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H2CE

Guidelines for the development of a hydrogen strategy or action plan

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Executive summary

Green hydrogen is often referred to as a key element in the transition to a sustainable energy system, playing a vital role in decarbonizing various sectors, including industry, transport, and energy. It is particularly essential for decarbonizing sectors that are difficult to electrify, such as heavy industry and long-haul transport. In addition, it can also be used as a storage solution for surplus electricity generated from renewable sources like wind and solar power. This supports the integration of renewable energy into the grid and helps stabilize the energy supply, even during periods of fluctuating renewable production caused by weather or seasonal changes.

Due to its numerous applications, green hydrogen is increasingly gaining attention from political authorities at global, national, and regional levels. However, its implementation remains in the early stages. While the financing prospects of the European energy transition are well prepared with a wide range of public and private funding, the implementation of green hydrogen is currently still in its initial stages. For example, it currently accounts for less than 2 % of energy consumption in Europe [1].

Important drivers of change could be the regions and public authorities, which are currently often mistakenly seen as primarily passive framework conditions in support materials, funding schemes, and even in research, which focus on the perspective of project owners and industry. This approach fails to recognize the valuable expertise and authority of these authorities and misses the opportunity to strengthen them as proactive drivers of change. As part of the H2CE project, this document provides **guidance on how regions can create a strategy** and an **action plan to actively integrate green hydrogen** and renewable energy into their local and regional energy planning.

The guidelines are introduced with an explanation of the potential of green hydrogen for enabling decarbonization across industries, transport, and energy sectors. Further, the project and the method are specified.

Subsequently, each step of the process “How to develop a Hydrogen Strategy and Action Plan” is divided into four phases:

- ***Phase 1 - Preparation and Analysis*:** This phase focuses on stakeholder engagement, conducting a regional analysis, and organizing a kick-off workshop. Subchapters offer guidance on effective stakeholder engagement and exploring various fields of action.
- ***Phase 2 - Strategy Development*:** In this phase, a vision is developed with stakeholder involvement, aligned with political targets and potential benefits. The strategy translates this vision into SMART (Specific, Measurable, Achievable, Relevant, Time-bound) targets and establishes indicators to track progress. Moderation of potential stakeholder conflicts is crucial. Subchapters provide guidance on identifying potential benefits and finding drivers and motivation.
- ***Phase 3 - Measure Planning and Action Plan*:** This phase begins by creating and evaluating measures, ensuring they do not conflict with one another. After prioritizing measures, an action plan is derived. The Subchapters explain the hydrogen value chain and provide guidance on how to select appropriate push and pull measures.
- ***Phase 4 - Implementation and Monitoring:*** This phase focuses on coordinating stakeholders, reviewing indicators, and adapting them as needed. The final step is to evaluate outcomes and extract lessons learned.

1. Introduction

Transitioning to green energy is essential for addressing climate change and building resilient, sustainable economies. Hydrogen produced through electrolysis holds significant promise due to its versatility. It can be used as an energy source for generating electricity and heat, as a crucial raw material in industrial processes, and as a clean fuel alternative in the transport sector. Nevertheless, it currently makes up **less than 2 % of Europe's energy use** [1].

At the European level, various guidelines exist to support the implementation of sustainable strategies across different sectors. Examples include the **Sustainable Urban Mobility Plans [2], the Urban Agenda for the EU [3], the Green Public Procurement [4], and the Renovation Wave [5].** Additionally, IRENA provides a guide for designing green hydrogen strategies, though it primarily targets national governments rather than regional authorities [6]. However, the literature reveals a significant gap: no comprehensive guidelines have been developed specifically to assist regions in integrating green hydrogen as a key technology for advancing the energy transition and achieving decarbonization. Such guidelines are critical for aligning regional efforts with the EU's climate goals, including attaining climate neutrality by 2050 and increasing the share of renewable energy sources in the overall energy mix.

This gap raises an important question: **What can regions proactively do to accelerate the integration of green hydrogen into their value chains?** To address this, the **objective is to develop comprehensive guidelines to enable regions to transition toward becoming "hydrogen-ready"**. These guidelines were created using modular approaches, drawing on prior experience from the H2CE project and enriched by a thorough review of existing literature.

The guidelines begin by introducing the H2CE project and its method in ***Chapter 2**: **About the project and method.*** The potential of green hydrogen as a transformative element in decarbonizing industries, transport, and energy sectors is explained in ***Chapter 3: Why Green Hydrogen?*** Hydrogen is essential for achieving decarbonization goals, integrating renewable energy sources, improving air quality, and reducing reliance on fossil fuels.

The framework for developing a Hydrogen Strategy and Action Plan is structured into four phases. The first phase, outlined in ***Chapter 5**: **Phase 1 - Preparation and Analysis***, focuses on initial groundwork and assessment. This involves engaging stakeholders, conducting a regional analysis, and organizing a kick-off workshop. Subchapters explore stakeholder engagement strategies and the identification of key fields of action. ***Chapter 6: Phase 2 - Strategy Development*** outlines the second phase, focusing on strategy formulation. Here, a vision is created in collaboration with stakeholders, derived from political targets and potential benefits. The strategy translates the vision into specific, measurable, achievable, relevant, and time-bound (SMART) targets, complemented by indicators to track progress. Moderation of potential stakeholder conflicts and the identification of benefits, drivers, and motivations are key components of this phase. The subchapters guide regions on how to identify potential benefits and find drivers and motivation. **Chapter 7: Phase 3 - Measure Planning and Action Plan**, focuses on designing measures and developing a structured action plan. Measures are created and evaluated for alignment, ensuring they do not conflict with existing objectives. Once prioritized, these measures form the basis of a comprehensive action plan. Subchapters provide insights into understanding the hydrogen value chain and selecting appropriate measures to balance incentives and regulations (pull-and-push). **Chapter 8: Phase 4 - Implementation and Monitoring**, *focuses on execution and progress tracking*. Stakeholders are coordinated, and indicators are reviewed and adapted as necessary. The process concludes with a review of outcomes to extract lessons learned, ensuring continuous improvement in strategy execution.

This structured yet flexible approach ensures regions have a clear pathway to effectively develop and implement hydrogen strategies.

2. About the project and method

The H2CE project **empowers** central European regions to **actively incorporate** green hydrogen and renewable energy in their local and regional energy planning. Current support materials understand public authorities primarily as passive framework conditions, focusing on the perspectives of project owners and industry. This approach lacks recognition of the valuable expertise and authority of public authorities, missing the opportunity to empower them as proactive drivers of change. H2CE recognizes the critical role of public authorities in the energy transformation. By equipping these authorities with tailored planning tools, the project aims to accelerate the deployment of hydrogen infrastructure and enhance the efficient use of resources. Key outcomes of the project include new mechanisms to **empower regional decision-make**rs in advancing a hydrogen-based energy transition, **creating a cross-regional and transnational network** of hydrogen-ready regions, and **implementing a digital collaboration platform** [1].

The partnership includes regions and partners from seven Central European countries: Berlin-Brandenburg (Germany), Pomorskie and Lower Silesia (Poland), Usti (Czech Republic), Styria (Austria), Euregio Tyrol, South Tyrol and Trentino (Austria/Italy), Emilia-Romagna and Veneto (Italy) as well as Zagreb and North-West Croatia (Croatia) and Slovakia.

The composition reflects the target groups of the project, namely:

(1) **all relevant stakeholders** such as regional policymakers including relevant authorities,
(2) **cross-sectoral stakeholders**, and
(3) **civil society actors** along the hydrogen value chain.

All partners are regional authorities or their representatives, ensuring effective coordination, development, and implementation of the project outcomes. Their commitment and authority are critical for driving the regional energy transition and advancing the hydrogen agenda.

Work package 1, H2-ready for European regional spatial planning and development (subsequently referred to as WP1), focuses on analyzing and addressing common challenges and solutions in planning and governance processes for regions transitioning to hydrogen readiness. The goal is to develop joint strategies and action plans from regional, transregional, and transnational perspectives.

Three districts in Berlin-Brandenburg will review the activities and outputs of WP1, integrating selected action fields at the regional level. The Regional Planning Community Prignitz-Oberhavel will **actively participate in networking** and **capacity-building initiatives** and **review spatial planning activities** to ensure alignment with regional needs. The structure of the kick-off workshop, conducted in ***Step 1 - Preparation and Analysis***, reflects a similar approach already applied in the region.

WP1, whose structure is shown in Figure 1, comprises two main components:

(1) A.1.1: **Planning the transition** in European regions - challenges and solutions in H2-ready regions.
(2) A.1.2: **Strategy and Action Plan Development**.

The component A.1.1 serves as the foundation for the outcomes of WP1. It begins with the creation of a jointly developed factsheet of common indicators. This factsheet addresses critical aspects such as regional planning activities, governance structures, acceptance, and spatial conditions for a coordinated H2 ramp-up in European regions. The primary target groups for this component are public bodies, including authorities and agencies. Regional partners have conducted analyses within their regions to identify potential, barriers, and challenges. The factsheet also forms the groundwork for identifying fields of action, analyzed during ***Step 1 - Preparation and Analysis***. The focus is on equipping medium- to advanced-stage hydrogen regions with tools to streamline planning procedures. The findings from A.1.1 will underpin the development of action plans and strategies, ensuring that regional efforts are well-aligned and effectively address identified challenges.

Component A.1.2 focuses on **creating action plans** and **strategies** to support the integration of green hydrogen into regional energy systems. This process builds on the experiences gained throughout the project and incorporates several essential elements. A foundational step was the development of the ***Factsheet of Common Indicators***, created through an iterative process.

Workshops conducted during the project provided valuable insights and served as a blueprint. A comprehensive literature review was also undertaken to analyze the structure of long-term planning processes for large-scale infrastructure projects and identify the critical steps involved. This framework was then tailored to the specific requirements and unique characteristics of green hydrogen.

In addition, existing guidelines and strategies that assist municipalities and regions in integrating green hydrogen into local value chains were critically examined and incorporated. The literature review was further enriched by expert insights and practical experiences gained during the project. These combined efforts ensure that the resulting guidelines are robust, contextually relevant, and practical for municipalities and regions.

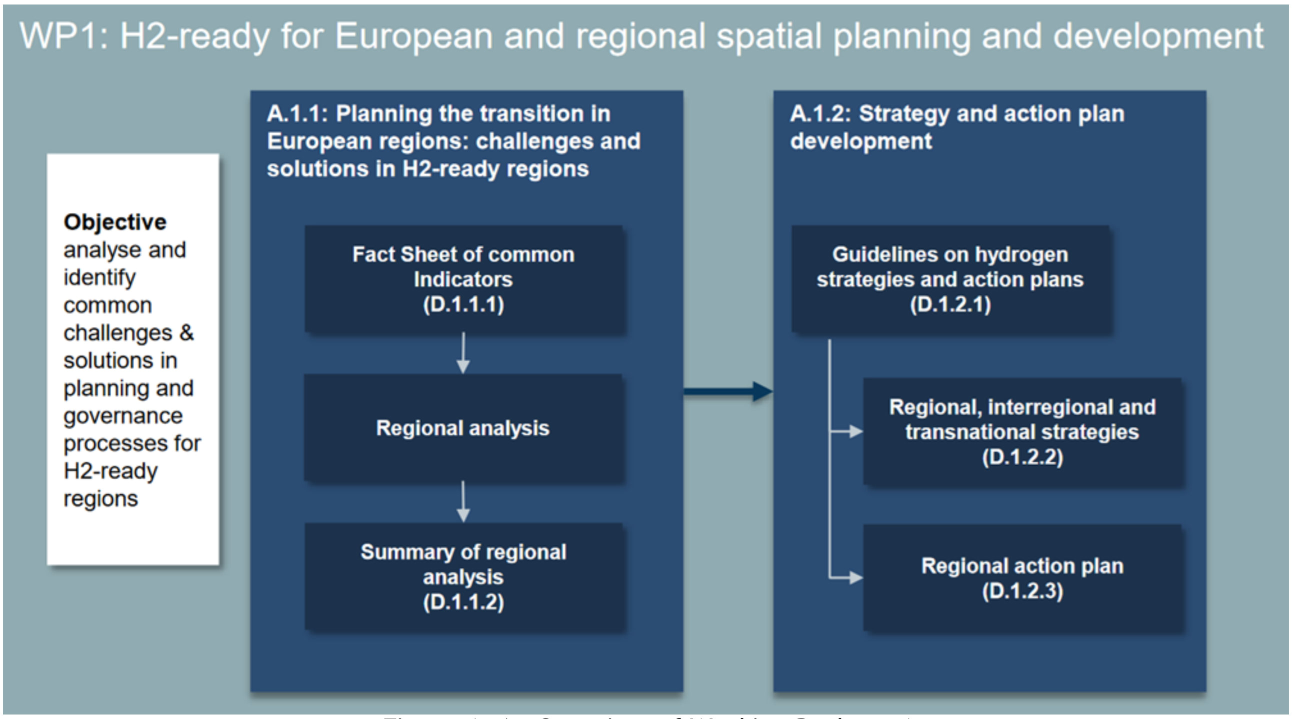

Figure 1: An Overview of Working Package 1

Various **outputs were created as part of the project**. The first was the Survey on Common Indicators, in which the individual regions received an Excel spreadsheet with multiple indicators on production, storage, distribution, demand, and governance. The demand area can be subdivided into industry, buildings, energy, transport, and general demand. The ***Regional Analysis*** was created on this basis. The **Guidelines** are a further project outcome.

3. Why Green Hydrogen?

To understand why a **green hydrogen strategy** is important, it is necessary to **understand the benefits** of green hydrogen. Often referred to as the **backbone of the transition to a sustainable energy system**, the energy carrier enables decarbonization across industries, transport, and energy sectors.

- Green hydrogen is essential for reaching **decarbonization goals**, particularly in sectors that are difficult to electrify, such as heavy industry and long-haul transport. It provides a clean energy alternative to fossil fuels, helping to significantly **reduce greenhouse gas emissions** and aligning with **global net-zero targets** [6].
- Green hydrogen supports the **integration of renewable energy** by **storing excess electricity generated** from sources like wind and solar. This long-term storage capability ensures a stable and efficient energy supply, even when renewable production fluctuates due to weather or seasonal changes [7]. By replacing fossil fuels in vehicles and industrial processes, green hydrogen **eliminates harmful emissions**, including emissions of particulate matter, nitrogen and sulfur oxides, and benzo(a)pyrene.
- This transition **contributes to better air quality**, especially in urban areas, improving public health and creating cleaner cities [6]. Green hydrogen **reduces reliance on fossil fuels** by offering an alternative energy source derived from renewable resources. This shift decreases dependency on volatile fossil fuel markets, enhances **energy security**, and supports a **more sustainable and resilient energy system** [7].
- The green hydrogen sector can **stimulate economic growth** by fostering innovation, **creating jobs** in renewable energy and hydrogen technology sectors, and **supporting industries** like electrolyzer manufacturing, infrastructure development, and logistics [8].

4. Developing a Hydrogen Strategy and Action Plan

As outlined in Figure 2, the framework for developing a hydrogen strategy and an action plan provides a structured and iterative process for planning, implementing, and monitoring a green hydrogen economy. The process is divided into four phases:

1. ***Preparation and Analysis***, including stakeholder engagement, regional framework analysis, and conducting an initial kick-off workshop.
2. ***Strategy Development***, where drivers and motivations are identified, targets are defined, indicators are derived, and potential conflicts are clarified.
3. ***Measure Planning and Action Plan***, where measures are created and evaluated, conflicting objectives are identified, and an action plan is set up.
4. ***Implementation and Monitoring***, which includes coordinating stakeholders, checking indicators, and adapting them if necessary, as well as reviewing the outcome and learning from it.

The framework is designed **to help regions accelerate and enhance their transition to a sustainable, hydrogen-based energy system**. While the **guidelines provide a structured approach**, they are flexible and can be adapted to meet the specific needs of each region. This represents an innovative approach, empowering regional public authorities to take the lead in hydrogen deployment.

Regional authorities occupy a unique and pivotal sandwich position, **balancing national and European policy objectives with the interests of investors.** Their role is critical in ensuring the smooth and effective implementation of the energy transition.

Figure 2: A Step-by-Step Framework for Developing a Hydrogen Strategy and Action Plan

5. Phase 1 - Preparation and Analysis

The initial phase of the framework emphasizes the importance of establishing a strong foundation through preparation, analysis, and exchange, which involves three steps.

1. The first step in setting up a Hydrogen Strategy and Action Plan involves **identifying and engaging stakeholders from government, industry, and academia.** These may include renewable energy producers, hydrogen electrolyzer manufacturers, transport infrastructure operators, and end users in the industrial and mobility sectors. As regions consolidate their investments, they must navigate a complex landscape of stakeholders from various projects that may align, diverge, or even conflict with one another. This highlights the critical role of regional actors and public authorities in harmonizing, managing, and integrating these activities into cohesive regional strategies, planning, and development efforts. However, regional players often **lack the capacity, expertise, strategy, processes, and necessary information** to adopt this role effectively, particularly when it comes to **understanding the broader context**, such as the horizontal integration of planning. This refers to how a region's plans and activities align with those of neighboring or cross-border regions. To address these challenges, *Chapter 4.1* provides detailed guidance on stakeholder engagement strategies to ensure a successful and inclusive planning process.

2. The next step in the process involves **analyzing the regional framework to establish a strong foundation for developing a hydrogen strategy**. Key topics to address include hydrogen production, storage, distribution, demand, the existing hydrogen-related infrastructure, and national and regional governance targets. Regions should **carefully define their current status,** as this is crucial for **effective planning**. Various approaches can be used to conduct this analysis, one of which is detailed in *Chapter 4.2*. This chapter outlines fields of action, explains their relevance, and provides guiding questions for regions to consider and discuss. This **framework is flexible** and can be tailored to each region's specific context, as not all aspects will carry the same weight in every case. If sufficient capacity and expertise are available, the initial analysis can be further enriched by developing scenarios to explore potential future pathways. A scenario-based approach allows regions to model various possibilities, considering factors such as renewable energy capacity, technological advancements, and projected hydrogen demand. By collaboratively evaluating these scenarios, **stakeholders can build a shared understanding of the opportunities and challenge**s ahead, providing a **solid foundation for a well-coordinated strategy.**

3. The final step of the first phase is to **conduct an initial kick-off workshop**, bringing together the identified stakeholders to **share knowledge, brainstorm ideas, identify resources, and allocate initial responsibilities.** Careful preparation is essential, and regions have the flexibility to tailor the workshop's content to their specific needs. A possible structure could begin with one or more thematic presentations, offering an overview of the results from the first analysis or highlighting key aspects of the regional hydrogen economy and value chain. Subsequently, a discussion can be held to gather stakeholder input on regional needs, production opportunities, new projects, and infrastructure development. This structured approach **encourages targeted and collaborative dialogue, ensuring that all participants are aligned and invested** in the process from the outset.

5.1. Stakeholder Engagement - Getting It Right from the Beginning

Engaging stakeholders effectively presents several challenges for regions. The first step **is identifying the right stakeholders before actively and constructively involving them**. To facilitate this, **stakeholders should be classified systematically** [6]. One possibility for classification is the *Eden and Ackerman Matrix*[1], which categorizes stakeholders **based on their levels of interest and power**. It is divided into four quadrants, each representing a distinct type of stakeholder [9]. The matrix can be found in Figure 2.

Subjects (High Interest, Low Power): These stakeholders are highly interested in the hydrogen economy but have limited influence over political or economic decisions.

- **Scientific research institutes and universities** possess high expertise but have limited power to influence political decisions.
- **Environmental and non-governmental organizations** campaign for a sustainable and just energy transition but have no direct influence on legislation or investment decisions.
- **Small hydrogen start-ups** develop and launch innovative technologies but often lack the financial resources or political connections to implement large-scale projects and influence decision-making processes.

Players (High interest, Substantial power): These stakeholders have a strong interest in the hydrogen economy and the ability to shape political and economic decisions.

- **Governments, ministries, and supranational organizations** set funding policies, regulations, and the legal framework.
- **Large energy companies and grid operators** develop and operate hydrogen infrastructure, investing in large-scale projects.
- **Automotive manufacturers and industrial corporations,** such as Daimler, Bosch, and Siemens Energy, utilize hydrogen for mobility and industrial processes.

Context Setters (High Power, Low Interest): These stakeholders have significant influence over the development of the hydrogen economy but are not directly engaged.

- **Financial institutions and investors** decide on large-scale investments but often prioritize economic viability over climate goals.
- **Citizen initiatives and local resident groups** can block or support infrastructure projects even if they are not directly interested in hydrogen projects. Their concerns are usually focused on local impacts.
- **Large chemical and oil corporations** may invest in hydrogen but often prioritize traditional fossil energy sources.

Crowd (Low interest and minimal power): This group has neither a strong interest in nor significant influence over the hydrogen economy.

- **General public**: Many citizens lack knowledge regarding hydrogen.
- **Small and medium-sized enterprises** that are not involved in the hydrogen value chain: SMEs that neither benefit from nor are affected by hydrogen development.

[1] The Eden and Ackerman matrix is a useful tool for initial stakeholder mapping, but it has limitations. By focusing only on influence and interest, it may oversimplify complex relationships, overlook evolving dynamics, and fail to capture stakeholder interdependencies. Subjective biases in assessing influence and interest can also lead to inaccuracies. Despite this, the matrix provides a helpful starting point for stakeholder engagement [6].

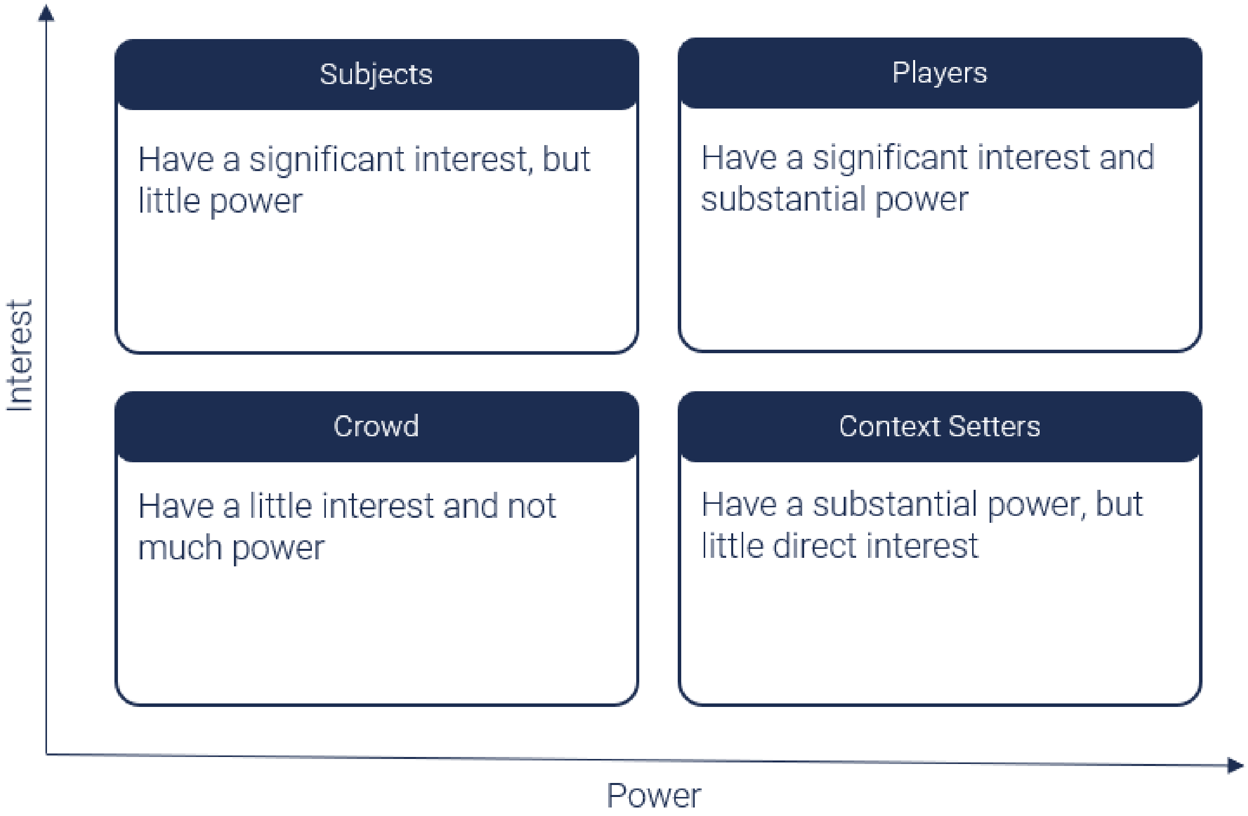

Figure 3: The Eden and Ackerman Matrix [9]

Best-Practice Example Chile [6]

A best-practice example of engaging stakeholders can be taken from Chile, where stakeholders were approached through a **structured** and **inclusive framework** as part of the green hydrogen strategy. Subjects were consulted on strategy design and encouraged to provide feedback. **Players** were **actively involved in consultations and decision-making** processes, contributing to the strategy's development. For these stakeholders, it is crucial to ensure top-level **support from the beginning**. Efforts to engage the non-engaged focused **on raising awareness** and **increasing their involvement**, while influencers were kept informed, consulted for input, and motivated to participate more directly.

After figuring out, who should be involved, it is also important to point out the potential benefits for the stakeholders, to motivate and convince them to participate in the process.

5.2. Laying the Groundwork - Analysing Fields of Action

Following the stakeholder analysis, it is essential to address key topics such as **hydrogen production, storage, distribution, national and regional policies and targets,** and the **current state of hydrogen-related infrastructure.** These topics form the foundation for the kick-off workshop. There are various approaches to conducting this analysis. One method is to examine specific *fields of action*: production, storage, distribution, demand, and governance. The demand field can be further broken down into industry, buildings, power, transport, and general demand. For each field, a brief explanation of its relevance is provided, along with key questions that regions might consider raising and answering. This approach enables regions to **identify critical issues, prioritize key topics, and deepen their understanding** of the hydrogen landscape.

Production, Distribution, and Storage

Production: The production of hydrogen serves as the backbone of any hydrogen strategy, especially when focusing on green hydrogen derived from renewable sources. Regions should raise critical questions about the current and potential hydrogen production capacity within a region:

Existing Production Sites	Are there operational hydrogen production facilities in the region? If so, what is their installed capacity in megawatts? Is there currently any larger hydrogen storage installed?
Production Pathways	What hydrogen production methods are currently in use or planned in your region? Are renewable energy-based methods, such as electrolysis, being utilized or explored? Are technologies like pyrolysis, plasma pyrolysis, natural hydrogen, or steam reforming with or without carbon capture being considered?
Future Opportunities	What potential exists to scale hydrogen production, and how does this align with regional renewable energy availability?[2]
Plans and Targets	What are the 2030 and 2050 plans and targets regarding preferred hydrogen production, the installed solar and hydropower production capacity, and wind energy?
Environmental conditions	Are there environmental issues such as water stress?

Storage: Hydrogen storage is essential for managing fluctuations in production and demand, ensuring a stable supply chain. Subsequent points should be analyzed:

Existing Storage Facilities	Are there large hydrogen storage systems, such as underground salt caverns in the region? What type of storage is planned? What are the goals for installed storage capacity by 2030 and 2050?
Regional Storage Capacity	What is the current storage capacity in the region, and is it sufficient to handle peak demands or seasonal variations? Does the region's industrial demand require more extensive storage solutions compared to regions with smaller-scale usage?

[2] For example, wind or solar energy could be coupled with electrolysis to utilize surplus renewable energy and enhance grid stability

Future Needs	How much additional storage will be needed to scale hydrogen adoption? What technologies, such as liquid hydrogen storage, can be deployed to meet future requirements?

Distribution: Efficient hydrogen distribution ensures that production sites are well-connected to end-users in the industry, transport, or power sectors. The region could focus on:

Hydrogen Refueling Stations	Are there hydrogen refueling stations currently in operation in the region?
Pipelines and Transport Methods	Does the region have existing hydrogen pipelines or is hydrogen transported via trucks or rail? [3]
Challenges in Expanding Networks	What are the main barriers to expanding hydrogen distribution in the region? How can challenges like the high investment costs of pipelines or regulatory approvals be addressed? What strategies can connect hydrogen production hubs with users across sectors?

Demand

Industry: The industrial sector is one of the largest potential consumers of hydrogen, particularly in decarbonizing processes like steelmaking and chemical production, also known as *"no-regret" applications*. Regions should consider:

Industrial Users	Are there industries in the region, such as ammonia or methanol production, that currently use hydrogen? Are there industries planning to transition to hydrogen in the near future? Could these industries drive significant hydrogen demand due to their high energy needs and reliance on hydrogen as a feedstock?
Decarbonization Potential	What opportunities exist for replacing fossil fuels with hydrogen in industrial processes?[4]

Buildings: The use of hydrogen in buildings is less common, but in some cases and under certain conditions, its use for heating could present an opportunity for the regional hydrogen economy. Important points are here:

Hydrogen for Heating	Are there plans to integrate hydrogen into residential or commercial heating systems?[5]
Alternative Heating Options	How does hydrogen compare to other low-carbon heating solutions, such as heat pumps or district heating systems?

[3] While pipelines are efficient for large-scale distribution, trucks offer flexibility for smaller quantities.

[4] E.g. green hydrogen could replace coal in steelmaking through direct reduction, significantly reducing CO_2 emissions.

[5] For instance, hydrogen can be blended into existing natural gas grids to reduce emissions in heating applications.

Power: Hydrogen's role in the power sector includes energy storage and renewable electricity integration. Key points include:

Power Storage	Is hydrogen being considered to store surplus electricity from renewables and supply it during periods of low generation to ensure grid stability?
Power Plants	Does the region plan to use hydrogen in gas turbines or combined heat and power plants to replace natural gas?

Transport: The transport sector is a major focus for hydrogen adoption, especially in long-haul and heavy-duty applications. Highlighted questions are:

Transport Hubs	Does the region have major transportation hubs, such as airports or ports, that could integrate hydrogen?
Refueling Infrastructure	What plans exist for hydrogen refueling stations, and how will they cater to trucks, buses, and other heavy-duty vehicles?

General Demand: Estimating and understanding hydrogen demand is critical for planning infrastructure and scaling production. The subsequent questions could address:

Import, Export, or self-sufficient	Does the region plan to import or export hydrogen or is it planning to meet its demand with local production?

Governance and Infrastructure

Governance plays a central role in coordinating hydrogen initiatives and ensuring alignment among stakeholders. Questions are here:

Policymaker Engagement	How knowledgeable are regional policymakers about hydrogen technologies and their potential?
Incentives and Regulations	Are there policies or financial incentives that encourage hydrogen adoption?

Infrastructure: The development of hydrogen infrastructure underpins the entire hydrogen value chain. Key questions include:

Existing Infrastructure	What hydrogen infrastructure, such as pipelines or storage facilities, is already in place? Is there a harbor in your region? Where are the gaps and opportunities for optimization?
Future Infrastructure Needs	How will infrastructure expand to meet future hydrogen demand across sectors, considering planning timelines, funding sources, and logistical challenges to ensure accessibility and scalability?
European Hydrogen Backbone (EHB)	Will your region be reached by the European Hydrogen Backbone (EHB)?

5.3. Initial Kick-Off Workshop

There are **several ways** to conduct **kick-off workshops**. One effective method can be a **focused workshop**, which follows a **structured approach** designed to address a specific topic or challenge in a targeted way. A focused workshop is a key tool for bringing together relevant stakeholders, facilitating discussions, and generating concrete solutions.

Characteristics of a focused workshop in the hydrogen sector are:

- The workshop is **dedicated to a clearly defined issue**, such as regional hydrogen infrastructure, market integration, or policy frameworks.
- **Targeted stakeholders,** such as experts, policymakers, industry representatives, and local authorities **participate**.
- The workshop uses **interactive methods**, such as structured brainstorming, scenario analysis, group discussions, and collaborative planning, to generate actionable insights.
- The primary goal is to **develop concrete recommendations and solutions** for the hydrogen strategy and the action plan.
- The discussion is **guided by a moderator**, ensuring a structured and results-driven process.

When applied to a Hydrogen Strategy and Action Plan Development, **possible focus areas** could be:

- Assessing **regulatory frameworks and legal requirements** for hydrogen projects.
- Defining **regional infrastructure needs**, such as pipeline networks, electrolyzer locations, and storage facilities.
- **Engaging key industry players** to understand hydrogen demand in sectors like heavy industry, mobility, and power generation.
- Developing **funding strategies** by identifying available subsidies and investment opportunities.
- **Enhancing public acceptance** by incorporating societal and environmental perspectives into hydrogen planning.

After the initial kick-off workshop, it is important **to keep in touch with the participants**, for instance by following up with individual participants to refine specific ideas or keeping the stakeholders informed through a newsletter.

Best-Practice Example Prignitz-Oberhavel

One best-practice example comes from the Prignitz-Oberhavel region in Brandenburg, Germany. The region conducted a focused **workshop to discuss the key issues** related to the hydrogen economy. The workshop was organized in collaboration with a research institute (Reiner Lemoine Institut), the local hydrogen network (PrOOH2V Netzwerk), and the regional planning department (Regionale Planungsgemeinschaft Prignitz-Oberhavel). The goal was to **provide thematic input and identify opportunities and challenges** for the regional hydrogen economy and infrastructure to create an action plan.

At the beginning of the workshop, the Reiner Lemoine Institute provided thematic input on the current legal framework, the developments of the Hydrogen Core Network, and the Network Development Plans for Gas and Hydrogen. In particular, the presentation focused on the current infrastructure development and network expansion. The amendment of the German Energy Industry Act (EnWG), which introduces integrated planning for gas and hydrogen networks for the first time, was discussed, focusing on how regional demands can be incorporated.

Another key point was the decision to exclude the "Doing Hydrogen" pipeline from the final Hydrogen Core Network and its implications for regional infrastructure planning. The “Doing Hydrogen” Pipeline was included in the draft of the Hydrogen Core Network and was supposed to connect the region with the national network.

Following this introduction, an interactive workshop session was held, during which key questions regarding regional hydrogen infrastructure were discussed. The discussions focused on the aspects below:

- **Hydrogen Core Network and Regional Connectivity**: Participants examined how hydrogen projects can be implemented outside of the “Doing Hydrogen” Pipeline.
- **Network Development Plan for Gas and Hydrogen**: The discussion addressed how companies and municipalities can be involved early in the planning process to report their demands in time and ensure their needs are considered in the Network Development Plan.
- **Funding Opportunities and Economic Conditions**: The current funding landscape for hydrogen projects in Brandenburg was presented and evaluated in terms of its applicability to the region.
- **Future Demand and Potential Applications**: Industrial and commercial sites with potenial hydrogen demand were identified to ensure that regional demand sources are mapped early.

At the end, an outlook on the next steps was given. The workshop facilitated a targeted exchange between regional stakeholders and served as a practical example of structured stakeholder engagement. The results of the discussions will be incorporated into the ongoing regional planning processes and contribute to the further development of the regional hydrogen action plan.

6. Phase 2 – Strategy Design and Development

The second phase focuses on **formulating a clear vision** and a strategy that aligns with the overarching **goals of transitioning to a green hydrogen economy**.

1. Building on the insights from the first phase, stakeholders collaborate to **develop a shared vision** aligned with the goals of the energy transition, such as achieving net-zero emissions or decarbonizing hard-to-abate sectors like steel production and heavy transport. This vision can be shaped through discussions or via an online process. Regions may begin by **drafting a strategic outline** to provide a foundation, which can then be refined through a participatory consultation with stakeholders. When creating a vision, two key aspects are crucial. First, it should **align with political targets and legislation**. Political targets refer to the *fields of action*, such as *Production*. An example can be taken from the German Hydrogen Strategy, which sets a national expansion target for electrolysis capacity of at least 10 GW by 2030 [10]. Second, it should **emphasize the benefits that act as drivers of change**, fostering intrinsic motivation among stakeholders. *Chapter 5.1* delves deeper into the specific benefits for regions, providing insights to inspire and motivate action.
2. After examining benefits, motivations, political targets, and legislation, a strategy can be developed to **translate the vision into concrete targets**. These strategies may address specific sectors or fields of action. Success relies on defining targets that are specific, measurable, achievable, relevant, and time-bound (SMART). For instance, regions might set targets for increasing the installed capacity of hydrogen electrolyzers or reducing the cost of green hydrogen production to a competitive level. These targets should be complemented by the establishment of indicators to track progress over time.
3. At this stage, stakeholder engagement is crucial for fostering consensus and aligning diverse interests. Potential **conflicts must be identified** and effectively moderated. Conflicts may arise between hydrogen consumers such as transport operators and industrial manufacturers, but also between business models and political strategies or even among different political strategies. By **facilitating open dialogue**, the strategy development phase ensures that these **diverse priorities** are **harmonized**, integrating the various components of the hydrogen value chain into a cohesive and actionable plan.

6.1. Develop a Vision - Defining the Strategic Role and Milestones

When developing a hydrogen strategy, regions should define a clear, long-term vision. This vision outlines the strategic role hydrogen is expected to play in achieving climate neutrality, industrial transformation, and energy security. The vision typically balances ambition and realism, aligns with broader climate goals, and positions the region for competitiveness in emerging hydrogen markets.

Best-Best Practice Example European Union [11]

The European Union provides a strong example of how regions can formulate a clear and ambitious hydrogen vision. In its Hydrogen Strategy, the EU defines hydrogen as a key driver of **decarbonization in industry, transport, power generation**, and **buildings.** It highlights hydrogen's role in addressing sectors where emission reductions are particularly urgent and difficult to achieve and securing the supply with renewable energies by enabling storage solutions for seasonal fluctuations. The EU's vision extends toward 2050, with renewable hydrogen expected to be deployed at a large scale across all hard-to-abate sectors.

This example demonstrates how regions can set long-term goals, identify lead markets and priority sectors. A formulated vision serves as the foundation for defining concrete, measurable targets.

The European Union demonstrates this approach by **translating its hydrogen vision into specific milestones:**

- By **2024:** at least 6 GW of electrolyzer capacity and up to 1 million tonnes of renewable hydrogen produced annually.
- By **2030:** expansion to at least 40 GW of electrolyzer capacity, production of 10 million tonnes of renewable hydrogen per year, and an additional 10 million tonnes imported.
- By **2050:** full integration of renewable hydrogen into all hard-to-abate sectors, with hydrogen growing to 13-14% of total EU energy mix.

This example illustrates how a strategic vision can be operationalized through time-bound milestones, enabling regions to measure progress and align efforts across sectors and stakeholders.

6.2. Potential Benefits - Find Drivers and Motivation

Designing and developing a hydrogen strategy should not only be done to achieve political goals, but it is also essential for driving economic growth, enhancing energy security, and promoting environmental sustainability. As the global energy landscape transitions to cleaner alternatives, regions with **a clear and comprehensive hydrogen strategy** will be **better positioned** to capitalize on this shift. Green hydrogen, produced from renewable energy sources, offers a zero-emission alternative to fossil fuels, significantly reducing greenhouse gas emissions and improving air quality. By integrating hydrogen into their energy systems, regions can align with climate goals, foster cleaner industries, and advance sustainable transportation.

- A well-defined hydrogen strategy **provides businesses with stability**, which is needed for long-term planning and investment. Clear policies, incentives, and infrastructure frameworks **reduce uncertainty, encourage investment in hydrogen technologies, and stimulate innovation.** This positions regions as leaders in the emerging hydrogen economy, attracting further investment and creating opportunities for economic growth.

- Hydrogen also optimizes the **use of locally produced renewable energy** by converting surplus wind, solar, or hydropower into hydrogen for storage and later use. This **maximizes the value of renewable resources, balances energy supply** and **demand, and ensures reliability during periods of low renewable generation**. By diversifying the energy mix, hydrogen reduces dependence on single energy sources, enhances energy security, and mitigates risks from supply disruptions or market volatility, **contributing to a resilient and balanced energy system**.
- Additionally, developing hydrogen infrastructure and industries **drives economic growth and job creation** in manufacturing, construction, engineering, and research. A robust hydrogen strategy aligns regions with national and international climate policies, unlocking **funding opportunities** and accelerating the **implementation of hydrogen projects**.

6.3. Potential Conflicts - Identification, Moderation and Solutions

Potential conflicts must be **identified** and effectively **moderated.** For instance, transport operators and industrial manufacturers may have differing priorities: transport operators might prioritize investments in hydrogen infrastructure, such as refueling stations, to decarbonize mobility, while industrial manufacturers may focus on securing a stable and affordable hydrogen supply for production processes. Besides **hydrogen consumers**, **conflicts between business models and political strategies** may arise. Energy producers, for example, may prioritize the export of green hydrogen to international markets where demand and subsidies are higher, while political strategies may advocate for prioritizing domestic hydrogen supply to ensure price stability and energy security. Additionally, **conflicts with other political strategies** need to be considered. One example is the potential conflict between hydrogen and electrification: Regions and governments may promote direct electrification (e.g., battery-electric vehicles and heat pumps) as the primary decarbonization strategy, potentially limiting support for hydrogen infrastructure. This could lead to competition for funding between hydrogen refueling stations and electric vehicle charging networks. A possible solution is a **sectoral approach**, where hydrogen is primarily used in areas where direct electrification is inefficient (e.g., heavy industry, long-haul transport) and electrification remains the focus for light-duty vehicles and residential heating.

Best-Practice Example Austria [14]

A best-practice example can be found in Austria, where the national hydrogen strategy emphasizes the integration of hydrogen within a broader decarbonization framework, ensuring efficient energy use. Under this approach, hydrogen is prioritized for applications where direct electrification is not viable or economically feasible. Specifically, the strategy focuses on:

- **High-temperature industrial processes**, where hydrogen can replace fossil fuels in energy-intensive production.
- **Applications in the transportation sector that cannot be electrified**, such as aviation and shipping. Synthetic fuels and e-methane are also considered complementary options in the medium term.
- **Non-energy uses of hydrogen**, including its role as a chemical feedstock or a reducing agent in industrial processes, supporting the transition from fossil-based value chains.

Consequently, hydrogen is **not promoted for applications** where more efficient **electrification alternatives exist**, such as light-duty vehicles and residential heating. This targeted approach ensures that hydrogen is deployed where it delivers the greatest system-wide benefit.

7. Phase 3: Measure Planning and Action Plan

The third phase focuses on **translating the vision and strategy** into concrete measures and creating an action plan.

1. **Designing integrated measures** that address multiple aspects of the hydrogen value chain can be helpful, as further explained in *Chapter 7.1*. **Each measure should be carefully evaluated** for feasibility, cost-effectiveness, and potential impact, as further described in *Chapter 7.2*. Subsequently, measures should be prioritized by consistently aligning them with the overarching vision and strategy. This **ongoing evaluation** ensures that the most impactful measures are selected to achieve the targets established in earlier steps. It is crucial to **involve stakeholders** when compiling and choosing the relevant measures.
2. Measures must be thoroughly **checked for potential conflicts between objectives**. For example, tensions may arise between cost considerations and climate goals, as green hydrogen is currently more expensive than hydrogen derived from natural gas. Once evaluated, the **measures are consolidated into an action plan** and **each measure is linked to specific targets**. The final action plan should include a **balanced mix** of regulations and incentives, also referred to as *push and pull measures*, tailored to accelerate hydrogen adoption by addressing the unique needs and resources of the region. Additional guidance on balancing push and pull measures is provided in *Chapter 7.3*.
3. **Financial planning and securing funding** are crucial components of this phase. It is essential to identify potential funding sources (such as public subsidies, private investments, or international grants) to ensure the implementation of the planned measures. The measure-planning phase translates strategic ambitions into a concrete roadmap by securing funding and financing.

7.1. Understanding the Hydrogen Value Chain

Regional public authorities are pivotal in advancing a sustainable hydrogen economy by addressing every aspect of the green hydrogen value chain, from production and distribution to utilization. A comprehensive understanding of each step in the value chain, as illustrated in Figure 3, is essential for fulfilling this role. Simultaneously, authorities must **prioritize** key elements of **regional development**, including **education, network building**, and the establishment of **supportive legislation**, to create a robust foundation for hydrogen integration.

The ***Production section*** outlines various methods for hydrogen generation. Renewable hydrogen production, which utilizes energy from renewable sources such as wind or solar, results in emission-free hydrogen. Another approach is fossil-based hydrogen production with carbon capture and storage (CCS), which relies on fossil fuels but mitigates emissions through CCS technology. Additionally, the transformation of hydrogen into chemical compounds or synthetic fuels is discussed, showcasing its versatility for use in a range of applications.

The ***Distribution & storage section*** explores various methods for **storing** and **transporting hydrogen**. On the one hand, distribution by pipeline is expensive to build, but on the other hand, it is highly efficient for large-scale transport. **Transport by ship, though more flexible, incurs higher energy losses.** Additionally, **truck distribution is only suitable for smaller-scale deliveries**. Efficient distribution systems are vital for the widespread adoption of green hydrogen. Regional authorities can play a crucial role in facilitating infrastructure development by **funding pilot projects** and **fostering public-private partnerships. Upgrading existing natural gas pipelines and building hydrogen-specific pipelines** are both viable options, with upgrades **preferred when feasible and cost-effective**. Hydrogen storage systems are also highlighted as critical for balancing supply and demand fluctuations. Establishing **regional storage and distribution hubs** can further optimize logistics and **reduce transportation costs**.

The ***Demand section*** highlights the versatility of hydrogen across various sectors. In industry, hydrogen serves as a feedstock or provides high-temperature process heat. Notably, "*no-regret*" applications include steel production, refining processes, and chemical manufacturing. In mobility, hydrogen can be utilized **across multiple transport modes, including road, rail, aviation, and maritime applications**. Hydrogen-based fuels such as ammonia and synthetic jet fuel are promising for reducing emissions in aviation and shipping. Hydrogen-powered fuel cell vehicles offer **longer ranges and faster refueling times compared to battery-electric vehicles**. Regional authorities can drive adoption by incentivizing hydrogen-powered public transport, expanding refueling infrastructure, and incorporating hydrogen technologies into municipal operations. Hydrogen is also presented as a sustainable solution for building heating, providing a **clean energy alternative** for **residential and commercial use**. Furthermore, in power generation, hydrogen plays a role in stabilizing the grid and meeting energy demands. It can be used in fuel cells or combustion turbines to generate electricity, further supporting the transition to a clean energy future.

Figure 4: The Hydrogen Value Chain [12]

Regional public authorities can build a resilient hydrogen ecosystem by **addressing the entire value chain** of green hydrogen. By **supporting production**, **optimizing distribution**, **promoting diverse applications**, and **prioritizing education**, **network-building**, and **legislation**, regions can unlock economic growth while advancing environmental sustainability. A comprehensive strategy positions regions as leaders in the transition toward a **clean** and **resilient** hydrogen economy.

7.2. Creating a measurement catalogue

The following sub-chapter lists potential measures as examples. They are derived from *Germany's National Hydrogen Strategy* [13] and serve as inspiration for regional implementation across Europe. All measures are to be understood as examples and must always be assigned to responsible stakeholders for concrete realization.

Production

Measure	Description	Push/Pull	Responsibility
CO2 pricing for fossil fuels in transport and heating	Improved framework conditions for the efficient use of renewable electricity	Push	Policymakers
Support for pilot projects	Exploration of new business and cooperation models between electrolysis operators and grid operators	Pull	National and regional funding
Promotion of electrolyzer deployment	Support through targeted innovation and decarbonization funding programs	Pull	Economic development institutions
Identification and designation of suitable areas for offshore hydrogen production	Offshore wind energy is ideal for hydrogen production due to high full-load hours	Pull	Spatial planning authorities
Support for offshore wind parks for hydrogen production	Creates investment incentives and increases production capacity for green hydrogen	Pull	Permitting authorities
Cooperation with grid operators to develop flexible business models	Enables grid relief and increases efficiency through coordination of electrolysis and electricity grids	Pull	Policymakers & network operators

Transport & Storage

Measure	Description	Push/Pull	Responsibility
Planning of import terminals and logistics hubs	Supports international hydrogen imports and efficient regional distribution	Pull	Port authorities transport planning
Integration of hydrogen pipelines into existing infrastructure	Utilizes and repurposes existing gas grids to save costs and time	Pull	Gas network operators & infrastructure planners

Industry

Measure	Description	Push/Pull	Responsibility
Support for pilot projects in the steel and chemical industries	Accelerates market ramp-up through large-scale demonstration of climate-neutral production processes	Pull	Industry & economic development institutions

Mobility

Measure	Description	Push/Pull	Responsibility
Introduction of ambitious emission reduction quotas	Stimulates demand for renewable fuels in the transport sector	Push	Policymakers
Establishment of test sites for hydrogen-based aviation and shipping	Enables testing and scaling of new applications in aviation and maritime transport	Pull	Airports and port authorities

Electricity

Measure	Description	Push/Pull	Responsibility
Support for H2-ready power plants	Increases security of supply and flexibility in the electricity system	Pull	Energy suppliers & agencies

Research & Innovation

Measure	Description	Push/Pull	Responsibility
Promotion of pilot and demonstration projects for hydrogen technologies	Facilitates technology transfer from research to practice	Pull	Research institutions

International Cooperation

Measure	Description	Push/Pull	Responsibility
Establishment of partnerships for hydrogen imports	Secures supply and supports diversification of international markets	Pull	Development agency

7.3. Evaluation of Measures

All proposed actions should be systematically evaluated based on their impact, feasibility, and cost-effectiveness to ensure that the selected measures are the most effective and practical.

1. Assessment of **Impact** on the Hydrogen System

- Evaluate how each measure influences hydrogen demand, supply, and infrastructure development.
- Assess the potential effects on the overall energy system, including interactions with electricity grids, renewable energy sources, and industrial decarbonization.
- Identify synergies and trade-offs between hydrogen and other energy transition pathways, such as direct electrification.

2. Prioritization Based on **Key Criteria**

- Measures should be assessed based **on their effectiveness** (alignment with climate and energy targets), **acceptance** (stakeholder and regulatory approval), and **cost-efficiency** (economic viability).
- A **structured evaluation process**, such as a multi-criteria analysis, can be used to compare different options.
- **Expert assessments** may be conducted, in which stakeholders from different fields (e.g., infrastructure planning, industry, and finance) rate measures based on their expertise.
- **Online tools** such as energy system modeling platforms or hydrogen roadmaps can support the objective evaluation.

3. **Feasibility Analysis**

- Analyze the **technical and financial feasibility** of each measure, ensuring that all cost factors are accounted for, including infrastructure, equipment, regulatory compliance, and operational costs.
- Ensure that both hydrogen production and distribution aspects are considered, including transport options such as pipelines, trucks, and storage solutions.
- **Consider regulatory barriers** and necessary permits for project implementation.

4. **Prioritization and Refinement** of Measures

- Based on the evaluation results, **filter out the most promising measures** that align with long-term hydrogen deployment goals.
- Provide a **detailed specification of selected measures**, including implementation timelines, responsible entities, and key stakeholders.

5. **Cost Analysis and Financial Planning**

- Develop **detailed cost estimates for each measure**, covering infrastructure development, stakeholder engagement, equipment, operational expenses, and necessary studies.
- **Engage financial experts** early in the planning process to ensure proper budget allocation and identify potential funding opportunities.
- Explore **public-private partnerships** and **government support programs** to facilitate investment in hydrogen projects.

6. **Cross-Sector Coordination**

- **Involve key departments and institutions**, including energy agencies, financial authorities, and industrial representatives, to ensure coordinated planning.
- Establish a **clear governance structure** to manage responsibilities and cost-sharing arrangements.
- Identify measures **requiring additional** technical **studies or** market **analyses** to refine investment decisions.

This structured evaluation approach ensures that hydrogen strategies are targeted, cost-effective, and scalable, contributing to the efficient integration of hydrogen into the energy system.

Best-Practice Example Bremen [14]

A best-practice example can be taken from Bremen, Germany, where experts selected measures in a multi-criteria evaluation workshop. They used a **structured evaluation process** to assess different measures based on their effectiveness and costs. A matrix was used to classify each measure. While this best-practice example originates from the transport sector, the methodology can be effectively applied to hydrogen strategy development. Just as Bremen used a structured evaluation approach to prioritize sustainable mobility solutions, regions developing hydrogen strategies can adopt a similar framework. By **integrating expert evaluations and multi-criteria assessments**, stakeholders can ensure that hydrogen-related initiatives align with regional goals, economic feasibility, and long-term sustainability.

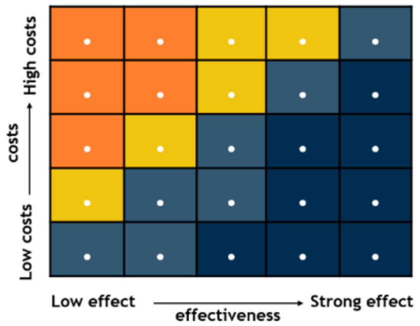

Figure 5: Own representation according to "Cost-Effectiveness Matrix for Evaluating Measures" [14]

7.4. Balancing Push and Pull Measures

A **balanced application** of **push and pull measures** is crucial for facilitating sustainable transitions in large socio-technical systems[6]. Push measures exert pressure on existing systems or technologies to drive transformation. Examples include regulations such as **CO_2 pricing** or **energy efficiency standards**, which make high-emission technologies less desirable. Additional strategies, like **banning inefficient technologies (e.g., traditional incandescent light bulbs) and reducing fossil fuel subsidies**, aim to destabilize established systems by reducing the attractiveness of outdated practices. These measures pave the way for the adoption of sustainable alternatives.

In contrast, pull measures provide incentives to foster the development and adoption of new technologies. For instance, subsidies for renewable energy sources like solar and wind power, and investments in research and development, **encourage innovation** in sustainable energy technologies. Market mechanisms, such as feed-in tariffs or green certificates, further **enhance the competitiveness of eco-friendly technologies**. By making sustainable options **more appealing** and **economically viable**, pull measures actively support their integration into mainstream systems.

The effectiveness of these measures often relies on their combined use. Push measures, while sometimes applied hesitantly due to their disruptive impact on established systems, are essential for phasing out environmentally harmful practices. When paired with pull measures, they provide a powerful mechanism for promoting the green hydrogen economy and ensuring a successful transition to sustainable energy systems [15].

In addition to a balanced use, the success of push and pull measures also depends on clear and reliable framework conditions. These conditions reduce uncertainties for investors and enable the necessary upscaling from pilot projects to industrial deployment. In this context, pull measures such as funding programs, for example, the EU Innovation Fund, Horizon Europe, or IPCEI, play an important role by lowering financial risks, fostering innovation, and supporting market integration of hydrogen technologies.

8. Phase 4: Implementation and Monitoring

The final phase focuses on ensuring the effective execution of planned measures while maintaining the flexibility to adapt to emerging challenges. For green hydrogen, this includes managing the deployment of infrastructure, adjusting production levels as needed, and continuously monitoring system performance.

1. **A skilled workforce** is a critical factor for success in the hydrogen economy. Authorities should prioritize **education** and **training programs**, focusing on STEM (Science, Technology, Engineering, and Mathematics) fields and renewable energy technologies. **Collaborating** with universities, technical schools, and industry partners can help prepare engineers and technicians for opportunities in the hydrogen sector. **Strong partnerships among academia, industry,** and **government** are essential for driving progress in this field. Regional authorities can **establish hydrogen councils** or working groups to coordinate efforts with broader strategies, facilitate knowledge sharing, and foster innovation. **Supportive policies** and **clear regulations** are equally vital for encouraging investment in hydrogen technologies. Measures such as **subsidies, tax incentives**, and **robust safety standards** for hydrogen production, handling, and transportation can build confidence in the sector. Additionally**, integrating** hydrogen into regional **climate and energy plans** ensures a cohesive, strategic approach that aligns with broader sustainability goals.

[6] Socio-technical systems refer to complex systems that involve a combination of social and technical components interacting with one another. These systems are characterized by the interplay between human behaviour, organizational structures, societal norms, and technical infrastructure or technologies.

2. **Effective coordination** among stakeholders is essential during implementation to **address potential bottlenecks**. For instance, delays in renewable energy projects could impede the timely commissioning of hydrogen electrolyzers. Likewise, logistical challenges in developing hydrogen transport and storage infrastructure must be tackled collaboratively to ensure smooth progress and alignment with project timelines.
3. **Monitoring and reporting** are essential for evaluating the effectiveness of implemented measures and identifying areas that may require adjustments. This process should be conducted periodically, ensuring that established targets for indicators are being met and adjusted when framework conditions change. To maintain efficiency and prioritize this process, **clear time frames** and **responsibilities** should be defined in advance. **Progress monitoring** involves the continuous assessment of key metrics established during the strategy development phase. Indicators such as hydrogen production capacity, cost trends, and adoption rates in industrial and transportation sectors provide valuable insights into the success of the measures. If progress falls short of expectations, corrective actions can be taken, such as **revising funding mechanisms** or **accelerating specific projects**, to keep the strategy on track.
4. The final step of this phase **involves reviewing** and **learning from the outcomes**. By analyzing both **successes** and **shortcomings**, stakeholders can refine their approach and enhance future iterations of the green hydrogen development plan. This iterative process ensures the **system remains flexible** and **responsive** to evolving conditions, including technological advancements and changes in market dynamics.

8.1. Monitoring and Reporting

Effective monitoring and evaluation are essential for the successful implementation of hydrogen strategies and action plans. A **structured monitoring process** allows for continuous learning, adaptation, and optimization of planning efforts. **Regular assessments** help ensure that progress aligns with long-term decarbonization and energy transition goals. Transparent monitoring also fosters accountability, justifying investment decisions and improving public engagement.

This may include:

1. **Identify** relevant monitoring **data**
2. **Indicators**:
   - Define expected impacts of hydrogen projects, such as CO_2 reduction or industrial adoption rates, and measure infrastructure expansion, such as the number of hydrogen refueling stations built, installed electrolyzer capacity, or kilometers of pipeline developed.
   - Track resource allocation, including investment and operational costs, to ensure financial feasibility and adjust plans if necessary.
3. **Stakeholder Consultation**: Engage key industry players, policymakers, and researchers to align monitoring criteria with practical implementation needs.
4. Use **established indicators** where possible to facilitate benchmarking and reporting.
5. **Define Monitoring and Evaluation Procedures**: Set baseline values and target benchmarks to track project effectiveness and implement regular review cycles to adjust strategies based on monitoring results.
6. **Clarify Responsibilities** and **Budgeting**: Assign monitoring to qualified personnel or external experts and allocate sufficient budget.

By establishing a well-defined monitoring and evaluation plan, hydrogen strategies can remain adaptive, effective, and aligned with long-term energy and climate objectives.

Best-Practice Example Toulouse [14]

A best-practice example comes from Toulouse, France, where an ambitious monitoring process was led by cross-institutional committees. Several committees regularly review progress, bringing together stakeholders from government, industry, research institutions, and civil society.

Key monitoring tools include:

- **Observation Platform:** Tracks initial objectives, allocated resources, expected outcomes, and key indicators, which are updated through regular data collection.
- **Performance Measurement Tools:** Assess the efficiency and impact of different initiatives, ensuring alignment with strategic goals.
- **Project Dashboard:** Provides real-time tracking of individual measures and their effectiveness.

A key success factor was the active involvement of various stakeholders in the monitoring process, ensuring transparency and continuous improvement. This structured approach can be applied to hydrogen development by establishing clear monitoring mechanisms for tracking hydrogen projects. Regular evaluations involving policymakers, industry leaders, and researchers can help ensure that hydrogen initiatives align with energy and climate targets. Tools such as hydrogen supply and demand tracking systems, infrastructure expansion monitoring, and impact assessments can improve transparency and facilitate data-driven decision-making for regional hydrogen strategies.

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