10.3390/pr12071317.
[20] «Hydrogen for heating: atmospheric impacts - a literature review».
[21] H. Zhou, J. Xue, H. Gao, e N. Ma, «Hydrogen-fueled gas turbines in future energy system», *Int. J. Hydrog. Energy*, vol. 64, pp. 569–582, apr. 2024, doi: 10.1016/j.ijhydene.2024.03.327.
[22] BloombergNEF, «New Energy Outlook 2024».
[23] Container Laboratory – ROFA. (n.d.). ROFA – Laboratory & Process Analyzers GmbH. Retrieved November 4, 2024, from https://www.rofa.at/products/container-laboratory/
[24] *A60 OFFSHORE MODULES*. (n.d.). Containers 271. https://www.271-containers.com/product/a60-offshore-modules/
[25] Modular construction. (n.d.). REM. Retrieved October 30, 2024, from https://rem.si/en/modular-construction/
[26] *Bosse - Cube 4.0 Dialogue & Designermöbel*. (n.d.). Architonic. Retrieved October 30, 2024, from https://www.architonic.com/de/product/bosse-cube-4-0-dialogue/20011693
[27] *Large Meeting Room*. (n.d.). High-Quality Modular Offices, Cleanrooms, & More | Allied Modular. Retrieved October 30, 2024, from https://alliedmodular.com/
[28] Lockers. (n.d.). https://www.theeducatoronline.com/k12/industry-news/civiq/new-lockers-protect-students-personal-belongings/248589

[29] Ganea, S. (2016, January 14). *Inspiring Office Meeting Rooms Reveal Their Playful Designs*. Homedit. Retrieved October 30, 2024, from https://www.homedit.com/office-meeting-room-ideas/
[30] Camera di Commercio di Mantova. (n.d.). Economia provinciale:sintesi. https://www.mn.camcom.gov.it/files/InformazioneEconomica/infografica_sunto_Mantova_2023(1).pdf
[31] Office Partition Walls - Glass Partitions. (n.d.). KNR Sliding Doors. Retrieved October 31, 2024, from https://knrslidingdoors.com/products/office-partition-doors/

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