Scenarios For Future Sourcing Strategies In The Context Of The Use Of Green Hydrogen To Achieve Carbon Neutrality In Dortmund By 2035 – Strategic Implications For DEW21:

"Phase II: Explore – Megatrend I & Megatrend II"

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M.Sc. in Management

Work project carried out under the supervision of:

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SCENARIOS FOR FUTURE SOURCING STRATEGIES IN THE CONTEXT OF THE USE OF GREEN HYDROGEN TO ACHIEVE CARBON NEUTRALITY IN DORTMUND BY 2035 – STRATEGIC IMPLICATIONS FOR DEW21:

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Abstract

Group work: In the subsequent Work Project, scenarios were built based on a deductive evaluation of potential supply strategies for green hydrogen. The framework for Dortmund Energy and Water Supply GmbH's (DEW21) future strategic alternatives was established by researching the external environment and conducting interviews with three essential experts. The reader is introduced to a spectrum of potential futures for the hydrogen sector and threats and opportunities that may emerge within the specified time frame. Finally, comprehensive strategy advice is provided to the company.

Individual work: In the subsequent individual work, “Phase: II – Explore” of the applied intuitive logics school scenario building framework is conducted. In this phase, DEW21’s contextual business environment is analysed with special regard to green hydrogen developments on a regional, national, European and global level. Influential drivers of change, such as megatrends and trends are displayed to capture essential and impactful green hydrogen developments, and by this, opening the space for tangible business recommendation for DEW21 in a later stage of the work project.

Keywords: Scenario Planning; Green Hydrogen; Supply Strategies, Dortmund; Net-Zero Emissions.

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Glossary

EU: European Union

H2: Green Hydrogen

LCOE: Levelized Cost Of Energy

LH2: Liquid Green Hydrogen

LNG: Liquid Natural Gas

LOHC: Liquid Organic Hydrogen Carriers

Mt: Metric Ton

MWh: Megawatt-hour

TWh: Terawatt-hour

Km: Kilometre

1. Introduction

Recent events have shown mankind that it needs to evolve to a new energetic paradigm to ensure human survival. It is essential that these changes happen before the planet reaches the point of no return. Such structural changes must include a complete shift in human mentality, from the implementation of recycling in every household all the way to redesigning the energetic supply chain in order to create a self-sustaining energy paradigm. This statement seeks to emphasize the importance of a net-zero energy paradigm, which will be aided in part by green hydrogen. The general premise guiding this work project is that green hydrogen will play a significant role in the global energy market of the future, serving as an essential renewable energy source and carrier for a wide range of applications, including residential and commercial heating, industrial feedstock, transportation, and energy storage. Current times are setting the pace for the green hydrogen's ramp-up phase, which will be widely explored throughout the entire report with respect to the considered horizon of ruptures in this analysis, 2035.

Specifically, the following scenario planning analysis focuses on the use of green hydrogen as a source of energy and as part of the city of Dortmund's efforts to achieve carbon neutrality by 2035. The aim of this work project was to provide the company with possible and plausible narratives that compress a wide geographical scope by highlighting future developments that impact DEW21's strategic positioning on a global, European, and domestic level, to further assist the company in modelling future strategic options in the green hydrogen context, in order to achieve the highest level of awareness and preparation for the foreseeable future.

Furthermore, the scenario process was based on the *Intuitive Logics School* and considered the following stages: (I) *Framing & Scoping*; (II) *Explore*; (III) *Synthesize*; (IV) *Act*; (V) and *Monitor*. This collaborative project between Nova SBE and Dortmund Energy and Water Supply GmbH (DEW21) had fundamental support from the company; via unstructured and semi-structured interviews, it was possible to obtain essential company information, industry insights, and expert outlooks to properly respond to the client's requirements, thus aligning the DEW21 goals with the project spectrum to maximise the report's strategic value.

2. Literature Review

The following literature review serves as fundamental scientific construct of this collaborative work project between the university *Nova SBE* and the selected client company *DEW21*, and thereby illustrates the *Strategic Foresight & Scenario Planning* tool applied in the course of this work. At first, the scenario planning origin and definition are exemplified by explaining the respective historic background driven by leading economists of the past century. Secondly, various scenario planning approaches are opposed, by displaying their main and unique characteristics. In a final step, and by initializing the subsequent methodology section, the scenario planning techniques are defined according to their nowadays most commonly applied area – capturing essential drivers of change of the contextual environment, creating plausible and relevant future scenarios, and finally deriving robust strategic implications for the relevant party.

2.1 Scenario Planning Origin and Definition

The introduction of scenario planning is generally attributed to Herman Kahn, a strategist who worked for the US Military at RAND Corporation in the 1950s. During those years, he devised a technique describing several possible futures to make military planning more efficient. On this occasion, the term "scenarios" was first used. Although Kahn is considered the father of scenario planning by most, in those same years, the French philosopher Gaston Berger was also developing a new method - later called “La Prospective” - based on the creation of future regulatory scenarios to guide public policy formulation (Amer, Daim, and Jetter, 2013). Initially considered too complex to put into practice, the scenario method wasn’t really employed until 1971, when Pierre Wack used it for the Royal Dutch Shell. On that occasion, the company successfully coped with the oil shock that occurred a few years later (Wack, 1985), marking the beginning of scenario planning exploitation by organizations (Chermack, Lynham, and Ruona, 2001).

There are several definitions for scenario planning. Kahn and Wiener (1967) defined scenarios as “a set of hypothetical events set in the future constructed to clarify possible chain of causal events as well as their decision points”, Schwartz (1991) as “a tool [for] ordering one’s perceptions about alternative future environments in which one’s decision might be played out”; while Ringland (1998) defined scenario planning as “that part of strategic planning which relates to the tools and technologies for managing the uncertainties of the future”. What is common about these different definitions is that scenarios are neither predictions nor forecasts of the future but a challenge to current paradigms of thought and stories to consider aspects that would otherwise be overlooked (Shoemaker, 1995). The purpose of scenario planning is to consider external factors and uncertainties that could greatly affect the environment, thus helping decision-makers adopt a more effective strategic approach.

2.2 Scenario Planning Approaches

Numerous scenario planning approaches have been developed over the years, such as the Intuitive-Logics School, Michael Porter’s Industry Scenarios, the Probabilistic Modified Trends School, and La Prospective. As no universally accepted method exists, planners must choose the one that best serves their objectives (Amer, Daim, and Jetter, 2013). In the literature on scenario planning, the intuitive logic technique has garnered the greatest focus. During the 1960s, Herman Kahn of the Rand Corporation advocated this strategy. Pierre Wack and his colleagues at Royal Dutch Shell utilised an intuitive logic framework; hence, this strategy is commonly referred to as the "Shell approach" to situations. The intuitive logic method posits that business decisions are based on a complex set of linkages between political, technological, social, resource, and environmental issues. These scenarios are fictitious event sequences developed with the aim of highlighting causal relationships and decision points. It is essential to comprehend these elements well to gain insight and enhance the decision-making process (Amer, Daim, and Jetter, 2013). This method was later popularised by Peter Schwartz, a former leader of the scenario team at Shell, in his book *The Art of the Long View* (Schwartz, 1991).

The Intuitive-Logics School constitutes the basis for this analysis and will be implemented by developing the following five steps: *Framing and Scoping*, *Explore*, *Synthesize*, *Act*, and *Monitor*. In the first phase, *Framing and Scoping*, a focal issue must be chosen, as well as the horizon of ruptures. To develop an efficient and relevant scenario planning exercise, the topic in question must be crucial or critical for the organization.

In the second stage of this process, *Explore*, the goal is to identify the predetermined elements, as well as macroeconomic events and driving forces outside the company's environment, the knowledge of which would assist top management in its task of charting the company's future course of action (Aguilar, 1967). During this process, trends, megatrends, uncertainties, weak signals, and wild cards should be identified.

Following that, in the third phase, *Synthesize*, the uncertainties should be mapped according to their level of uncertainty and impact on the focal issue. From there, the two uncertainties with the highest level of impact and uncertainty should be picked and plotted against one another on axes to build the scenario logic's foundation. It is imperative to guarantee that the two selected key uncertainties are sufficiently independent. In other words, these two uncertainties cannot overlap. After the 2x2 matrix is constructed, the resulting scenarios must be named, described, and create a narrative for each of the four scenarios, alluding to some of the elements that have been identified throughout the process.

In the fourth and fifth phases, *Act* and *Monitor* the goal is to build the strategic implications of the scenarios related to the focal issue and the early signs that will help identify which scenario is more likely to materialize.

2.3 Scenario Planning as a Strategic Tool

Scenario Planning was recently described as identifying and rehearsing strategic options for various possible futures (Sridharan, 2022). When defining the scenario planning journey, Schwartz (1991) emphasizes the need to coordinate scenarios with strategy by establishing robust strategic implications. Complementarily, Wilson (2000) affirms that the ultimate reason to apply the scenario planning process is to translate the implications of the scenarios into strategic action. Even though scenario planning can be used for several purposes, Lindgren and Bandhold (2004) have identified four dimensions that drive scenario planning techniques: Strategy/Planning, Innovation, Scenario Learning, and Evaluation. The first dimension outlines scenario planning techniques motivated by planning considerations to drive strategic development activities and outcomes. The second dimension selects scenario planning techniques as an inspirational tool to validate new ideas while maintaining flexibility and openness in strategic thinking. Third, scenarios can be used to learn or promote change (Lindgren and Bandhold, 2004). Lastly, scenarios are used for evaluation purposes by assessing existing business concepts, strategies, or products. Using scenario planning for different purposes and outcomes highlights how different and challenging perspectives may, in such critical situations, be advantageous, if not necessary, for the survival of an organization (Bood and Postma, 1997). Scenario planning improves the robustness of a policy or strategy by identifying and challenging the underlying assumptions and established wisdom while enabling better strategic decision-making by discovering and framing uncertainties (World Economic Forum, 2014). The process of distance from one-dimensional or linear thinking forces managers to challenge their assumptions in a non-threatening, hypothetical environment and test them in the glare of a possible adverse future (Heijden et al., 2002). Ultimately, scenarios provide a structure for dealing with uncertainties by uncovering unavoidable or nearly unavoidable futures (Cornish 1977), which reflects the goal of the present Work Project by exploring the possible futures of the energetic sector evolution in Germany until 2035.

3. Methodology

The methodology chapter reveals the overall scientific structure and process followed for the development of this work project. In the following sections, the key stages of the applied strategic foresight & scenario planning tool are displayed, followed by an illustration of the client involvement in this collaborative work. After, a concrete and more specific description of this work's scneairo building process is provided. The chapter is then finalized by highlighting additional scientific frameworks integrated in the final stages of this work.

3.1 Research Design

As mentioned in the previous chapter (Chapter 2.2), this scientific paper will be developed following the qualitative approach of scenario planning belonging to the Intuitive Logics school, as its flexibility makes it particularly suitable for the exploration of contexts dominated by a high level of uncertainty (Kahn, 1967). Over the years, the Intuitive Logics School has been applied several times in the energy field to approach climate change, and its implementation is continuously growing (Metzger and Rounsevell, 2010). In fact, the energy sector often requires significant long-term investments, implying a high risk for companies, as the industry's future depends on many unpredictable drivers. Strategists, therefore, must take into account possible events such as new technological discoveries, political conflicts, revolutions, embargoes, which, despite being very rare events, have extremely high impact on the sector and respective economies (Marcus, 2019). Creativity, coherence and plausibility are scenario narratives' characterizing aspects that allow the exploration of wide time horizons, for which, with such uncertainty, it would be extremely difficult to perform accurate quantitative projections (Metzger and Rounsevell, 2010) – consequently, the research team and the client company DEW21 together selected this approach for the resolution of the work project's *Focal Issue* (Chapter 4.1). The method provides DEW21 the possibility to apply a 360-degree scan of its most influential environment, to follow latest contextual developments and to prepare for four different plausible future scenarios based on that analysis. The particularly participatory nature of this methodological approach (Stokke et al., 1990), moreover, allows to integrate key information provided by the company itself, to guide the research process according to their perception. Interviews and/or workshops with stakeholders and experts in the field, can in fact be prepared and integrated at any stage of the process, allowing to effectively respond to the company's needs. While constructing and analysing deductive scenarios, different frameworks can be implemented as well, such as the SWOT Analysis or the Business Model Canvas. As mentioned in Chapter 2.2, the scenario planning process used in this scientific paper follows the Intuitive Logics school scheme. The research process is therefore divided into five phases, namely: *Framing and Scoping, Explore, Synthesize, Act,* and *Monitor.* The first phase includes the Strategic Focal Issue and Time Horizon identification, elements around which the whole project develops. Two consultations with the client company were fundamental in this phase. The first, served to understand what the most important challenge for the company was and obtain essential information for the elaboration of the Focal Issue, the Supporting Questions, and the Time Horizon; the second validated the choices made by the researchers.

Subsequently, in the *Explore* phase, an environmental scanning was carried out following the research approach - but not the classification - of the PESTLE Analysis, which involves an inspection of six key areas for the identification of the drivers of change that influence not only the company but also the surrounding environment (Cadle et al., 2010). This phase provides essential information for the company; therefore, researchers have devoted ample space to this step, conducting a thorough analysis. Hence, predetermined elements, megatrends and trends, wildcards and weak signals were identified (Chapter 5).

The third phase, *Synthesize,* began with a careful discussion focused on the factors analysed in the previous phase, which led the researchers to form a list of possible critical uncertainties, based on the level of impact and probability of each. The research was then followed by a presentation to the client company, aiming to deepen the analysis of the uncertainties (Chapter 5.4) and identify the two key ones (Chapter 6.1) that characterize the context in which the challenge of DEW21 develops. Additionally, three interviews were organised with the company's stakeholders and industry experts in order to give the researchers more insight into the industry and the key uncertainties previously identified, which were then used for the construction of the scenario-matrix, basis of the configuration of the four scenarios. For each of the matrix's quadrants, a narrative was then elaborated and validated by the client.

Deep analysis was the key to the *Act* phase. At this stage, researchers implemented the SWOT Analysis framework to identify strenghts, weaknesses, opportunities, and threats arising from each scenario to link the narratives with their implications and elaborate accurate strategic recommendations that could potentially solve the Focal Issue (Chapter 7.1). Again, the researchers worked closely with the client company, presenting their findings and proposals.

Finally, in the *Monitor* phase, a series of early indicators was identified to allow DEW21 constant monitoring to recognize in advance the possible development of one of the previously mentioned scenarios (Chapter 8.1).

Figure 1: Research Design Roadmap | Source: Own creation based on the Intuitive Logic School

3.2 Involvement of the client

To develop a paper that adequately responds to the client's requirements, it is fundamental to involve interesting personalities with a broad and deep knowledge of the client company, the industry, and the market. Through unstructured and semi-structured interviews, it was possible to obtain essential company information, industry indisghts and expert outlooks for this collaborative project between Nova SBE and DEW21.

In particular, the constant support of Stephan Stollenwerk, Head of Technical Innovations and Services, and the availability of Peter Flosbach, Technical Director of DEW21, Dr. Jens Kanacher, Head of Asset Steering of DEW21, and Maximilian Blum, city of Dortmund's Climate Technologies Coordinator, to share their knowledge and experience in the energy sector was crucial for the scientific paper's development.

In the first phase of the scenario planning process, an unstructured interview was set up with Stephan Stollenwerk. The meeting consisted of free speech between the participants, focusing on DEW21 and the sector in which it operates to obtain a more profound knowledge. The outcome of the meeting was the information regarding the main characteristics of the company, its main challenges, and prospects for the future. This process allowed researchers to formulate the strategic *Focal Issue* and the *Time Horizon*, which was subsequently further validated by the company.

After having distinguished and classified all key factors through intense research sessions and literature review, the researchers deeply discussed identifying the critical uncertainties until identifying the two key uncertainties that would have constituted the basis of the four deductive scenarios. Finally, in order to validate the findings, a semi-structured interview with Stephan Stollenwerk was arranged. The meeting began with a brief presentation of the work done so far, with particular attention to the identified drivers of change and a greater focus on the critical uncertainties. The insights and considerations provided by Mr Stollenwerk allowed the definitive identification of the key uncertainties that would have constituted the Scenario Matrix.

Crucial to the project's development were the three semi-structured interviews with Peter Flosbach, Technical Director of DEW21 (Appendix 2); Dr Jens Kanacher, Head of Asset Steering of DEW21 (Appendix 3); and Maximilian Blum, city of Dortmund's climate technologies Coordinator (Appendix 4). The researchers considered it essential to deal with people impersonating different roles within the company and stakeholder environment. In particular, they were interviewed in order: one of the company's strategic leaders, an expert with technical knowledge, and a representative of the city of Dortmund, headquarters of DEW21. The aim was to hear the opinions of people with distinct experiences, interests, and knowledge across the energy sector. This allowed grouping of the necessary insights for a more accurate delineation of the scenarios' narratives, focusing on the most critical themes in the energy field. In particular, the interviewees were provided with a form containing an instructive explanation of the ongoing project’s main context. In order to allow the research team to maximize the evaluation and integration of the collected data, the participants kindly allowed the recording of each contextual discourse.

In a further, more exhaustive section of the shared document, divided into four parts - Energy sector evolution towards carbon neutrality, Green Hydrogen considerations, Level of infrastructure development, and Political stability – contextual questions for the interviewees were displayed. Addressing the aligned work project’s focal issue, in this stage, the purpose was to investigate the experts’ multi-sided perspectives surrounding the issue at stake, namely carbon neutrality targets and strategies, and the green energy transition towards green hydrogen matureness - with special focus towards the two identified critical uncertainties for DEW21 and the development of green hydrogen. The questions - 24 in total - were aligned for all three interviewees to compare different views and perceptions (Appendix 1).

The outcome of each interview was subsequently integrated in all specific phases of the work, combining them with further scientific research and other sources of enlightenment – all together evaluating and deriving strategic implications for DEW21 in a later stage of this paper. Finally, to complete the comprehensive client interaction in this collaborative project, and to ensure the delivery of value adding work for DEW21, two further and final meetings were organized with Stephan Stollenwerk: The first intended to validate the scenarios developed by the researchers and to discuss first strategic implications of each narrative, whereas the second meeting assessed their feasibility in more detail and discussed concrete next steps for the company.

3.3 Scenario Building Process

Following the extensive analysis of the second phase, *Explore* (Chapter 5), which involves the identification of driving forces that affect the evolution of the energy sector, the Intuitive Logic school provides for the third phase of the scenario planning process, *Synthesize*. This phase consists in the design of a limited number of scenarios in which the insights gathered during the previous phases are projected into the scenario building process (Bradfield et al., 2005). The development of scenarios provides a useful tool to address uncertainties (Cornish, 1977), discovering the unavoidable, or almost unavoidable, futures of the renewable energy industry within the next decade. Hence, the aim of the Synthesize phase is the development of plausible and internally coherent storylines that describe possible future prospects of the sector within the defined Time Horizon. The narratives are built on the data collected in the previous stages of the process, with a particular attention to the driving forces that have an impact on the Focal Issue.

The different approaches for developing the industry scenarios are identified as scenario typologies. Each scenario typology represents an essential tool for communicating, understanding, comparing, and developing strategies for possible futures (Börjeson et al., 2006). Scenario typologies are divided into four categories: inductive, deductive, incremental, and regulatory scenarios. The inductive approach shapes each scenario step by step, from the discussion and exploration of driving forces, following a bottom-up approach for the development of the scenario structure (Bradfield et al., 2005). The deductive approach, further described and analyzed, follows a top-down approach, in which the researcher first attempts to infer a general framework, then implements the data found through the analyses (Bradfield et al., 2005). Thirdly, the incremental approach follows a process that aims to develop a scenario similar to the official future, but different enough to move in a different direction than expected. The incremental approach is often applied in cases where the scenario-based strategic planning is not fully understood and shared by the client organization (Bradfield et al., 2005). Finally, the normative approach aims to create scenarios that have the function of finding a way to achieve specific future objectives (Börjeson et al., 2006).

As mentioned in the previous chapters, this scientific paper will follow the deductive scenarios approach. The deductive framework bases the scenario construction around two critical key uncertainties, identified as the scenario dimensions. Scenarios are then developed around the two extreme evolutions “extremes” of the selected key uncertainties to describe the four plausible futures for the Time Horizon previously defined. The two selected key uncertainties are placed as the axis of a 2x2 scenario matrix, where the final scenarios are displayed in four quadrants that reflect four different futures (Wulf, Meissner, and Stubner, 2010). Key uncertainties, basis of deductive scenarios, represent unpredictable driving forces characterized by two extreme, opposite, and plausible variations (Goodwin and Wright, 2004). To form the basis of the scenario-matrix, the two key uncertainties must satisfy three requirements: high level of impact, high uncertainty, and sufficiently independent interaction. This means that uncertainties must have a strong impact on the focal issue, a high uncertainty about the probability of their realization, and be able to plausibly coexist in any potential variation within the same future scenario (Wright and Cairns, 2011). This justification of sufficient independence is executed in the *Scenario Development Process* in *Phase III: Synthesize*.

In this scientific paper, to select the two key uncertainties, the researchers initially identified six critical uncertainties for the Focal Issue under study, and with the subsequent definition of the end-states of each, representing plausible future situations (Appendix 5). Once the identification of the uncertainties and their end-states was completed, a semi-structured meeting was organized between Stephan Stollenwerk, Head of Services and Technical Innovations and correspondent of DEW21, and the project team. A deep discussion was then developed on the impact, the level of uncertainty and the relevance of each uncertainty to the project's focal issue. The potential level of impact was critically discussed on the range of possible events that each uncertainty could generate and the relative significance of these in determining the overall results of the focal issue (Wright and Cairns, 2011). The uncertainties were then further classified according to their degree of uncertainty and potential impact for the company to identify the most crucial environmental drivers that a corporation must consider in its planning techniques (Schwartz, 1991; Bradfield et al., 2005; Schoemaker, 1995). The assessment of the level of impact and uncertainty was carried out on a scale-based rating from 0 to 10 (Appendix 6). The classification finally led to an overall mapping of the respective uncertainties. After the scaling process, the researcher team proceeded with the construction of the respective scenario matrices (Figure 14) and finalized their analysis by identifying its implications and strategic recommendations for the final resolution of this scientific paper (Schwartz, 1991).

3.4 Framework Implemented

The context-specific analysis of each scenario narrative required the research team to apply a suitable framework to capture all strategic dimensions of each future state based on a proven scientific foundation. The SWOT analysis (Figure 2) proved to be an appropriate framework to assess each world's essential developments and to link the narratives with the client's strategic positioning, allowing to derive value-adding recommendations for DEW21 (Ringland, 2003). Applying a SWOT Analysis permits the recognition of aspects being located in the internal and external environment of a company, and by that, fundamental knowledge for aspired business objectives can be assessed (Benzaghta et al., 2021). More precisely, the implementation of this framework allows the identification of the *Strengths* and *Weaknesses* of the business at stake, and the *Opportunities* and *Threats* arising from the external environment of each specific scenario. Successively, DEW21's strategists can use the information gained to re-align the company's strategic positioning, to maximize company-specific *Strengths* and existing *Opportunities* of the surrounding context (Weihrich, 1982).

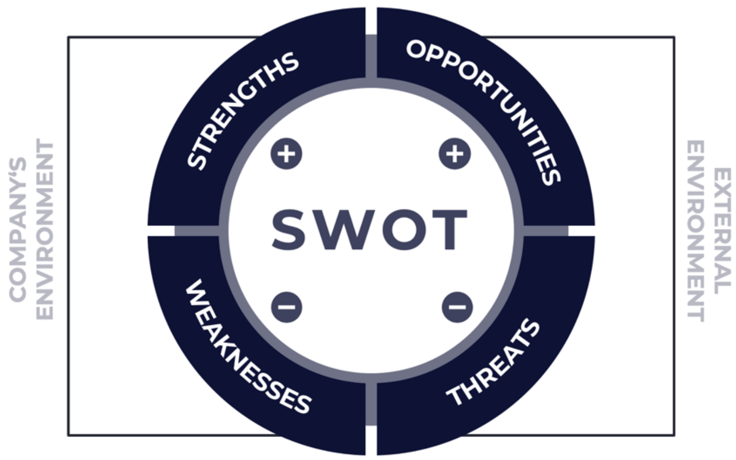

Figure 2: SWOT Analysis Framework | Source: Own Creation

4. Phase I: Framing & Scoping

This project started with Dortmund Energy and Water Supply GmbH (DEW21) acceptance to participate in this project, thus becoming this project's client.

During the first meeting with the client, the team learned that one of the company's main goals was to achieve carbon neutrality in the city of Dortmund by 2035, which is part of the European effort to achieve carbon neutrality by 2050.

According to Schoemaker (1995), the first thing that must be done to align the scenario thinking process is to establish the time horizon and the project's scope. Scenario planning must be relevant to your organization, its consumers, and its markets. Hence, for any scenario planning exercise, it is essential that the focal issue of the project address a core issue for the client at hand, as well as have a well-specified temporal horizon that permits the horizon of ruptures to unfold. (Carvalho, 2021)

It is then imperative that DEW21 goals are aligned with the project spectrum to maximise this report's strategic value.

4.1 Focal Issue

The selected *Focal Issue* is based on the premise that green hydrogen is the future of energy when it comes to heating and, more generally, energy consumption. According to McKinsey and the Hydrogen Council (2021), hydrogen has a vital role in assisting the world in reaching net-zero emissions by 2050 and limit global warming to 1.5 degrees Celsius. Using green electricity for industrial heating and other energy-intensive industrial operations is not a realistic option. However, the use of environmentally friendly hydrogen is viable. Green hydrogen can potentially be employed as a direct-use fuel in fuel cells used for mobility or stationary power or as a source of high-grade heat required for cement manufacturing or grid power generation. It is a feedstock for the production of ammonia, synthetic fuels for the marine and aviation industries, and a reductant for the processing of iron ore for clean steelmaking (McKinsey &

Company, 2022). Between 2014 and 2019, the price of alkaline electrolysers manufactured in North America and Europe decreased by 40 percent, while Chinese systems are already up to 80 percent less expensive than their western counterparts. Estimates indicate that if electrolyser production can be scaled up and costs continue to decline, renewable hydrogen could be produced for the price of natural gas by 2050, making it competitive with current natural gas prices in Brazil, China, India, Germany, and Scandinavia on an energy-equivalent basis and less expensive than producing hydrogen from natural gas or coal with carbon capture and storage in the majority of the world by 2050 (Bloomberg NEF, 2020).

The certainty of the presence of green hydrogen in the near future, along with the forecasted reduction in the cost of producing green hydrogen brought about by the rapid advancements in technology over the next few years, make up the predetermined elements of this thesis, as elaborated in more detail in the following *Phase II: Explore*.

Given the factors described above, the topic was proposed to DEW21, which suggested a report focused on the sourcing strategy for implementing green hydrogen. As a result, the following focal issue was formulated: "What are the different sourcing strategies in the context of green hydrogen to achieve carbon neutrality in Dortmund by 2035?". Furthermore, the following supporting questions were developed as a more in-depth approach to the explanation of the defined focal issue: (1) “What kind of infrastructure is needed for the transmission and distribution of green hydrogen?”; (2) “What type of transformations will be required to scale up the utilization of green H_2?”; (3) “What macro-network will be available in Germany to lower distribution costs?”; (4) “What efforts is the German government undertaking to accelerate the widespread industrial acceptance of green hydrogen, e.g., by providing funding, setting-up task forces and domestic H_2 strategies?”; (5) “What possibilities exist to integrate the city of Dortmund into planned transregional hydrogen pipeline networks?”

4.2 Time Horizon

When considering a time horizon, it should not extend so far into the future that "science fiction" thinking is required, nor should it be so close that the future is largely predictable. It should represent a suitable planning horizon for the long term in terms of the company's issues (Cairns and Wright, 2011). The optimum Time Horizon is the horizon of ruptures.

As it was previously mentioned, one of the company’s main challenges is reaching carbon neutrality in Dortmund by 2035, and so this information already contributes in a major way to the formulation of the time horizon. This paper aims to align this analytical process and its individual phases with DEW21 strategic plans and business development time schedules once the energy transition is a systemic change and, as such, requires a medium-to-long-term process planning. Germany aims to get 100 percent of energy from renewable sources by 2035 (Reuters, 2022). Furthermore, the decade to come is where most events will unfold because green hydrogen is capturing momentum, and its development is, at this stage, exponential. Additionally, Europe will be one of the major players in the future market for green hydrogen, as it is home to over 30 percent of proposed hydrogen investments globally (McKinsey & Company, 2021). Other consequences, such as the unfolding of the war in Ukraine, will also occur in the following decade and will have significant impact on the focal issue.

Capturing the maximum climatic value of hydrogen to reach the 2050 net-zero goal requires tripling the investment in hydrogen by 2030 to USD 700 billion, or an extra USD 460 billion invested in hydrogen projects through 2030 (McKinsey & Company, 2021). As all the events mentioned above will unfold, and DEW21 strategic 2035 net-zero commitment along their corporate value chain, 2035 is identified as the most suitable horizon of ruptures.

5. Phase II: Explore

In *Phase II: Explore*, an environmental scan to investigate driving forces independent of DEW21's control and that will shape future dynamics in both expected and unforeseen ways is conducted (Ramirez and Wilkinson, 2014). As a first step, the predetermined element of green hydrogen's essential role as major future renewable energy source is elaborated and justified. Subsequently, impersonating the main body of this *Phase II: Explore*, the scanning process of the client's contextual macroenvironment is conducted to reveal its main drivers of change. This analysis reveals various megatrends, trends, weak signals and wild cards, suggesting predictable and unpredictable influence on DEW21's business environment. Investigated on a global, European and national level, those drivers intend to provide the necessary contextual background for resulting strategic recommendations in a later stage of this work. This chapter is finalized by the listing, definition and powerrating of the focal issue's main uncertainties – whereupon the following *Phase III: Synthesize* identifies the project's two key uncertainties, to consequently draft the scenario narratives.

Research & design structure. As a commonly utilized and coherent external business environment analysis tool, according to Cadle et al. (2010), the PESTLE framework allows a comprehensive scanning process of six key areas when identifying sources of change, namely political, economic, socio-cultural, technological, environmental, and legal. As there is little, if any, utility in classifying these elements and the categorization of overlapping elements does not add further value, only the research approach covering those six key areas, but not the structure of this chapter, followed the PESTLE framework's benefits (Cadle et al., 2010). This chapter instead is organized by clustering DEW21's main driving forces and their respective sub trends, demonstrating synergies and contextual coherences between them. Megatrends hereby are categorized as disrupting forces that unsettle major industries, whereas sub-trends usually can be considered as their consequences, but with distinct specific impact on parts of certain industries or environments. In combination with an outside-in thinking approach (Figure 3), the following three main influential factors, so-called megatrends, were identified: **Global warming** as the central accelerator of the green energy transition and the basis of the rising cleantech industry, **demographic shifts**, which suggest relevant consumer behavioral changes due to the powerful green initiatives as of political and environmental awareness, and finally **digitalization**, establishing disruptive technical norms for the effective usage and distribution of green energy sources (Scearce and Fulton, 2004).

Figure 3: Outside-in thinking | Source: Own Creation, Inspired by Searce and Fulton, 2004

5.1 Predetermined Element

This work project is built on the assumption of green hydrogen's major role in the global future energy market, acting as essential renewable energy source and carrier for a high range of applications – from resdential and commercial heating, to industrial feedstock, transport means and to energy storage utilization. In the course of this work, this assumption is addressed based on the analysis of this section, capturing green hydrogen's dominant role as accelerator of the green energy transition. Major scientific developments, resource commtimments and implementation strategies are displayed to demonstrate the technologies future role.

Investigating further predetermined elements, in close cooperation with the client DEW21, resulted in the confirmation of the initial hypothesis, that only one, the illustration of **"Green hydrogen as industry-wide energy source and carrier"**, settled assumption serves the purpose of this work project. Additional specific conditions and future tendencies, within the scope of the focal issue, all were characterized by a considerable degree of uncertain developments and did not lead to the justification of further predetermined elements.

Predetermined element: Green hydrogen as industry-wide future energy source and carrier

Political targets and initiatives. Germany's 2030 decarbonization targets and the published National Hydrogen Strategy both prioritize the extensive use of green hydrogen in their action plans. Green hydrogen is perceived as essential pillar of the national decarbonization strategy, with a multi-layered incentive scheme set in place to promote its use, e.g., by governmental funding for green H_2 projects worth billions of Euros, auction mechanisms, and CO_2 pricing. The publicly available National Hydrogen Strategy formulated that "hydrogen will play key role in enhancing and completing the German energy transition" (German National Hydrogen Strategy, 2020). Two main phases are announced: Phase 1 (2020-2023) includes an action plan proposing 38 measures to be implemented by the federal government to ramp up the H_2 market and lay the foundation for domestic green H_2 production and consumption, whereas Phase 2 (2024-2030) intends to focus on stabilizing the growth of the domestic market while accelerating the ramp-up in European and international markets with involvement of the German industry. Not only promoting green hydrogen's key role in the German energy transition, but also linking the NHS with DEW21's core business application, Measure 18 and 19 include residential and commercial heating in the hydrogen action plan, aiming at funding for Energy Efficient Program and Fuel cell heating, and at "hydrogen readiness" under the Combined Heat and Power Act (German National Hydrogen Strategy, 2020).

Moreover, compared to their 1990 level, Germany announced in 2021 aiming to cut 65 percent of their carbon dioxide emissions by 2030 (88 percent by 2040, 100 percent by 2045). Figure 4 demonstrates the classification per industrial sector to be met by 2030, ranging from ~36 percent reduction in agriculture to ~77 percent in the energy sector (Figure 4).

Sectors	2020 status (Reduction from 1990 levels)	2030 target (Reduction from 1990 levels)	2020 relative achievement of 2030 target
Energy	53%	77%	69%
Buildings	43%	68%	63%
Transport	11%	48%	23%
Industry	37%	58%	64%
Agriculture	24%	36%	67%
Other	77%	90%	86%
Total	41%	65%	

Figure 4: Progress of Germany's biggest sectors in achieving their decarbonization targets formulated in 1990 | Source: Own Creation, following BMWK 2021

Consequently, the German Federal Government approved an Intermediate Action Program in June 2021, supported by EUR 8B funding, to achieve the revised climate goals (National Reform Programme, 2021). The program includes a wide green H_2 action plan, funding the renewable energy expansion, carbon contracts for difference, H_2 IPCEI[1] projects, the H_2Global mechanism, offshore electrolysers, and various other green H_2 supporting measures (Federal Ministry of Finance, 2022; Clean Energy Wire, 2021).

Green hydrogen's key role is further demonstrated on a European level, with Germany shortlisting 62 hydrogen production and infrastructure projects as *Important Projects of Common European Interest* (IPCEI), aiming at European financial support for the listed projects. Two of those projects, currently in the application process for funding by the European

Union, target advanced green hydrogen heating projects, supporting residential and commercial heating of blended or pure green hydrogen. The “H_2-20” project establishes an injection of up to 20 percent of green H_2 in the natural gas networks in Lower Saxony, and the municipal utilities of Schweinfurt test H_2 fuel cells for heating systems. Both projects serve as leading pilot projects of green hydrogen as a residential heating power source (DVGW, 2021).

Exhaustive collaborative green hydrogen projects, receiving governmental and public support, e.g., by financial, research and infrastructure investments, are specifically pursued by consortia and dedicated hubs along the entire green hydrogen value chain. The initiatives are characterized by a strong strategic alignment with the formulated NHS to achieve political targets by domestically becoming a hydrogen pioneer (Chapter 5.2.1, “Sub-trend II”).

Industrial demand. Renewable and green energy sources, commonly applied since the beginning of the 21st century, such as solar or wind energy, represent effective and economically viable options for the generation of renewable electricity (IRENA, 2022). Nevertheless, the energy demand of many essential industrial applications in Germany and worldwide cannot solely be covered by green electricity: extremely energy-intensive industrial applications, e.g., heating for the steel and refinery industry, or heavy-duty long-distance transport in the mobility sector demand green alternatives replacing traditionally so-called “grey” fossil fuels. Currently mostly powered by grey hydrogen, the estimated total demand for hydrogen in Germany will increase from 2020 to 2030 by +108 percent, reaching a total of ~115 TWh by the end of this decade (Fraunhofer IWES, 2022). Main sources of demand arise from industry (e.g., steel-, refining-, and chemical industries) and transport sectors (Figure 5).

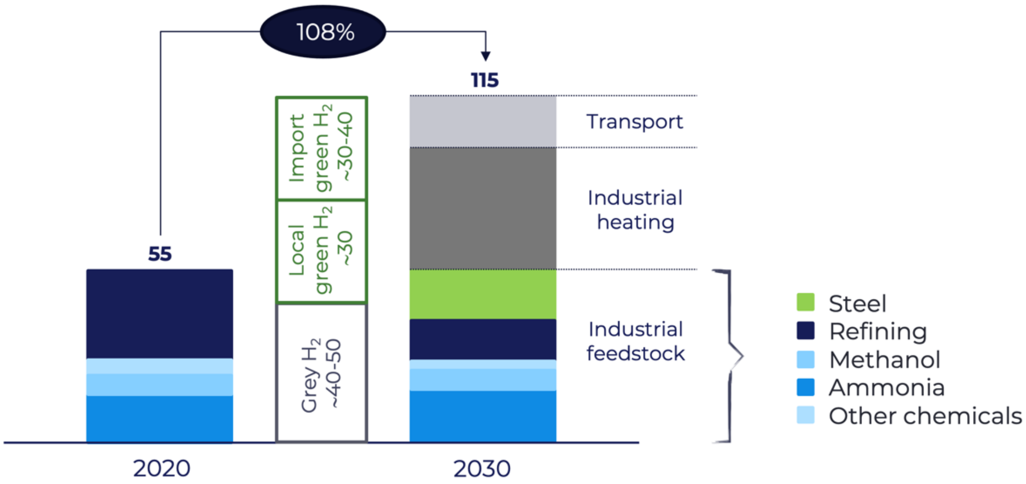

Figure 5: Estimated H_2 demand in Germany and potential H_2 sources (TWh), Source: Own Creation, following Fraunhofer IWES (2022) and The National Hydrogen Strategy (2021)

Representing ~24 percent of Germany's total GDP in 2020, industries are essential cornerstones of the German economy, further demanding a rapid transition into renewable energy sourcing to secure their competitive and economic position, and to meet Germany's ambitious decarbonization targets (OECD, 2022). Combining the urgent industrial demand for a green alternative to emission-intensive fossil fuels with the German Federal Government's action plan and budget allocation, the forecasted essential role of green hydrogen in the national energy transition becomes even more uncontested (Engie, 2022).

Variety of use case applications. Historically, technologies applicable to different sectors show a faster pace in reaching technology maturity, economic viability, and industry acceptance. Moreover, they allow synergies between other sectors, accelerating the development of key factors along the technologies' value chain (Bondarenko, 2017).

Green hydrogen applies to many use cases within different industries, leading to a broad utilization range (Figure 6). With 62 IPCEI projects listed in Germany along this utilization range and multiple heavily funded green H_2 hubs operating along the technology's entire value chain (Figure 6), synergetic effects arise and further accelerate its degree of innovation, longterm viability and industry success (S&P Global, 2021).

	Use case	Hydrogen's role
Industry feedstock	Oil refining	Hydrotreatment and hydrocracking
	Ore reduction	Reducing agent to remove oxygen from ore e.g., iron
	Methanol production	Synthesize methanol together with carbon-containing feedstock
	Ammonia production	Synthesize ammonia atmospheric nitrogen
	Methane production	Synthesize methane via co-electrolysis or methanation
Heating	High temp. Industrial	Generate heat for industrial processes e.g., melting, gasifying, drying, steam production
	Low/mid temp. Industrial	
	Resi. And commercial (100% hydrogen)	Generate heat via H_2 directly in fuel cells or dedicated H2 boilers
	Resi. And commercial (Blend with natural gas)	Generate heat using H_2 as ad-mixture to natural gas in existing natural gas infrastructure (e.g. Considering boiler)
Power	Long-term, large-scale storage	Used as electricity storage to balance electricity demand and supply on monthly or seasonal scale
	Off-grid power supply	Generate electricity in regions not connected to a large, centralized power network
	Power system balancing	Used as fuel (e.g., for gas turbines, CCGT, fuel cells) for flexible power gen. To balance the power system on a daily or shorter scale

	Use case	Hydrogen's role
Transportation	Container ships	Used directly as H_2 in fuel cells or as processed synthetic fuel in existing internal combustion engine (e.g., ammonia for shipping, synthetic kerosene for aviation)
	Coastal & river ships	
	Ferry / harbour ships	
	Short-haul aviation	
	Remote trains	
	Well-connected trains	
	Off-road vehicles	
	Light-duty vehicle	
	Heavy-duty vehicles (short distance)	
	Heavy-duty vehicles (Long distance)	

Figure 6:Overview on green hydrogen's main use cases Source: Own Creation

5.2 Megatrends & Trends

This section is introduced by a dedicated overview (Figure 7) of relevant "Sources of Change", visualizing all captured influential drivers of DEW21's contextual environment.

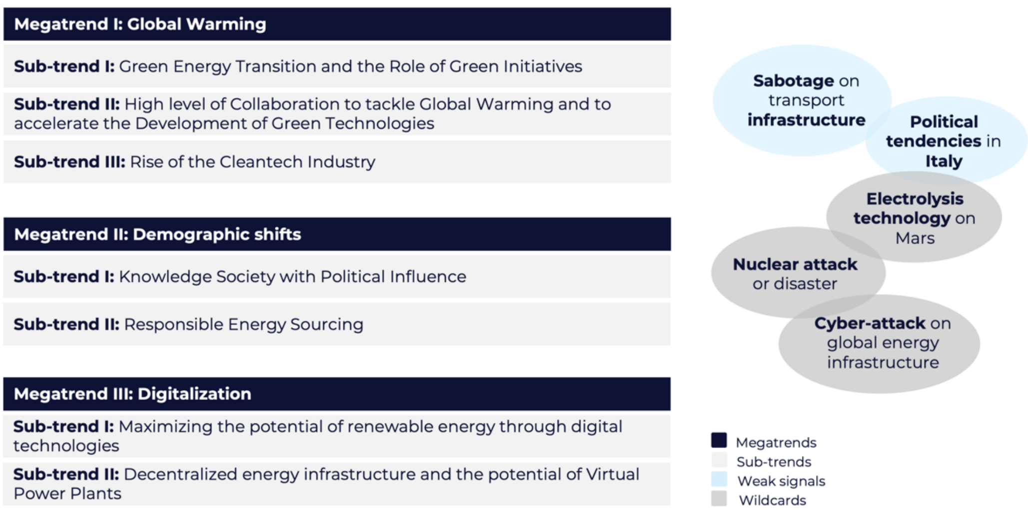

Figure 7: Sources of Change | Source: Own Creation

5.2.1 Megatrend I: Global Warming

The phenomenon "global warming" describes the impact human activities have on the Earth’s climate, polluting ecologically hazardous emissions of “greenhouse gases”, such as carbon dioxide, into the atmosphere. These gases result particularly from burning fossil fuels (e.g., gas, oil, and coal) and widespread deforestation, operating as shields over the Earth's surface and absorbing infrared radiation released by the cover, hence keeping it warmer than it would ordinarily be. Consequently, climate changes occur, threatening the existence of entire species and leading to natural disasters (Houghton, 2005).

Initially discovered at the end of the 19th century and scientifically further investigated in the mid-20th century, global warming has received rising international attention throughout the last ~130 years. Reaching its medial peak of attention around the turn of the 21st century through several scientific studies or popular exhibits, such as the film *An Inconvenient Truth* by former U.S. Vice President Al Gore in 2006, global warming disrupted, and still disrupts, the entire basis of human lives and every primary industry (The Conversation, 2016). Energy suppliers like DEW21 face never-seen challenges and requirements since the turn of the 21st century, leading to challenging adaptions of their full power and energy distribution networks. The megatrend global warming disrupts any production and consumption behaviour on a private, public and economic level, ranging from individual energy sourcing to general waste- and emission management and to the decarbonization of any corporation’s value chain (Zhang et al., 2022).

Therefore, global warming and its hazardous consequences are directly linked to DEW21, urging the energy supplier to transform its residential and commercial heating applications from conventional emission-intensive practices into a green, low-carbon alternative.

Sub-trend I: Green Energy Transition and the Role of Green Initiatives

The green energy transition is the logical and direct consequence of global warming's fatal threat to a sustainable future for human and non-human lives on Earth. Green initiatives, such as the most recognized environmental organization "Greenpeace", serve as accelerator of the green energy transition (Eden, 2004). Since the 1970s, Greenpeace and other assemblies expose global environmental problems through a diverse set of activities: Public education, political lobbying, whistleblowing, and attention-rising demonstrations led to the mobilization of a worldwide disruptive movement, gaining wide media attention and pressurizing global economies to decarbonize (Macmillan, 2016). Throughout high media presence, an international stage for famous activists such as Greta Thunberg or Leonardo DiCaprio, green initiatives still serve a robust and growing trend, playing a key role in accelerating the contextual global, European, national and regional green energy transition (Grimm and Malschinger, 2021).

The influence of Greenpeace and other NGOs achieved its first major success in 1997 with the introduction of the Kyoto Protocol. The Kyoto Protocol can be described as the first international legally binding agreement on the systematic reduction of greenhouse gases, with more than 150 countries participating. Greenpeace, WWF and Friends of the Earth, for instance, not only created a sense of public awareness for global warming's dramatic consequences, but also participated in political lobbying and advisory services in domestic climate policies and the accomplishment of their targets (Gulbrandsen and Andresen, 2004). In The NGOs further aimed at supervisor roles in designing compliance regimes, where their commitment and environmental expertise intended to advise participants and monitor their decarbonization progress. With most of the Kyoto Protocol's participants only achieving a small percentage of the climate objectives, the compliance regime, e.g., by the strong involvement of WWF, played a strategic role in introducing the successive Paris Agreement in 2015 (NRDC, 2021). Joined by some of the most prominent global players, e.g., the United States, China and India, that were missing before, the Paris Agreement yet serves as a benchmark achievement of green initiatives, pressuring economies to accomplish carbon neutrality with technological advancement and political will. Consequently, the European Union formulated a binding "net zero commitment" by 2050, with the German government aiming at a net zero status by 2045. Following this national decarbonization strategy, the city of Dortmund announced this achievement for 2035, creating an urgent demand for DEW21 to accelerate the city's green energy transition (Science, 2020).

Sub-trend II: High level of collaboration to tackle global warming and to accelerate the development of green technologies

From various perspectives, there can be observed increasingly international collaboration to tackle global environmental problems and a high degree of cooperation in discovering and developing innovative green technologies. As commonly agreed with DEW21, in this section, the collaboration is analyzed on a global, European and national (German) level, and respective the project's focal issue, the focus lies on collaboration within the green hydrogen space. Current tendencies implicate a strong collaborative movement, including strong political and economic involvement from governments, leading researchers and industry players – consequently, this section exhaustively analyzes current developments to capture DEW21's contextual driving forces and, thus, to open the space for subsequent scenarios narratives and strategic implications (Chapter 6.2 and 7.1).

(1) Global perspective

Maximizing geographically favourable conditions. As previously discussed, *(sub-trend I: Green Energy Transition and the Role of Green Initiatives)* the Kyoto Protocol (1997) and the Paris Agreement (2015) serve as popular cross-border projects to reduce global warming's hazardous effects collaboratively on a global scale (Macmillan, 2016). As practical and technological solutions of the green energy transition demand a high level of cooperation, such as sharing resources and best practices and making use of geographically favourable conditions (e.g., for the efficient generation of solar power in sun-intensive regions), the trend of collaboration nowadays focuses on bringing different expertise and conditions together, and on jointly maximizing green technologies' efficiency (Santoalha and Boschma, 2019). With green hydrogen playing a crucial role in achieving global decarbonization targets, vast amounts of affordable and renewable electricity are required. Solar and wind (on- and offshore) technologies are the most commonly applied and economically viable green electricity sources, but energy output levels often lack consistency and differ depending on geography and climatic conditions (e.g., high variation in the sun- and wind availability and intensity). Figure 8 illustrates those varying solar PV and wind output levels further by showing a global country comparison of location-dependent solar and wind generation favorability (Figure 9).

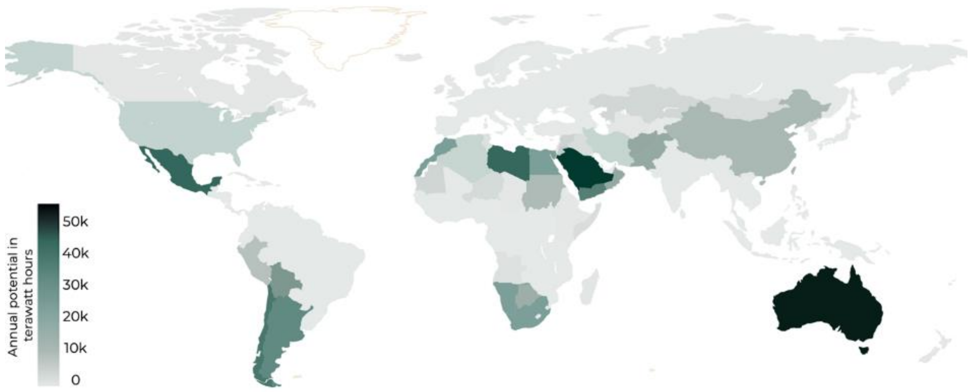

Figure 8: Estimated wind and solar PV resources potential by country | Source: GlobH2E (2021), Chu et al. (2020)

H_2 import models and the central role of green ammonia. Cross-continental collaboration in form of energy import and export is therefore considered as an efficient solution to balance green electricity households in regions where demand levels exceed domestic production levels and capabilities (Figure 9). This Figure 9 emphasizes the unbalanced green hydrogen household in Germany until 2050, indicating the urgent need for substantial (green) hydrogen import to satisfy the growing domestic demand (Australian Embassy, 2021).

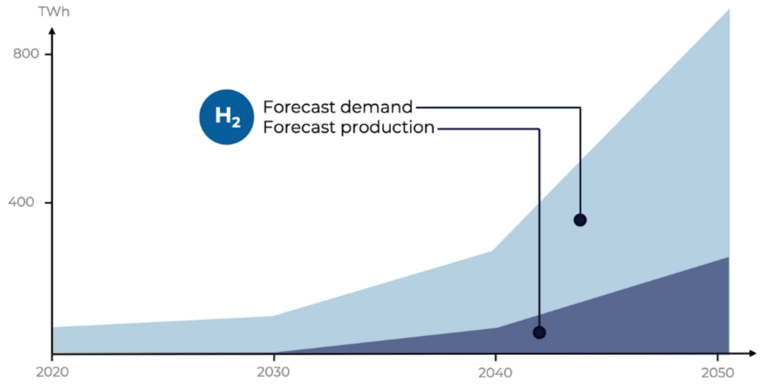

Figure 9: Germany's unbalanced hydrogen household until 2050 | Source: Own Creation, following Fraunhofer Institute (2021), German National Hydrogen Strategy (2021)

One of the leading cross-continental examples approaching that challenge is the *Australia-Germany Hydrogen Partnership:* While Australia's green electricity abundance, due to their vast solar, wind and hydro resources, offers perfect and reliable conditions for the world's cheapest green hydrogen production, on the contrary, Germany is characterized by less favourable conditions for green electricity generation and aims at an economically feasible H_2 import. The collaborative project *Shipping the Sunshine*, with governmental solid, industry and research involvement from both partners, investigates the feasibility of producing green H_2 on Australian territory and afterwards shipping it in the form of green ammonia to the ports of Germany (German National Hydrogen Strategy, 2020). Ammonia offers a more efficient and straightforward transport solution compared to the highly challenging shipment of hydrogen. In comparison, hydrogen's molecules are more difficult to store, and transport and its shipment would require large additional capital investments to construct vessel technologies with complex cooling options down to -250°C. Experts are convinced that the transformation of green H_2 into synthetic LNG or green ammonia is inevitable for shipment purposes to implement economically viable business models, and the re-transformation into green hydrogen via multi-functional LNG terminals at the targeted destination is the preferred way to handle long-distance H_2 import/export activities (Bloomberg, 2022, Figure 10).

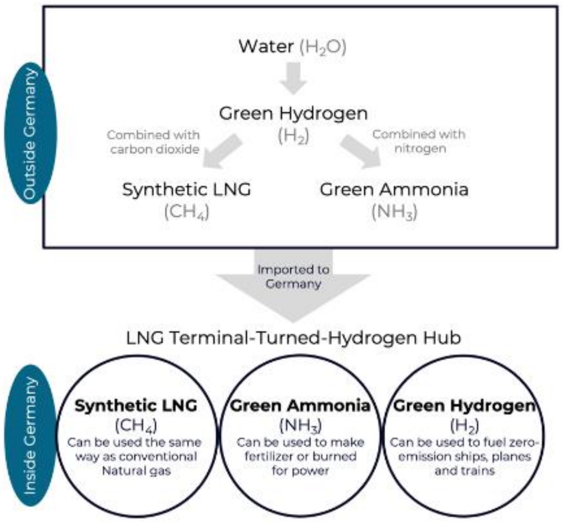

Figure 10: Hydrogen production and shipment transformation process | Source: Own Creation, following Bloomberg (2022)

The complexity of this multi-location production, shipment and transformation process demonstrates the necessity for a high level of international collaboration along the green hydrogen import/export value chain.

Instead of constructing highly complex and capital-intensive dedicated green H_2 terminals, reworking existing LNG terminals', only requiring ~15 percent of the investment amount needed for a new facility, efficiently results in their flexible capability to handle (receive, process and distribute) all, natural gas, green ammonia and green hydrogen, offering the perfect investment opportunity for present and future versatile gas import plans. While in the short-term, LNG terminals can play a crucial part in the urgent solution to breach Germany's dependency on Russia's natural gas by using alternative import options to the existing East European gas pipelines, the terminals can function as green ammonia/hydrogen import stations in the long-term, e.g., when projects like *Shipping the Sunshine* reach practical maturity (Bloomberg, 2022).

Global H_2 projects between industry players. Border-crossing and concrete plans for the construction of versatile terminals, especially in Northern Germany due to its sea accessibility, were announced by the German government and big energy industry players: In cooperation with the company *Air Products*, Germany's first green ammonia import terminal plans to be operational by 2026 and will welcome vessels in the port of Hamburg from Saudi-Arabia. German Economy Minister *Robert Habeck* underlined the project's importance by naming it a "crucial starting point" in accelerating the country's energy supply diversification process (Clean Energy Wire, 2022).

A second major global project illustrating the trend towards high global collaboration in the green energy sector results from a partnership between *E.ON*, one of Germany's largest utilities located 40 Km near DEW21's headquarter and with direct influence via their 39.9 percent capital share of the client, and *Fortescue Future Industries (FFI)*, an Australian global green energy/hydrogen company (E.ON, 2022). Collaboratively, the companies plan to install a 2 GW electrolyser in Australia and to export 5M tons of green hydrogen to Germany, the Netherlands and other European cities by 2030 (Reuters, 2022).

With E.ON inhabiting a dominant role in the green hydrogen hub H_2.Ruhr (section "National Perspective") and participating in the Ruhr area hydrogen development plan, the German energy giant actively seeks a pioneering role in the green hydrogen space, covering all major value chain steps - from production to storage, distribution and conversion (E.ON, 2022).

(2) European perspective

EU's impact on full H_2 value chain coverage via funded IPCEI projects. Cross-country ambitions and projects in the green hydrogen space to accelerate the green energy transition especially face a high level of collaboration within Europe. The European Union historically acted as a strong political and economic alliance since its establishment in 1993 and created a common ground for its nations to jointly formulate its *Paris Climate Agreement 2015* decarbonization targets (Dröge and Geden, 2015).

A total number of 41 green H_2 IPCEI projects on a European level successfully surpassed the application stage and unlocked a total amount of EUR 5.4B in EU funding (Federal Ministry for Digital and Transport, 2022). Including 15 member states and 35 small to medium-sized companies, the initiative *IPCEI Hy₂Tech* covers projects in all stages of the hydrogen value chain, promoting innovation and first industrial applications with R&D activities and commercial pilot deployments. In addition, the incentivized projects expect to release a further EUR 8.8B of private investments, with famous industry players participating, such as Sunfire, Alstom, Daimler Truck or Iveco (European Commission, 2022). Executive Vice-President Margrethe Vestager directly addresses and highlights the rising trend of collaboration within the green hydrogen space with her following statement:

“Today's project is an example of truly ambitious European cooperation for a key common objective. It also shows how competition policy works hand in hand with breakthrough innovation.” – Margrethe Vestager, 2022

European Hydrogen Backbone as continental pipeline interconnector. A further example of continental collaboration towards the establishment of a powerful green hydrogen lobby is the European Union’s heavy resource commitment to create the joint *European Hydrogen Backbone.* The hydrogen backbone, a planned European hydrogen pipeline network, intends to serve as a continental interconnector to unlock geographical-dependent renewable energy potentials and create common ground to balance green energy supply and demand. Involving the EU, national governments, leading scientists and companies across the hydrogen value chain, the project strives to create a functional European hydrogen market and to optimize the economic viability of H_2 production, transport and consumption (Ontras, 2022). By repurposing existing natural gas pipelines and constructing new strategic “hub-connectors”, the European

Hydrogen Backbone plans to have 28,000 Km of operational pipelines by 2030 (Appendix 7). Until 2040, the network intends to measure a total number of 53,000 Km pan-European and predicts an investment amount of EUR 80B – 143B (Appendix 8). The far-reaching project confirms the hypothesis of a strong and growing collaboration trend within Europe and demonstrates its necessity in accelerating the green transition and in pushing innovative renewable technologies towards economic viability and industrial maturity (EHB, 2022).

(3) National perspective

The national perspective in this collaboration section represents the most tangible level for DEW21, from which later (Chapter 7.1) various strategic recommendations, as effective starting point to enter the green H_2 space, are derived and from which distinct sourcing strategies can be pursued.

Hydrogen hub's pioneer role in accelerating Germany's status as a "green hydrogen nation". The operational focus of hydrogen hubs, initiatives and consortia strategically and geographically covers the entire green H_2 value chain and, moreover, areas in Germany's largest industrial H_2 anchor demand centres, characterized by favourable H_2 transport conditions (road-, rail-, water-, and pipeline accessibility).

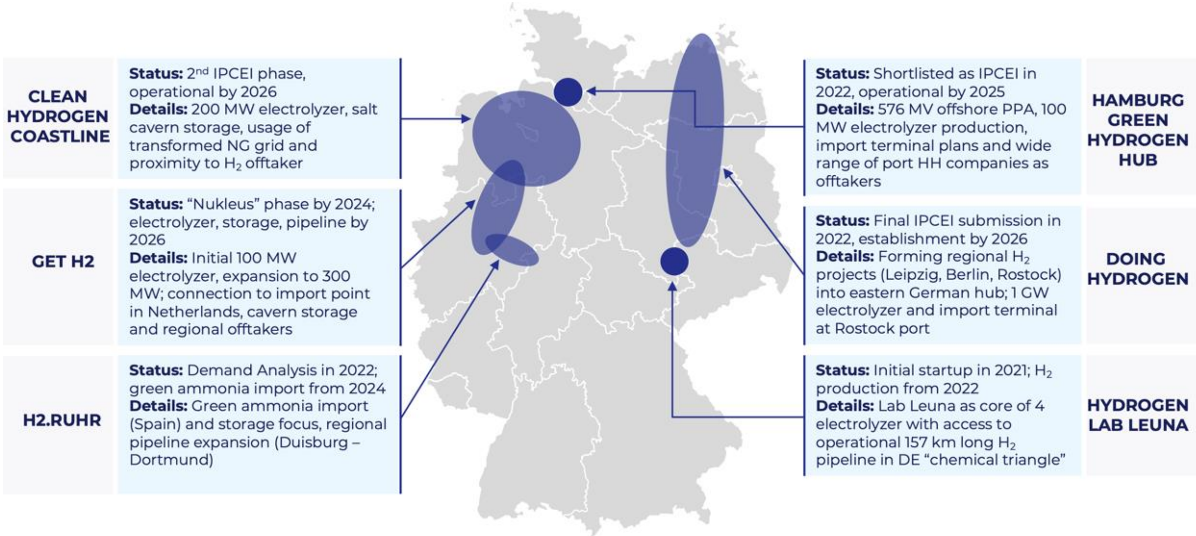

Figure 11: German H_2 Hub Overview | Source: Own Analysis, following Federal Ministry for Economic Affairs and Climate Action (2021), Electrive (2021) and German National Hydrogen Strategy (2021)

Five anchor demand centres for the utilization of green hydrogen were identified in the course of this project and find themselves covered by at least one major green hydrogen hub (Figure 11):

1. **Bremen:** Significant green H_2 demand arises from the steel industry, mainly being concentrated on one demand driver, i.e. the company ArcelorMittal steel (ArcelorMittal, 2022)
2. **Rhein-Ruhr:** Very industry-dense region with several steel production facilities, refinery and methanol production – many high-demand companies are accessible via the existing H_2 pipeline (Thyssenkrupp, 2022) (TÜV Nord, 2021)
3. **Cologne:** Significant hydrogen demand from the chemicals industry (ammonia and methanol) and refining, with an existing H_2 pipeline (HyCologne, 2022) (TÜV Nord, 2022)
4. **Hamburg:** Several potential high-demand companies operating in the refinery and steel industry; a city with concrete plans to establish a hydrogen pipeline network to connect industrial players (Schütte et al., 2022) (TÜV Nord, 2022)
5. **Leipzig/Leuna:** Strong demand from refining and methanol production in the chemistry triangle (Invest in Saxony-Anhalt, 2020)

Moreover, the demand centres already inhabit Germany's existing H_2 pipelines, with a total length of 420 Km. Three main pipeline sections are identified, connecting the chemical/industrial parks of Rhein Ruhr/Cologne (240 Km), Leipzig/Leuna (150 Km) and Hamburg area (30 Km) (TÜV Nord, 2022). By targeting those areas, hydrogen hubs serve as an accelerator of both regional and national green H_2 movements and represent an integral part of the domestic green H_2 strategy (German National Hydrogen Strategy, 2021). By starting this collaborative environment with access to shared resources and standard practices, all companies operating along the green H_2 value chain, from innovative cleantech start-ups to large-scale energy industry players, become part of the national hydrogen movement.

Rising trend of hydrogen hubs offers concrete business opportunities for DEW21. In this report, among the most ambitious green hydrogen hubs, the initiatives *Get* H_2 and H_2 *Ruhr* are important to highlight, as DEW21's geographical proximity to the Rhein-Ruhr area and E.ON's (39.9 percent shareholder of DEW21) leading role in the initiative H_2 *Ruhr* offer concrete and tangible business opportunities.

Get H₂. *Get* H_2 is a consortium of companies that aim to establish a nationwide hydrogen infrastructure, connecting the Lingen and Rhein Ruhr area via H_2 pipeline in its initial "Get H_2 Nukleus" phase, including the construction of a 100 MW electrolyser for green H_2 production in Lingen by 2024. The project aims to expand the pipeline network for hydrogen import purposes to the Netherlands in 2025 and aims to construct further electrolyser and dedicated salt cavern hydrogen storage facilities by 2026. Prominent Ruhr energy players, e.g., RWE and Evonik industries, and other internationally operating companies, such as BP and Salzgitter AG, participate in the initiative, respectively, to their H_2 value chain expertise (Get H_2, NRW.Energy, 2022).

H_2. Ruhr. H_2.Ruhr is part of the larger pan-European "CEO Alliance" of industrial companies cooperating to decarbonize Europe. The goal is to utilize renewable electricity from Italy and Spain and supply green ammonia/hydrogen to end customers in Germany. After achieving the first milestones in 2024 and 2025 by starting the ammonia import and building a 20 MW electrolyser in the Ruhr area, and under the leading role of E.ON, the initiative plans to construct a regional H_2 pipeline from Essen/Duisburg to Bochum/Dortmund by 2032 (H_2. Ruhr, 2022) (E.ON, 2022).

Both initiatives imply tangible business opportunities for DEW21 to enter the green hydrogen space and pursue different sourcing strategies, depending on the industry's overall development. The hubs cover various strategic directions within the green H_2 sector by not only offering exhaustive value chain coverage and valuable pioneer expertise, but also by reinforcing international cooperation and viable H_2 import interests (CSIS, 2021).

Sub-trend III: Rise of the cleantech industry

The rise of the cleantech industry is a trend addressing the major contemporary challenge to accelerate a sustainable and economically viable green energy transition by fostering technological pioneers and by advancing green innovations further into market maturity and profitability (Bergman et al., 2019).

With only the global renewable energy market being forecasted to become worth ~ USD 1.98T by 2030, at a CAGR of 8.4 percent from 2021 to 2030, the cleantech industry shows substantial annual growth rates and moves towards the realization of the sustainable development goal *"Affordable, reliable, sustainable and modern energy for all"* by 2030 (SDG 7) (Allied Market Research, 2021). A high degree of alignment on diverse green energy technologies is required for that achievement. Over the past decade, solar and wind renewables managed to decrease production costs by 70 percent – 90 percent due to economies of scale and scope, after passing through multiple development stages and finally resulting in far-reaching industrial applications (Seedstards, 2019).

The cleantech industry is further shaped by a highly diverse and growing set of renewable technologies targeting various use cases and often acting as a complementary force in establishing a functional net-zero infrastructure, e.g., considering the role of battery energy storage systems (BESS) as a supplement for green electricity sources. Figure 12 captures the current status and future outlooks of innovative and promising clean technologies, finding themselves in different advancement stages and individually moving towards market maturity and technological/economic productivity (Silicon Valley Bank, 2022).

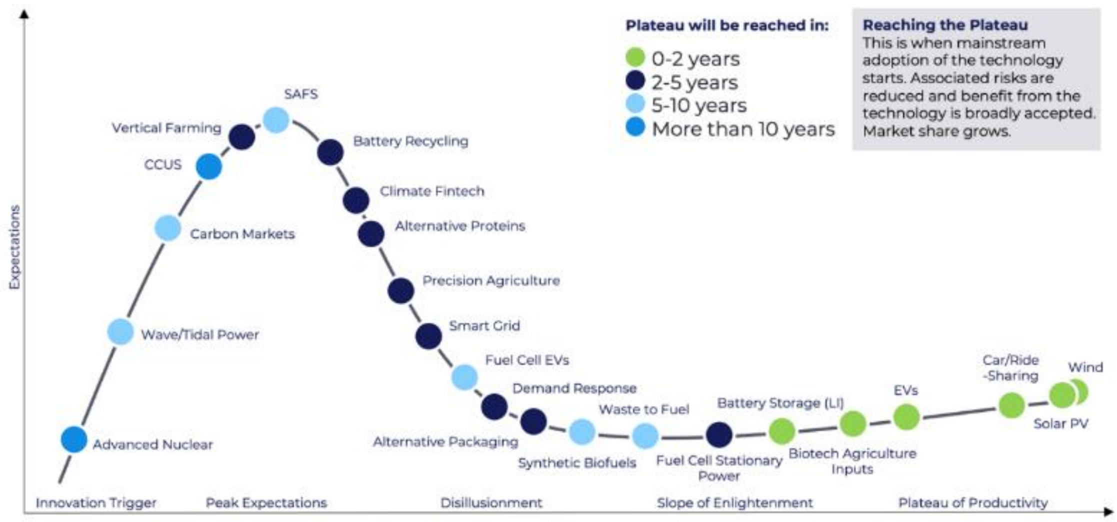

Figure 12: Climate Tech Innovation Hype Curve | Source; Own Analysis, following: Silicon Valley Bank (2022)

The high degree of innovation, vast investment amount, growing industry size, and the success and industrial acceptance of the green highlighted technologies prove the important role of the cleantech industry in achieving a sustainable and economically healthy energy transition, currently representing one of the most far-reaching and disrupting driving forces within DEW21's contextual environment.

5.2.2 Megatrend II: Demographic shifts

Gen Z is rising. The greatest generational cohort in history will have a significant impact on the next decades. This 1.8 billion-strong cohort of individuals, who range in age from 10 to 24, is expanding quickly and makes up 24 percent of the world's population at the moment (EY, 2020). Gen-Z is distinguished by its very high technological, political, and environmental affinity, even if it may be claimed that previous generations are integrating themselves more into the digital and environmentalist era. The emergence of sustainable lifestyles, global awareness, and a greater desire for world news and procedures are the main themes associated with Gen-Z. (PWC, 2020). It is further necessary to note that Gen-Z attitudes are primarily the result of globalization, which gave rise to interactive global news and the sharing of scientific knowledge. In this regard, the scientific enlightenment especially refers to sustainability topics. The megatrend of Gen Z consequently has disruptive effects on consumer industries and on the energy sector, e.g., by exposing recyclability topics in consumer industries or by pushing towards transparent and sustainable energy supply (Resource Innovations, 2019). According to a quote by the *Bank of America*, Gen Z is said to be “the most disruptive generation ever” (WEF, 2022).

Sub-trend I: Knowledge society with political influence

Gen-Z may be further characterized as the "knowledge-society" as a response to the growing haziness around the veracity of sources. They pay great attention to social and environmental concerns, seek out reliable news sources, and seek out scientific exposure (Mosca et al., 2019). The demographic shifts and rise of Gen Z are moreover displayed in the latest political trends, with Germany’s green party achieving its most successful election result in the 2021 federal election (14 percent share of primary votes) (Bundeswahlleiter, 2021). In 2022, the Green Party inhabits an integral part of the German federal government and consequently takes a decisive role in pursuing national decarbonization targets and determining budget allocation plans. The party’s influence on DEW21’s contextual environment becomes visible through their strong involvement in and plea for the German National Hydrogen Strategy, or the EUR 8B net-zero Immediate Action Programme. Incentive schemes with a heavily funded renewable energy expansion are strong signs of the government’s plan to navigate Germany towards an international green technology leadership role (Council of Foreign Relations, 2022).

Sub-trend II: Responsible energy sourcing

The sub-trend of responsible energy sourcing is one further consequence of the disruptive demographic shifts and matured into a far-reaching industry trend, directly affecting DEW21’s business environment. Two perspectives, **(1) International** and **(2) Regional**, are analyzed within this section to capture the full impact of this sub-trend.

International perspective. The Russian invasion of Ukraine in 2022 impersonates the decisive incident causing Germany's strategic turnaround towards responsible energy sourcing – the government's vehement refusal of Russia's aggressive behaviour consequently intends to replace all Russian energy imports by mid-2024. High-level German politicians, such as the German president Frank-Walter Steinmeier or former German finance minister Wolfgang Schäuble, uniformly acknowledged the government's crucial mistake from the past to almost exclusively rely on economically attractive energy imports from Russia (The Guardian, 2022). The challenging effort to reverse this commitment, with Russian gas accounting for 55 percent of all German gas imports in 2021, requires immediate energy import alternatives, e.g., by shifting investments towards green technologies and versatile import infrastructure and focusing on more reliable business partners (WEF, 2022). The German turnaround marked its starting point by establishing the cabinet's energy reform ("*Easter Package*") in April 2022, resulting in a prompt drop in Russian import share from 55 percent down to 26 percent by the end of June 2022. The ambitions to achieve independent and responsible sourcing options are underlined by a diversification strategy for the German energy portfolio with various countermeasures, e.g., reaching a renewable power generation share of 100 percent by 2035, speeding up the construction of viable import LNG/green ammonia terminals, and implementing levies to accelerate the expansion of domestic energy storage projects – many of those countermeasures being linked to the application of green hydrogen (GIS, 2022). Potential new energy import partners are being investigated by Germany, prioritizing exchange relations that are characterized by high economic, political and ethical stability. Energy import from Benelux countries, Norway and France, has already been intensified, whereas import options from Canada, the U.S., or Saudi Arabia are currently being explored (Reuters, 2022). Unfolded consequences for DEW21 are potential natural gas shortages and higher sourcing prices, urging the company to increase the share of renewable energy usage in their business model and to realign towards a diversified heating portfolio with alternative technologies.

Regional (household) perspective. The trend of responsible energy sourcing on a regional level can be considered as a consequence of modern social and sustainability standards and especially becomes visible through the introduction of transparent supply chains and customer offerings in the energy sector. Shifted customer demands and more sophisticated regulations urge energy supply companies to live up to these modern transparencies and reliable sourcing standards, especially when reaching out to residential and industrial areas (MIT Sloan, 2021). Our partner

company DEW21 represents one of the leading examples of municipal utilities addressing this trend by offering a flexible range of different heating packs in their customer portfolio. The six options (Figure 13), essentially varying in the applied heating technology, consequently differ in their respective price, primary energy factor and CO_2 emission (DEW, 2022).

PRICE LIST	Classic	Smart	Smart+	Ideal	Ideal[iq]	Exclusive
Quality → Primary energy factor	1.3	0.7	0.55	0.45	0.45	0.3
Co2 emissions up to	220 g/kWh	135 g/kWh	100 g/kWh	80 g/kWh	80 g/kWh	40 g/kWh
Annual base price	50.16 EUR/kW	107.65 EUR/kW	107.65 EUR/kW	107.65 EUR/kW	57.05 EUR/kW	139.00 EUR/kW
Heat consumption price	5.36 Cent/kWh	5.36 Cent/kWh	8.36 Cent/kWh	10.42 Cent/kWh	4.42 Cent/kWh	12.70 Cent/kWh
CO_2 surcharge	0.607 Cent/kWh	Depending on energy use			0.00 Cent/kWh	0.00 Cent/kWh

Figure 13:DEW21's customer heating packages | Source: Own Creation, following DEW (2022)

The company's transparent heating division business model integrates the customer in the technology selection process and unfolds respective environmental consequences – thereby, responsible energy sourcing can be addressed on an individual household level and captures diverse municipal demands.

5.2.3 Megatrend III: Digitalization

The impactful megatrend digitalization historically disrupted, wiped out and re-created entire industries. Its seemingly never-ending ongoing development plays a crucial role in the energy sector, offering existing and innovative technologies a wide range of opportunities – especially in the space of renewables; digitalization provides effective tools and ways to maximize energy potential, output and efficiency (McKinsey, 2020). A system-wide digitalization energy action plan called "Digitalisation the energy system - EU action plan" was introduced by the Commission in October 2022. It intends to facilitate the development of a sustainable, (cyber)secure, transparent, and competitive market for digital energy services while maintaining data privacy standards and securing financing of the pan-European digital energy infrastructure (Euractiv, 2022). Through research and innovation projects within the Horizon Europe research program and in coordination with other programs like the Digital Europe Programme, the LIFE Clean Energy Transition sub-programme or the Connecting Europe Facility, the European Commission is building a fundamental network to advance the energy system digitalization. Five key areas are targeted to achieve the highest possible impact, namely (1) setting up a continental data sharing & monitoring infrastructure, (2) implementing transparent citizen-integration tools, (3) intensifying the usage of digital technologies in existing grids, (4) establishing a real-time cybersecurity system network, and (5) pushing for higher collaboration between IT sector and climate neutrality initiatives (European Commission, 2022).

Digitalization poses not only far-reaching opportunities but also possible threats and challenges to the interconnected energy infrastructure – as elaborated in section 5.3 (Massive cyber-attack on the global energy infrastructure), potential cyber-attacks resulting in data leakages or deliberate energy blackouts require unprecedented security standards (IEA, 2017).

Sub-trend I: Maximizing the potential of renewable energy through digital technologies

As a consequence and sub-trend of the disruptive megatrend digitalization, numerous innovative technologies, practices and infrastructure projects arise in the energy sector to maximize the use of renewable energy. Renewable technologies (e.g., solar and wind power) often share the common challenge of balancing uneven energy supply and demand levels – not only due to different geographical conditions, but also due to excess generation hours during the day (e.g., from sunlight and wind abundance), and insufficient generation on the contrary at night - conditions that can hardly be influenced by human impact. Consequently, this uneven energy distribution regularly results in a loss of energy surplus as long as comprehensive energy storage facilities are missing. Considering the consequences of energy loss, e.g., lacking renewable energy utilization targets, or missing out on vital income to refinance costly green technologies, leading industry players and governments are in the spotlight to yield practical solutions (Power Technology, 2018). Therefore, smart grid solutions, with integrated digital monitoring and distribution tools, are developed, not only leading to a more efficient electricity transmission with lower cost and consumption but also to the critical exposure of potential grid constraints or the integration of large-scale renewable energy technologies (e.g., energy storage units) (Techopedia, 2017). Linking those smart grids with complementary energy storage solutions, e.g., in the form of Battey Energy Storage Systems (BESS), green hydrogen storage tanks as an energy carrier, or dedicated storage facilities such as salt caverns, offers an efficient digital solution to address the unbalanced energy distribution and the loss of surplus energy (Zhou et al., 2020).

Sub-trend II: Decentralized energy infrastructure and the potential of Virtual Power Plants

Furthermore, this digital and physical interconnectedness between power generation units, power storage systems and power consumers can mature in advanced networks called “Virtual Power Plants” (VPP) – characterized as decentralized energy infrastructure, VPPs function as battery aggregation an energy sharing structure, controlled by one principal control unit (Sympower, 2022). The increasing trend of decentralization in this context serves two major purposes: Firstly, to erase the vulnerability of few centralized, large-scale power stations, and secondly, to prevent constraints in the power grid that are caused by overloading in single areas – decentralization distributes the power load too many individual units (Toshiba, 2022).

5.3 Other sources of change

In general, this section 5.3 extends the contextual environments analysis scope from severe trends to more unlikely but potentially highly relevant future sources of change. The chapter lists various potential sources of change accordingly to two main categories: **(1) Weak Signals** and **(2) Wild Cards**. Weak signals refer to occurring external warnings that are presently not at a matured stage but already show tendencies of certain developments, making it challenging to accurately analyze their impact on change. In a later stage, they could evolve into a wild card – events that are unlikely to arise from a current perspective and that show no concrete signs of appearance, but if so, unfold dramatic and disruptive consequences for the formulated focal issue and business context of DEW21.

5.3.1 Weak Signals

Sabotage on critical transport infrastructure. On 26th September 2022, authorities detected three leaks in the Nordstream pipeline, which led to a drop of pressure in the pipeline channel. Danish and Swedish authorities confirmed that gas was leaking from the Nord Stream 1 pipeline near the Danish island of Bornholm at two locations. The explosions probably also caused damage to the Nordstream 2 pipeline (BBC, 2022). The European Union now considers sabotaging as probable cause for the leaks in the Nord Stream gas pipelines. It is unclear which actor caused the attack on the pipelines, but the effort for such action is extensive, and therefore it is likely that a highly professional group or possibly a state were involved in the sabotage. It is not yet clear whether it will be possible to repair the pipelines in the future, but in optimistic scenarios, repair time requires at least six months. As the pipelines are located offshore in a water depth of about 50 m, a complex restoration can only be carried out with diving robots and deep-sea divers. If the leak size is not too big, the repair can be accomplished with clamps. Otherwise, the corresponding pipeline section has to be replaced by a new pipe with precisely the exact dimensions (MIT Technology Review, 2022). However, the explosions could destroy the pipelines forever if the leaks are not sealed quickly and adequately. The inflowing saltwater could soon cause corrosion, rendering the pipelines unusable (BBC, 2022).

Although there are efforts to strengthen critical infrastructure monitoring, this is hardly possible due to the significant number of pipeline networks (Interview Peter Flosbach). Moreover, 18 percent of total European gas imports and 50 percent of Russian gas exports went through Nordstream 1, reinforcing the importance of energy security of supply from such pipelines (MIT Technology Review, 2022). Supposing that Germany and European countries remain dependent on individual transport routes for their energy supply, this could lead to extreme price fluctuations and security bottlenecks.

This incident shows how vulnerable pipelines as main energy infrastructure means are, and how further related developments could lead to serious supply problematics. Diversification efforts, in regard to infrastructure expansion, e.g., by shipment or railway transport, should be taken into to consideration to keep this weak signal’s threat to an acceptable minimum (Interview Dr Jens Kanacher).

Threatening political tendencies in Italy. The post-fascist party Fratelli d'Italia (FdI) led by Giorgia Meloni, became in September 2022 the most potent force in Italy (Reuters, 2022).
There is great concern that Italy, under right-wing populist leadership, will join the ranks of EU critics. If one also considers the new right-wing government in Sweden, the Italian right-wing turn could contribute to changing the fronts in EU politics (BBC, 2022). There is a trend as governments come to power in Europe that are more to the right of the political landscape and are often critical of Europe. In that case, it can complicate and hinder European cooperation regarding the development of shared green H_2 research, production, or infrastructure projects. The failure of intended pipeline projects due to lack of consent from transit countries shows the example of France with the failed construction of the Pirineus- MidCat pipeline. In 2013, France and Spain planned a new gas pipeline to connect the Midi region in southern France with Catalonia in Spain and cross the Pyrenees over a distance of 180 Km (European Commission, 2016).
Construction of the pipeline on the Spanish side has started and runs from Barcelona to the edge of the Pyrenees. However, France has already terminated the project and will not continue to build the pipeline on French territory. This is justified by missing economic efficiency and ecological effects (RFI, 2022). Furthermore, since many infrastructure projects are carried out jointly within the EU, it is crucial that all countries make their contribution to infrastructure development. However, EU-critical governments may delay essential projects and put their national interests first. Therefore, it will be critical that this weak signal does not turn into a trend and thus slows down the necessary energy infrastructure expansion.

5.3.2 Wild Cards

Electrolysis on Mars. The mainly undiscovered planet Mars is characterized by freezing temperatures; consequently, hardly any liquid water exists, but if so, liquid water contains an enormously high level of salt. Following usually applied “electrolysis” hydrogen production techniques, where vast amounts of water are involved, a complex process to remove salt from the absorbed water is required. In latest developments, engineers at the McKelvey School of Engineering at Washington University in St. Louis developed a new technology in which oxygen and hydrogen can be extracted directly from the salt water, making the process much more efficient. The new system can produce 25 times more oxygen with the same amount of energy than a conventional electrolysis process. The brine electrolysis system was validated under typical terrestrial conditions and tested in a simulated Martian atmosphere at -33 ºF (-36 ºC).

This novel process represents a wild card that enables uncontested efficiency possibilities in green hydrogen production, leading to higher output levels by adding non-pure water to conventional electrolysis technologies (Washington University in St.Louis, 2020). In conclusion, the electrolysis process can become much more cost-efficient by this innovative discovery, especially when applied in regions that are characterized by a high PV-output potential and high proximity to salt-containing water sources.

A nuclear attack by Russia. A Russian nuclear strike would throw the world into chaos and provoke a counter-reaction from the West. Regarding nuclear weapons, a fundamental distinction is made between tactical and strategic nuclear weapons.

If Russia feels isolated by its surrounding countries and fears losing the ongoing conflict between them and their neighboring state Ukraine, the possibility exists that Russian forces could launch several tactical nuclear strikes against the western world and their closest enemy. In response, the NATO would be forced to enter the conflicts and initiate direct operations targeted at Russia. Such spiral of heavy escalation could quickly develop into a scenario of a global war, resulting in fatal consequences, not just for any existing energy infrastrcuture (Council on Foreign Relations, 2022).

A catastrophe in a nuclear facility in Europe. A significant incident in a nuclear power plant illustrates one further threatening wild card that could cause dramatic consequences for any future energy development – with the highest risk for such catastrophe to happen being located in the country of Ukraine.

The Zaporizhzhya nuclear power plant, with six reactors, the largest nuclear power plant in Europe, has been controlled by Russian troops since the beginning the Russian invasion in March 2022. In recent weeks, the area around the nuclear plant has been repeatedly shelled, for which Ukraine and Russia have blamed each other. According to the Russian occupiers, there have also been attacks on buildings at the power plant site. This fuels fears that Zaporizhzhya could suffer a nuclear disaster similar to the one that occurred in 1986 in Chornobyl, Ukraine, which was then part of the Soviet Union (Reuters, 2022).

The head of the International Atomic Energy Agency (IAEA), Rafael Grossi, warned of the danger of a nuclear catastrophe after inspecting the plant. UN Secretary-General Guterres called for establishing a safety zone around the Zaporizhzhya nuclear power plant. Artillery shells have been hitting the power plant site since early August 2022. However, these can be intercepted by the outer protective cover made of concrete, as nuclear power plants are built very robustly and are equipped to withstand aircraft crashes (Reuters, 2022). Nevertheless, directly targeted missile attacks with stronger explosive forces still pose a serious threat.

Moreover, in the event of a large-scale power failure and the loss power supply for several weeks, a “super meltdown” could occur that overpressures the reactor and consequently leads to a nuclear disaster.

However, the probability of this wild card to evolve in serious consequences remains limited, as both parties, Russia and Ukraine, would suffer significant damages (CBS, 2022).

Massive cyber-attack on the global energy infrastructure. The trend section in *Phase II: Explore* already displayed the vulnerability of any digital energy infrastructure to fatal cyber attacks, resulting in a far-reaching and large-scale power outage across Europe. A power outage could last at minimum hours, potentially even several days, forcing impacted regions to a feared stand-off condition – by failing all means of non-physical communication and disrupting all essential technologies, pure chaos would be likely to occur (Planet Wissen, 2019). Moreover, any unexpectedly massive fluctuation in the powergrid can lead to system breakdowns. Despite that, cyber attacks, any other forms of sabotage, and extreme weather conditions, represent the most feared wildcards in this context to evolve into reality (McKinsey, 2020).
However, leading powergrid and system operators developed various security mechanisms, e.g., by implementing decentralized network structures, and therefore, this dystopian scenario remains unlikely to happen, but relevant to bear in mind (Allianz, 2016).

5.4 Uncertainties

Uncertainty definition and power ranking

At this stage, the goal is to capture and define relevant uncertainties of the focal issue and to evaluate potential key uncertainties. In this section, respective uncertainties are identified, defined, and moreover, ranked according to their level of uncertainty and impact on the focal issue. The ranking is based on the "Uncertainty Mapping Scale" (Appendix 6), which constitutes a classification range for both factors of interest, namely the level of uncertainty and the level of impact, between 0 and 10. The scale ranges from "certain to predict" and "impactless" to "unpredictable" and "transformational impact". The ranking of each uncertainty passed through a severe decision-making process: Scientific research, the consultation of online sources, expert interviews and intensive client interaction were integrated into this evaluation process. Thus, the following uncertainties were elaborated: ***Economic viability****; **Regulations for H_2 transport and green H_2 production**; **Hydrogen transport options**; **Political stability**; and **Infrastructure development***. In the subsequent *Chapter III: Synthesize*, a comprehensive visualization of all uncertainties and their respective ranks will be provided and further demonstrated.

5.4.1 Uncertainty 1: Economic viability

As of 2022, it is not economically feasible to produce and utilise green hydrogen. As long as the cost of carbon emissions is not factored into the price of fossil fuels, they remain significantly less expensive than renewable energies.

In order to transform green hydrogen into a price-competitive energy source, the cost of hydrogen technology needs to be pushed further down. Presently, the production price for green hydrogen ranges globally between USD 2.7 to 8.8/kg, with all analyses predicting a significant price drop by 2030 to a range of USD 2 to 6/kg, considering that in the production of green hydrogen, operating expenses are highly tied to the cost of renewable power and are thus the primary factors in reducing production costs (EPRI & PWC, 2019a). Solar power already has levelized costs below USD 17.50/MWh, and these costs are predicted to decline further. Economies of scale and manufacturing efficiencies are predicted to be generated in the future; hence, the electrolysis capital expenses are anticipated to reduce dramatically over time (EPRI & PWC, 2019a).

Overall, the global production and consumption of hydrogen must be accelerated in order to exponentially advance such technological development and economies of scale, let alone attain the critical mass of hydrogen required for some early sectors to migrate to the new technology

(National Hydrogen Strategy,2020). If the conditions regarding the scale-up of electrolysis and the cost decline are met, Bloomberg's analysis suggests that before 2050, green hydrogen could be produced for USD 0.7 to 1.6/kg in most parts of the world, making this energy source price competitive with natural gas (Bloomberg NEF, 2020).

Power ranking. *All things considered, this uncertainty has a four out of ten level of uncertainty and a five out of ten impact rating. In this particular instance, economic viability will vary according to the macro conditions of the hydrogen network. Nevertheless, as defined by the predetermined element that hydrogen will play a major role in the future energy market, it will be only moderately relevant to the focal issue. As hydrogen will be a major energy carrier, as long as climate neutrality targets need to be met, and with the issue of the final price passing on to the end customer, its uncertainty can be described as somewhat predictable.*

5.4.2 Uncertainty 2: Regulations for H2 transport and green H2 production

Similarly to other nations, hydrogen's legal and regulatory framework is still incomplete in Germany. The German Parliament enacted an amendment to the Energy Act containing new rules for the regulation of hydrogen networks on July 24, 2021. The Energy Act change is intended to facilitate the gradual development of a hydrogen infrastructure in Germany, but nevertheless, it is still a transitional solution. Definitive legislation implementing German law is expected to begin in 2025, and it is predicted that the rules for hydrogen networks will continue to be shaped in accordance with changes in European laws (CMS, 2021).

On the topic of European laws, there is still no consensus about the criteria for determining what percentage of renewable electricity needs to be used in the production of hydrogen via electrolysis for this to be considered renewable. Germany advocates more flexibility is required for the criterion of renewable electricity for the generation of renewable hydrogen, particularly during the ramp-up phase of the market. Germany proposed a progressive phase-in, with 20 percent in 2026, 25 percent in 2028, and 30 percent by 2030, as opposed to a requirement that electrolysers use only renewable power. Additionally, Germany asked the Commission to consider introducing a clause that allows hydrogen imports from outside the EU to be considered “green” under similar conditions to establish strong global supply chains (Kurmayer, 2022).

According to Bloomberg's projections, it will be possible to achieve a delivery price of around USD 2/kg in 2030 and USD 1/kg by 2050. For these scenarios to be possible, there must be a significant increase in demand as well as cost reductions in transport and storage technologies. Despite the fact that hydrogen is a popular topic at the moment, there is little government legislation in place to facilitate these developments (Bloomberg NEF, 2020). The policy is essential to achieve a delivery price of $1/kg for green hydrogen, along with a significant increase in demand combined with cost reductions in transport and storage technologies, as previously mentioned. And while hydrogen is now a hot issue, there is little government regulation in place to facilitate its use. In general, policy measures are frequently centred on costly road transport applications, and programmes receive inadequate funding. In addition, government money will play an essential role in the development of these initiatives (Bloomberg NEF, 2020).

Power ranking. *This uncertainty has a level of uncertainty of <u>six</u> out of <u>ten</u> and an impact rating of <u>five</u> out of <u>ten</u>. As there is still no consensus about many of the variables in the context of green hydrogen imports and local production, there is still some uncertainty around the subject, although there is already a range of options. As for the degree of impact on the focal issue, it is moderately impactful, as it balances the risk level for hydrogen investors, hence accelerating or delaying the ramp-up phase.*

5.4.3 Uncertainty 3: Hydrogen transport options

Presently, hydrogen is delivered from its site of production to its point of consumption by pipeline, via road, and via the sea. The recently introduced European Hydrogen Strategy acknowledges the significant role that hydrogen transport will play in facilitating the adoption of renewable hydrogen in Europe. Pipelines are installed in places where a large demand per day, several hundreds of tonnes, is anticipated to stay consistent for in the long run. In places where demand is modest or emerging, liquefaction plants, liquid tankers, and tube trailers are utilised. Distribution of hydrogen through chemical carriers, such as big barges, is also being looked at for large-scale uses like export markets. (*Hydrogen Delivery*, n.d.)

Compressed hydrogen gas proves to be the cheapest alternative for short lengths up to 3,000 Km, particularly in the case of pipelines. Above about 16,000 Km, the least expensive solutions relate to ships carrying chemical carriers containing both liquid organic hydrogen carriers (LOHC) and ammonia, which may be the preferable method of hydrogen supply (Appendix 9). A more dispersed distribution scenario with smaller quantities of hydrogen leads to different findings since transport and storage costs considerably increase (Ortiz Cebolla et al., 2022).

As there is no universally ideal hydrogen distribution method applicable to all transit scenarios, the most cost-effective method of transporting hydrogen varies depending on distance, quantity, and the availability of existing infrastructure. Compressed and liquefied hydrogen solutions, particularly compressed hydrogen pipelines, are less expensive than chemical transporters across distances that fit with European territory. It is anticipated that the reconversion of existing natural gas pipelines for hydrogen consumption would dramatically reduce the cost of distribution, enabling pipelines to be even more competitive in the future, with savings of more than 15 percent compared to a newly constructed pipeline (*European Hydrogen Backbone*, 2022). Chemical carriers, on the other hand, become more competitive when delivery distance increases due to their reduced transport costs, thereby expanding import choices to Chilean or

Australian providers, for instance. Unloading chemical carriers account for a substantial portion of their entire cost; hence, optimising unloading operations is crucial to enhancing the competitiveness of chemical carrier pathways (Ortiz Cebolla et al., 2022).

Power ranking. *The above-analysed uncertainty has a degree of uncertainty of seven out of ten and an impact rating of six out of ten. The adopted method for hydrogen transport is widely dependent on the available infrastructure as well as the partnerships developed, making it quite uncertain to predict. Regarding the degree of impact on the focal issue, it is seriously impactful once the cost varies greatly with the delivery method, thereby increasing or decreasing hydrogen's competitiveness with other energy sources.*

5.4.4 Uncertainty 4: Funding

As of early 2022, the industry had 680 large-scale hydrogen projects worldwide, of which 534 are expected to be fully or partially runnig by 2030. This represents USD 240 billion out of the USD 700 billion required in direct investments in hydrogen value chains by 2030. About a third of these 534 project ideas are undergoing feasibility and FEED (front-end engineering design) investigations, totalizing USD 109 billion. Though only about 10 percent of the projects, USD 22 billion, have an undisputed final investment decision (FID), and are under development operating. Europe comprehends roughly 30 percent of the world's anticipated hydrogen investments, with over 314 project proposals and 258 aiming for full or partial commissioning by 2030, totalizing USD 76 billion, of which USD 32 billion of this amount is in the planning stage, while USD 6 billion represents committed investment. The rapid adoption of financial mechanisms to promote the deployment of hydrogen is, therefore vital and will drive more developed initiatives forward. As indicated previously, in Europe, there are USD 32 billion worth of project ideas through feasibility or FEED studies, and an acceleration of financing might help move them forward, significantly accelerating the development of hydrogen networks (McKinsey & Company, 2022).

Although a variety of governments have committed direct public financing until 2030 to build their national hydrogen industries, the mobilisation of private money is equally essential to achieving net-zero goals. The European Union has established the European Clean Hydrogen Alliance to aid in the development of a clear and robust pipeline of viable investment projects, with the aim of coordinating investments and policies along the hydrogen value chain and fostering cooperation between private and public actors. Nevertheless, the majority of government programmes are ambiguous about private investment mobilisation (EPRI & PWC, 2019b).

Hydrogen hubs, also known as clusters of large-scale demand, are geographic places that are home to a high number of current and potential hydrogen consumers who work in a wide range of sectors. Co-location within hubs can make the process of expanding infrastructures like industrial pipelines, storage facilities, and refuelling stations more efficient by fostering economies of scale and synergies from sector coupling to assist in the development of the value chain (EPRI & PWC, 2019b). To be determined is whether or not the existing hubs for trading gas in the EU will also serve as hubs for trading H_2 in the future. Even though the Port of Rotterdam appears to be in an excellent position to ensure the Netherlands' status as a key H_2 hub, it is anticipated that more hubs may arise. For instance, the Dutch government plans to invest up to 338 million euros in environmentally friendly hydrogen projects in the north of the Netherlands to develop an integrated hydrogen ecosystem. This is in addition to planned investments of EUR 9 billion, the majority of which will come from private sources (EPRI & PWC, 2019a). Furthermore, as stated by Saudi Crown Prince Mohammed bin Salman20, Greece has the potential to become the preferred hub for H_2 imports from North Africa and the Middle East (*A Guide to Solve EU's Hydrogen Dilemmas*, 2022).

Power ranking. *The previously analysed uncertainty has a degree of five out of ten and an impact rating of four out of ten. The degree of uncertainty in this topic is characterised by its neutrality, as there are still few insights on the funding source, that is, whether hydrogen projects will be funded with private or public funds. As for the level of impact on the focal issue, as the major role of hydrogen in the future energy market is a predetermined element, this funding uncertainty is also pressured by climate neutrality targets, thus making it a low-impact issue.*

5.4.5 Uncertainty 5: Political stability

Germany intends to develop a robust domestic market that encourages other nations to adopt hydrogen technology in order to expedite the introduction of green hydrogen in Europe. Incentives for accelerating the deployment of hydrogen technology in Germany are to be created, especially for the creation and operation of electrolysers that are compatible with the energy transition. However, local production of green hydrogen will fall short of meeting all new demands, therefore, the majority of hydrogen will have to be imported (Federal Ministry for Economics Affairs and Climate Action, 2020).

There are a number of locations in the EU where substantial amounts of power are derived from renewable sources. These provide tremendous promise for the production of green hydrogen. To this purpose, a collaboration between the European Member States is crucial, including those bordering the North and Baltic Seas where perfect sites for wind energy are located, as well as those in southern Europe with enormous potential for photovoltaics and wind energy, in order to secure the expansion of generation capacity. This possibility can provide a significant long-term opportunity for renewable hydrogen production. Furthermore, Europe's well-developed gas infrastructure helps facilitate the transportation of hydrogen. To this end, it is necessary to create solutions for the generation of wind and solar energy in the respective regions, and for the delivery of hydrogen, cross-border cooperation is essential. Germany aims to provide suppliers, consumers, and investors in Germany and abroad with the confidence to plan ahead and to use its hydrogen strategy to promote the establishment of production capacity and new supply chains, as well as to provide our partner nations with the relevant technology and targeted solutions (Federal Ministry for Economics Affairs and Climate Action, 2020).

As highlighted above, importing renewable energy from outside the European internal market will become a need in the medium and long term. Therefore, international commerce of hydrogen and its derivatives is an important industrial and geopolitical element that raises a number of complex concerns. If centred on the needs of the parties, international collaboration with potential suppliers and importers can increase their contribution to climate change mitigation, can accelerate the deployment of hydrogen technologies, and can offer chances for sustainable growth and development (Federal Ministry for Economics Affairs and Climate Action, 2020). It is determinant to ensure international coordination, as well as support credible shared standards and robust certification mechanisms for international trade. To achieve the production of hydrogen with the smallest carbon footprint and to fully exploit its climatic advantages, a consistent standard technique for evaluating all hydrogen production methods is required. Robust certification systems are essential for establishing customer confidence and clearing the road for global hydrogen commerce, which will facilitate scale-up and lower the price of hydrogen (McKinsey & Company, 2022).

In the context of political stability, the biggest factors to take into account are conflicts in the scope of either politics or economics between EU countries, as well as between countries that play a crucial role in the green hydrogen value chain. In more severe conflicts where there is already a scale-up of tensions, for example, between Algeria and Morocco, or even a full-out war such as the one in Ukraine, this uncertainty maximises its impact.

Power ranking. *The political stability uncertainty has a degree of* *seven* *out of* *ten* *and an impact rating of* *eight* *out of* *ten*. *The political stability is quite uncertain to predict, and especially in the present, where Europe has a full-scale war at its doorstep, as well as political economical factors that are generating tensions between various countries, both in the EU and in some of the countries that play an important role in the hydrogen value chain. Regarding this uncertainty's impact on the focal issue, it is very high once the establishment of the various delivery options are critically linked to the ability of the various players along the value chain to cooperate with each other and create reliable supply options*

5.4.6 Uncertainty 6: *Infrastructure development*

In contrast to other renewable energy sources, hydrogen is a new renewable energy carrier, which necessitates that its supply, demand, and infrastructure all be increased simultaneously. Unlike wind and solar power, which create a final product with established demand and pre-existing infrastructure, electricity. It takes several years to develop and implement the infrastructure for large-scale hydrogen use, such as pipelines and export and import ports. For instance, it can take up to twelve years to develop and construct a natural gas pipeline and ten years to construct a LNG terminal, and the duration required to construct a hydrogen infrastructure would not be any different. In a perfect scenario, the necessary infrastructure would be constructed concurrently with a rise in hydrogen demand and a decline in its price, such that sufficient amounts of hydrogen could be sold and transported by 2030. Post 2030, the more aspirational scenarios foresee an increase in hydrogen consumption, followed by a further increase beginning in 2035. This is consistent with the time necessary to create the infrastructure, for which planning has already begun, in order to meet the hydrogen objectives and the anticipated increase in demand after 2030 (EPRI & PWC, 2019b).

In order to capture the greatest climatic value of hydrogen, the investments in hydrogen by 2030 must reach around USD 700 billion; essentially, additional investments of USD 460 billion in hydrogen projects through 2030 are critical. In reality, this represents less than 15 percent of the investment made in oil and gas over the previous decade. Across the entire value chain, investments in the infrastructure that connects supply and demand are not performing as well as they should because there isn't enough information about demand (McKinsey & Company, 2022). Numerous nations, such as Germany, will not be able to meet all of their hydrogen demand through domestic production; hence, hydrogen trading represents the future of the whole hydrogen value chain. Hydrogen infrastructure has the largest gap between stated projects and those necessary to reach net zero targets. Only ten percent of projected expenditures now target hydrogen infrastructure, showing a shortfall of around 85 percent of the necessary $200 billion in spending through 2030. The industry should concentrate its efforts on developing infrastructure to facilitate cross-border commerce and generate more ideas in these areas. As international collaboration among governments increases, the private sector should actively assist in prioritising efforts to facilitate international trade flows that efficiently match supply and demand. Terminals, large-scale hydrogen storage, hydrogen transports, conversion technologies, and networks of refuelling stations must be included in such proposals (McKinsey & Company, 2022).

Moreover, infrastructure for hydrogen generation, transport, and storage presents considerable obstacles to its adoption in end-use industries. The cost of infrastructure, which varies based on the location of supply and demand, used technologies, and early-stage public and private assistance, might offer challenges to future advances (EPRI & PWC, 2019b). In reality, hydrogen-specific characteristics, such as the low density of hydrogen, make it more difficult to store than fossil fuels and more expensive to transfer by road or sea. However, hydrogen runs through pipes approximately three times quicker than methane, making it a cost-effective choice for large-scale transportation. To make hydrogen as prevalent as natural gas, however, would need a massive, planned programme of infrastructure renovations and development, as hydrogen is frequently incompatible with current pipelines and systems.

If hydrogen were to replace natural gas in the global economy today, three to four times more storage infrastructure would need to be constructed by 2050 at the cost of USD 637 billion in order to maintain the same degree of energy security. Given that low-cost, large-scale options, like salt caverns, are geographically constrained and that the cost of altering it is typically higher than the cost of creating hydrogen in the first place, large-scale hydrogen storage will be among the key difficulties for a future hydrogen economy (Bloomberg NEF, 2020).

Power ranking. *The infrastructure development uncertainty has a degree of nine out of ten and an impact rating of eight out of ten. The infrastructure connecting European countries and the fixed infrastructure for hydrogen imports is inconclusively predictable, as it constitutes the greatest pressure point on the hydrogen value chain, as its development might quickly turn hydrogen into a highly efficient and easy-access renewable energy source or into an expensive and inefficient renewable source, delaying the ramp-up phase, a Regarding the impact on the focal issue, it is very high, as the sourcing options will be highly dependent on the infrastructure developed from the point of production to the point of delivery.*

6. Phase III: Synthesize

6.1 Scenario development process

Uncertainty mapping & identification of two critical uncertainties

In the narrowing phase, we refined the uncertainties associated with the driving forces and thus, developed an all in all “Uncertainty Mapping” (Figure 14). As visualized and explained in the previous section, we prioritized them according to two criteria: (1) the degree of importance to the focal issue, and (2) the degree of uncertainty surrounding those forces. The map illustrates the derived two key uncertainties “Political Stability” and “Infrastructure Development”, both characterized by the highest consensus with the formulated requirements. In this *Phase III: Synthesize*, the critical uncertainties are captured to create resulting scenario narratives of foresighted future states.

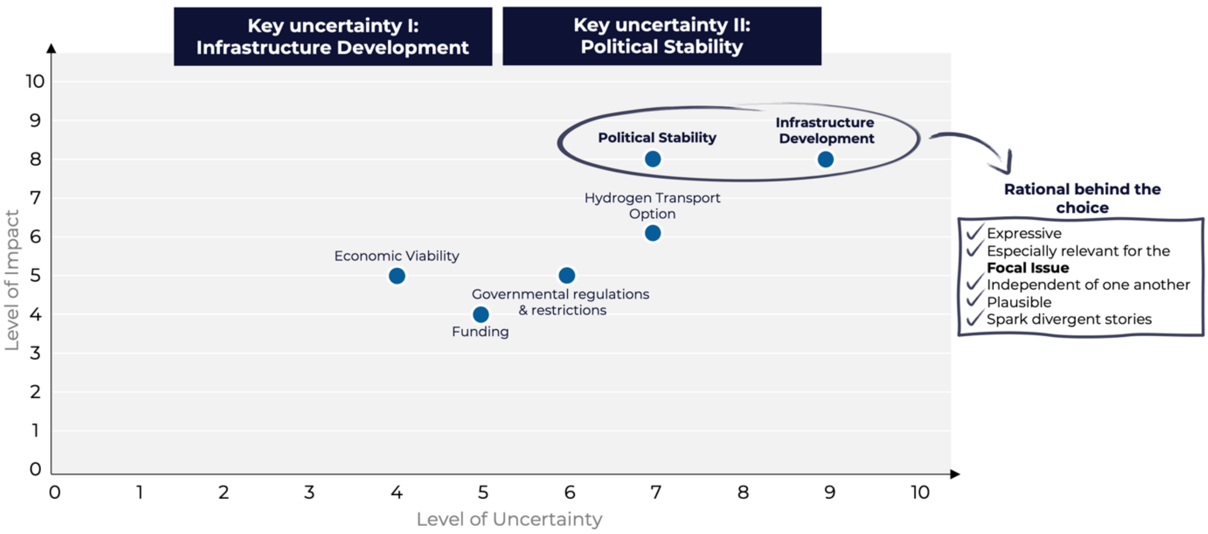

Figure 14: Scenario Uncertainty Mapping | Source: Own Creation

Critical uncertainty I: Political Stability (Recap)

The first critical uncertainty, “Political Stability”, means to address national, pan-European and global collaboration in the space of renewable energy and green hydrogen - the technology’s development demands intensified research, supply chain, and transport collaboration to reach a state of far-reaching industrial matureness. Moreover, as a highly related determining factor for this collaboration level, political stability is further investigated in the countries at issue, e.g., by determining the degree of potential border-crossing conflicts, economic developments or domestic political tendencies. All factors directly affect domestic political stability and impact the level of vital international collaboration. Consequently, the highly varying outcome ranging between the two extremes of this critical uncertainty marks a crucial starting point for the scenario development process.

Critical uncertainty II: Infrastructure Development (Recap)

The second critical uncertainty, “Infrastructure Development”, is equally shaped by extreme uncertainty regarding its future development and has a drastic impact on the future green hydrogen sourcing options for the client DEW21. In *Phase II: Explore*, various megatrends and sub-trends reveal the joint international aspiration to create a high level of interconnectedness between relevant hydrogen players – a connection that allows maximizing the efficient usage of this renewable technology. For that, a far-reaching hydrogen infrastructure network is required, e.g., by exhaustive pipeline backbones, common transport means, or LNG/green ammonia import terminals. Heavy capital investments, long construction periods and other obstacles lead to impactful uncertainties that open the gap for different future scenarios.

Sufficiently independent interaction between the critical uncertainties

The intuitive logic school foresees a sufficiently independent existence between the two identified key uncertainties. To be precise, meaning that both uncertainties have the ability to co-exist in all expressions within the continuum of possibilities ranging between the two extremes, independently from the counterpart’s status quo. This serves as a fundamental condition for the development of independent and plausible future scenarios.

Both selected critical uncertainties clearly show the possibility of ranging between their two extremes without affecting the state of the other, demonstrated by **two examples**:

Firstly, high political stability can prevail, e.g., by no existing conflicts, a high level of cooperation in green H_2 research, joint H_2 initiatives and electrolyser projects. Still, due to required intensive capital investments, long construction periods and other obstacles, infrastructure development remains limited in the majority of regions.

Secondly, on the contrary, a plausible development, not affecting the respective counterpart, is characterized by low political stability, e.g., due to regional conflicts, varying political tendencies and a low level of collaboration to share green hydrogen resources, but many regions nevertheless successfully developed a matured hydrogen infrastructure, as means of exploiting its economic benefits and of prioritizing domestic green hydrogen production and consumption.

Set-up of the four scenario narratives

As a result, it was chosen to construct our matrix using the two critical uncertainties of "Political Stability" and "Infrastructure Development" since these are expressive and relevant to the focal issue; they are independent of one another and plausible (Wright and Cairns, 2011). Combining them sparks divergent stories, which intend to scrutinize current strategic decision-making at DEW21. We visualized them on the "axes of uncertainty", reflecting a spectrum of potential outcomes spanning two extremes, considering a timeframe of 13 years until 2035 (Scearce and Fulton, 2004). This drove the development of the following four plausible scenarios: *High Tension, Victorian Development*, *Hydrogen Apogee,* and *Electrolysis Apprehension.*

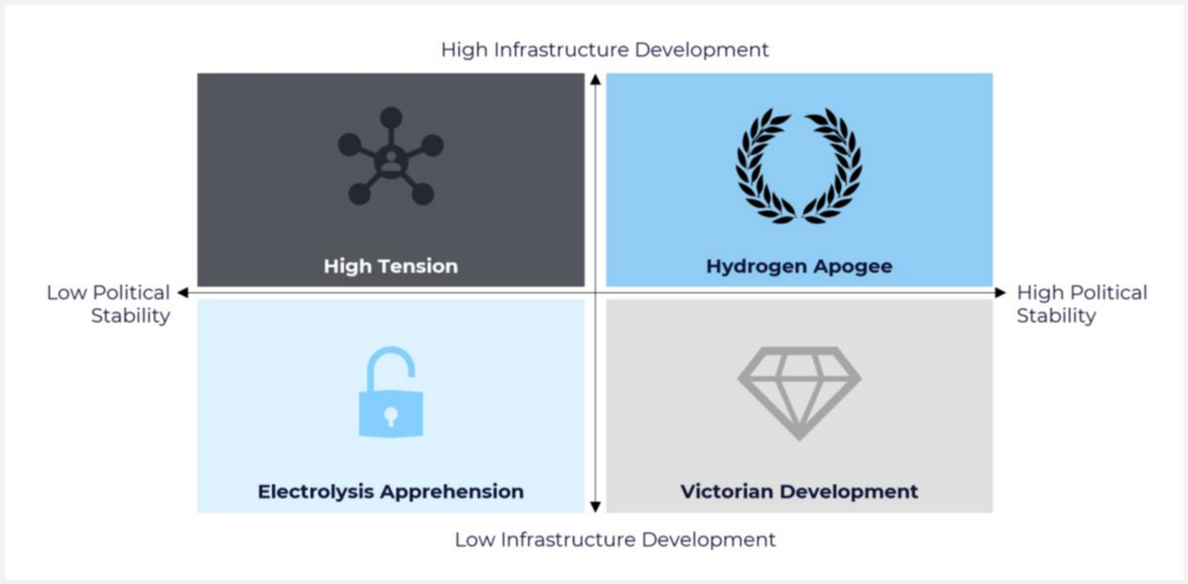

Figure 15: Scenario Matrix | Source: Own Creation

The four derived scenario narratives capture the scenario paradigm based on the continuum of possibilities ranging between the two extremes, and express how the drivers of change, illustrated in *Phase II: Explore*, mark their influence on the future states (Schwartz, 1991). The narratives apply a wide geographical scope, by highlighting future developments that impact DEW21's strategic positioning on a global, European and domestic level. As investigated in cooperation with DEW21, both critical uncertainties and their respective drivers of change strongly impact the future state of green hydrogen in Germany and worldwide – affecting production, distribution and consumption levels. The foresight process further results in outlining green hydrogen's main cost drivers in each scenario narrative, with costs representing a decisive component for DEW21's final sourcing options and strategies, according to the company (Interview Peter Flosbach – Appendix 2).

7. Phase IV: Act

Scenarios are management tools that aim to enhance the quality of decision-making (Wilson, 2000). The fourth phase *Act* deals with clarifying and responding to the issue identified in the first phase by building a solid link between the narratives developed in the *Synthesize* stage and the strategic recommendations aimed at the company to achieve its business goal. For this purpose, it is fundamental to identify the implications deriving from the external factors of each scenario and extrapolate the strategic options available to the company. This research has been carried out through the application of a SWOT Analysis, a framework through which it is possible to identify strengths and weaknesses inherent in the company itself and opportunities and threats from the external environment. Thanks to the implementation of this scheme, the researchers were able to outline strategic recommendations aimed at DEW21 to help the company find the right sourcing options for the achievement of its carbon-neutrality target in the city of Dortmund by 2035.

8. Phase V: Monitor

0 goal of the final phase, "*Monitor*," is to re-link the foresighted scenarios and derived strategic implications for DEW21 with real events and developments across the *Focal Issue*'s contextual environment. Strong signals, re-occurring patterns, or specified leading indications are what make some incidents more significant and turn some uncertainties into present elements. Thus, this section strives to determine what possible *Early Indicators* exist for each of the scenario narratives (developed in *Phase III: Synthesize*). In general, *Early Indicators* are quantifiable metrics that indicate how the world is developing and to which *Scenario Narrative* the outlook points out the most. As Early Indicators are identified on the horizon, companies remain agile, and strategies can be put in place to respond to the emerging reality. They can be clustered in a sort of early warning system for each scenario and involve strategy analysts (Marr et al. 2004).

Hence, in this particular instance, these indicators will serve as a guide for the client company DEW21 to determine which scenario is more likely to materialize.

8.1 Early Indicators

Early Indicators- High Tension

The configuration of the key uncertainties in the *High Tension* scenario is as follows: High Infrastructure development; Low Political Stability. The following Early Indicators were developed to indicate the emergence of this scenario's reality: (1) The **war in Ukraine lasts longer** than expected; (2) the Launch of **new** green hydrogen **hubs** at both **national** and **international** levels; (3) Construction of **new** LNG **pipelines** and **terminals** with the prospect of **converting them later to hydrogen**; (4) **Right-wing** parties gain exponentially in **popularity** in some **European** countries; (5) Continuity in growing **disagreements** between **EU** nations over a joint **regulatory plan** for the green hydrogen **market**.

Early Indicators- Victorian Development

The configuration of the key uncertainties in the *Victorian Development* scenario is as follows: High Infrastructure development; Low Political Stability. The following Early Indicators were developed to indicate the emergence of this scenario's reality: (1) **Stagnant** or **declining GDP** growth in Germany and the European Union, despite **high inflation rates**; (2) **Lower** construction investments in **Germany** and the **European Union** than in previous years; (3) **Qatar's** planned liquefied natural gas deliveries proceed **without** any significant **political** or **economic conflicts**; (4) The **Fragile State Index** within the EU and with important exporters such as Morocco, Saudi Arabia, or Chile is **develops positively**; (5) **Early resolution** of the **Russian - Ukrainian** conflict.

Early Indicators- Hydrogen Apogee

The configuration of the key uncertainties in the *Hydrogen Apogee* scenario is as follows: High Infrastructure development; Low Political Stability. The following Early Indicators were developed to indicate the emergence of this scenario's reality: (1) **Exponential growth** in the number of projects with an undisputed **final investment decision**; (2) **Increase** in the number of **international trade deals** accomplished; (3) **Early resolution** of the **Russian - Ukrainian** conflict; (4) **Continued peace** in the **North of Africa**; (5) **Expansion** of the hydrogen network and infrastructure for **cross-border** and **international trade**.

Early Indicators- Electrolysis Apprehension

The configuration of the key uncertainties in the *Victorian Development* scenario is as follows: High Infrastructure development; Low Political Stability. The following Early Indicators were developed to indicate the emergence of this scenario's reality: (1) The **war in Ukraine lasts longer** than expected; (2) **Right-wing** parties gain exponentially in **popularity** in some **European** countries; (3) Permanent **high inflation** rates could lead to an **economic crisis**, thus a significant **slowdown** in the development of **green hydrogen infrastructure**; (4) Continuous **disagreements** on EU’s green hydrogen **Regulatory Framework**; (5) Germany’s **conservative** approach to undertake green hydrogen **foreign investments**.

9. Conclusion

The research of this collaborative work project followed a multi-sided and complex research approach, including regular client interaction, expert interviews, and scientific investigations to identify and display concrete green hydrogen sourcing options for DEW21 by 2035.

Jointly elaborating on the client's most relevant business challenges and linking those to interconnected time horizons in the energy sector, the research's focal issue and its corresponding time frame were constructed.

This main theme and respective supporting questions were further addressed respectively to DEW21's company size, strategic positioning, and future ambitions by capturing essential sources of change in the contextual environment. Especially relevant revealed to be the identification of dedicated resource commitments for the collaborative development of green hydrogen, e.g., by heavily funded national hydrogen strategies, hydrogen hubs, and numerous border-crossing hydrogen infrastructure projects.

The identification of the critical uncertainties "Political Stability" and "Infrastructure Development", challenged & confirmed by the client, initiated the formation of four plausible divergent stories of the future – the following narratives were developed, and resulting implications derived:

High Tension: High Infrastructure Development leads to the successful expansion of border-crossing H_2 pipeline projects and LNG terminals, but low Political Stability slows down crucial joint research processes and endangers bilateral agreements with reliable H_2 supply. DEW21 is advised to reinforce hub business relations to integrate Dortmund in the near and advanced pipeline network, and to source from close and reliable partners.

Victorian Development: This narrative of high Political Stability with extensive international green H_2 collaboration, but low Infrastructure Development due to delayed and costly construction periods, leads to hydrogen's main means of transport being via existing water-, rail-, and road- routes. DEW21 should intensify business partnerships with hubs and transport companies that cooperate with Northern ports and the few existing international import partners.

Hydrogen Apogee: High Political Stability and Infrastructure Development offer the most favourable sourcing conditions for DEW21, with successfully expanded infrastructure networks and a high degree of collaboration across the entire green H2 value chain by 2035. DEW21 can capture added value by joining regional green H2 hubs to source from economically attractive international partners, and by integrating Dortmund in diversified sourcing networks.

Electrolysis Apprehension: The low status quo of both critical uncertainties results from ongoing political conflicts and distrust in the cooperative realization of costly investments for infrastructure expansions. DEW21 is forced and advised to focus on partnerships for regional and domestic production, as import sourcing options are not valid in this future state.

Displayed in a **final monitoring** phase, and by re-linking the four narratives and corresponding business strategies, DEW21 is advised to stay agile and prepared for reoccurring patterns and rising trends that could later mature into an impactful reality.

Concluding, the work project managed to capture and expose the complex and inscrutable environment of the client and, specifically designed to their business characteristics, created concrete and tangible business recommendations for DEW21 and their respective green hydrogen sourcing options.

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11. Appendix

Appendix 1: List of the questions addressed for the Subject Matter Experts' Interviews

#	Question
1. Energy sector evolution towards Carbon Neutrality	
1.1	How would you describe to be the energetic sector paradigma by 2035 worldwide, at the European level & at German level?
1.2	Do you believe it will be possible to achieve Germany's strategic goal of achieving carbon neutrality by 2045?
1.3	Do you believe that there will be delays regarding the achievement of carbon neutrality in Dortmund by 2035? If yes, what do you believe to be the root causes for that delay?
1.4	What do you believe that are the steps that DEW21 is taking towards carbon neutrality?
2.1	What do you believe to be the greatest advantages and opportunities & the greatest obstacles of Green Hydrogen?
2.2	Up to which level would believe that Green Hydrogen can be a substitute energy resource to what are today's main sources of energy?
2.3	What do you believe should be the key considerations to take into account when considering the expansion of Green Hydrogen as energy source?
2.4	Do you see Green Hydrogen to be a viable source of energy when scaled up its application?

2.5	W notices the Green Hydrogen project in Holzwickede, transporting 100 percent Green Hydrogen through the natural gas pipeline system. Do you have any interesting insights about this project, regarding the sourcing of Green Hydrogen and the realization of the project?
3. Level of Infrastructure development	
3.1	To increase Green Hydrogen production to a mainstream scale, what do you believe to be the infrastructures that will need to suffer changes? (electrolysis infrastrcutures, cross-countries & cross-continents pipelines, etc)?
3.2	From the infrastructures you mentioned, what do you believe to be the main opportunities & obstacles that can influence the infrastructure development towards the mainstream of Green Hydrogen?
3.3	Since the pipeline development constitutes a critical point to mainstream Grreen Hydrogen and requires a high level of international collaboration to develop those infrastructures, how would you predict to be the international collaborations in the future regarding this matter? Do you see possible obstacles related with the international collaboration?
3.4	What do you believe it will be the role and positioning of DEW21 regarding Green Hydrogen?
3.5	What do you believe it will be the strategic options and decisions DEW21 will take regarding Green Hydrogen?
4.1	Reflecting on the war between Russia & Ukraine and considering all the consequences felt in Europe, how do you believe this political event will influence the energetic trnasition and how can it influence Green Hydrogen infrastructure development?
4.2	Reflecting now on the political divergencies that have been occuring between the 3 German parties, how do you believe these different visions can somehow affect the state investment & funding decisions and the how it can somehow possibly delay the energetic transition?
4.3	How do you believe the European Union & German Government funding incenctives for the production of Green Hydrogen will influence the sector in the expansion of these new source of energy?
4.4	For what purposes do you believe these funding incentives will be atributed for?
4.5	Once the energetic sector is a high regulated industry, do you believe that new regulatory l and taxation laws that will arrise from the mainstream of Green Hydrogen will drive towards the facilitation of infrastructure development or will constitute a barrier to it?
4.6	In what manner do you believe the political momentum of shifting towards a reduction of gas dependence will constitute an opportunity to streamline the production of Green Hydrogen?
4.7	How do you predict to be the evolution of political stability worldwide within the next decade?
4.8	How do you belive the political stability situation will impact the import options regarding the energy sector?
4.9	How do you believe the threat on pipeline attacks will evolve?
4.10	And how do you believe it will affect Germany's and DEW21 strategic options regarding the importation of energy sources?

Appendix 2: Interview with Peter Flosbach (Technical Director of DEW21)

Energy sector evolution towards Carbon Neutrality

- *How would you describe to be the energetic sector paradigm by 2035 worldwide, at the European level and at German level?*

  First of all, I think that the most important driver in this sector will be the issue of natural catastrophes. Indeed, climate change has a massive impact on carbon neutrality.

  I personally believe that now there are three items that make energy transition even more challenging.

  1) Industrial Performance. Industrial performance will shrink, and this makes not possible to strongly increase carbon neutral footstep.

  2) Growing population worldwide. This situation will certainly lead to a strong pressure

coming from the third world parties, where people are still unable to have fresh drinking water and heating. Thus, I personally believe that the biggest challenge worldwide (note that, as today, 2050 is the target to be globally carbon neutral) will be to shift the progress we made in the first world to the second and third worlds, as they will probably be the major responsible for the production of great part of the new climate neutral resources.
3) Ukrainian crisis. I personally believe that the current Ukrainian crisis will affect this process, and the energy transition will be done faster than expected. Especially, in Germany, I now see more motivation towards a greener energy, and investments made for this purpose by the population in Dortmund are increasing much faster than last year.
For example, this morning we had our managing directors meeting, and the message was that the number of volt boxes for electric vehicles has tripled this year, and we also have doubled the photovoltaic connections. I think it is really impressive to see that there is this change in the mindset and thinking, and the hunger of being more independent from fossil energies is increasing as well.

- *Do you believe it will be possible to achieve Germany's strategic goal of achieving carbon neutrality by 2045?*
  I personally believe it could be possible to achieve this goal even earlier. I cannot say the same thing worldwide, as we can see that other countries have different priorities (e.g., India and China).
  In Europe and Germany, instead, the motivation for this priority is constantly increasing. Obviously, the key solution to reach the goal of carbon neutrality would be international cooperation. Indeed, what I clearly see is that it will be impossible to produce the energy for Germany in Germany. Therefore, we strongly need international collaboration, especially with third and second world countries, for solar electricity production, and to make the conversion to ammoniac or hydrogen.
  This will be the key for achieving these goals: the import of green energies (i.e., electricity, gas, and/or hydrogen).

- *Do you believe that there will be delays regarding the achievement of carbon neutrality in Dortmund by 2035? If yes, what do you believe to be the root causes for that delay?*
  I'm always optimistic. It is obviously very ambitious, especially at the beginning. My concern is that of course we will face a delay due to the high costs – it is not affordable to do it fast. For example, we have found out that for electricity only we need to invest up to 3-4 billion euros to produce it on our own on a renewable basis.
  Another issue is the Ukrainian crisis and the war, which could cause a collapse in the industry. We already see that delivery times are increasing, as the delays in the value chains. We need a lot more of wind power, a lot more of power stations etc. to achieve the goal of carbon neutrality.
  Thus, I would say "Yes, it is possible to reach the carbon neutrality target", but there will certainly be some delays, especially at the beginning. And of course, at the end it will be done on paper, so we only have the chance to buy CO_2 certificates, I think.

- *What do you believe that are the steps that DEW21 is taking towards this direction?* First of all, we are polishing our strategy, derived from the target of carbon neutrality by 2035. We need to have the right assets strategy and a clear vision. “Will Hydrogen have the power, and will it be competitive? Will the technology be as mature as it is necessary?” The first step, the priority, for me, is the development of green energy for Dortmund. Thus, we go for own green production.
  The second step would be strong investments to decarbonize the traffic sector; the third one would be promoting green gases and having, of course, an integral approach for the transition.
  One step we have already done is for industrial heating, for which we will use biomass or wood.

Green Hydrogen considerations

- *What do you believe to be the greatest advantages and opportunities, and the greatest obstacles for Green Hydrogen?*
  The first advantage is the political will in Dortmund; our local government has decided on green hydrogen. They see it to be very valuable and they believe it is necessary to introduce it fast.
  Another advantage is that Dortmund has an history of coal production. The area used to have a big coal industry and a big steel industry, which then collapsed. The town had the capacity to react fast, therefore I think Dortmund has shown its ability to quickly adapt when the pressure is high. That is something positive, for sure.
  Another opportunity is the additional pressure we are living now as the energy prices are exploding. Price pressure is bad, for sure, but it is also an incentive to go fast and reach carbon neutrality as soon as possible. That is why I think it is a good opportunity.
  The first greatest obstacle of Green Hydrogen, instead, it’s the technology development. Indeed, technology needs to be realized in a scale of hundreds I assume, while today we only have pilot projects and operations.
  The second issue would be that we need a lot of partners not to make the same mistake we made with Russia. Therefore, we must not only negotiate with Qatar, but also with Saudi Arabia, Morocco, South Africa, Australia, and China as well.
  Another big obstacle is that 95 percent of photovoltaic modules are produced by China, which means extreme dependency on one market, the same thing we have with Russia and the fuel. China has the technology and production capability, and that is a big obstacle, I think.
  Finally, there is affordability: do we have the money to invest to reach this target?

- *Up to which level would believe that Green Hydrogen can be a substitute energy resource to what are today's main sources of energy?*
  I think it really is a valuable substitute. Today, primary fuels are 20 percent electricity and 80 percent molecules, which are used for transports, industries, and heating. Thus, being hydrogen a molecule, I strongly believe it will be the key fuel. Furthermore, hydrogen has also some derivatives that can be useful for some purposes. For example, the transport chain will not probably use hydrogen, because it has a very low energy density. However,

hydrogen can be switched to ammoniac, and this could be used for shipping (although there are a lot of safety issues to be considered).
So up to which level? I believe 45 percent.

- *What do you believe should be the key considerations to take into account when considering the expansion of Green Hydrogen as energy source?*
First, parties which have the theoretical conditions to realize green hydrogen production need to be willing to cooperate. That is the biggest issue overall.
In the past, for example, colonies were exploited for different reasons, but it wasn't a real cooperation, it was more of an exploitation, thus it had its limits. Therefore, I think it is really important to have something like a win-win situation, for which also the "exploited" countries can see positive sides, like employment opportunities and education, for example.

And of course, we also need to consider that such a transition will have a strong impact on the nature and landscape of the countries that will house the production plants, and this is an obstacle.
So, for me the key question is: "Will the individual governments, which have very different cultures, law systems, and ideologies be willing to cooperate?".
And of course, from the technology side, I think the biggest issue will be to have water production. Indeed, we have seen from pilot plans, that the technology (in small scale) works, and through electricity and electrolysis it is possible to produce hydrogen. But we need water to do this.
So, if we are in a desert where there's no water, we would need to transmit electricity to the coastal area, and then produce water out of salt water, and I think this is of course a big R&D issue which needs to be faced, and that could be a huge obstacle.

- *We noticed the Green Hydrogen project in Holzwickede, transporting 100 percent Green Hydrogen through the natural gas pipeline system. Do you have any interesting insights about this project, regarding the sourcing of Green Hydrogen and the realization of the project?*
First of all, we can say that we have already had some experience with hydrogen and the gas grid, because until 1980 - when we received the first natural gas which was produced in Holland and in the North Sea - we had the "town gas" in Dortmund, which was a kind of "coal gas". The town gas had a share of 55 percent of hydrogen in it, which means that this gas was dominated by hydrogen.
Furthermore, at that time, working for another company, I was in charge of developing and construct power-to-gas plant, electrolysers, and therefore I gained some experience in that field, and I have a close business relation with a company which is operating the hydrogen grid in Dortmund. At the beginning we also did a material test on polyethylene, which is able to use hydrogen without having leakages. Then, we also have had a switch in the plans of four industrial clients, which now use hydrogen as a primary fuel for heating.
I think that's a simple approach. We are deeply involved and got involved in 15/18 projects which are running all over Dortmund. The biggest association is called DVGW, and they are responsible for the technology standards, and I am in the supervisory board, and I receive

all the material about projects developments. For us in Dortmund, the biggest obstacle from a technological point of view, is that we have 40 percent of pipelines which are made from cast, and this technology is a very old kind of steel, which presumably won't be able to transport hydrogen, as the former town gas was much more humid.

Level of Infrastructure development

- *To increase Green Hydrogen production to a mainstream scale, what do you believe to be the infrastructures that will need to suffer changes? (Electrolysis infrastructures, cross-countries & cross-continents pipelines, etc.)?*
  Coming from the downstream side, I think that Dortmund, in particular, would be able to use 90 percent and even more of the existing gas grid present in the area for Green Hydrogen transportation.
  Previously, this gas grid was used to transport two types of gas – namely low gas and high gas. Now, low gas is running out, which means that we have some free pipeline capacity. Furthermore, there's an initiative for open grid by Europe, which is the biggest gas transporter. The project includes a great grid development plan, and it is foreseen that from 2028 we will have a major hydrogen pipeline capacity, and it will be possible to link the coastal areas to Dortmund, and to have a hundred percent of hydrogen.
  My assumption is that, even though it would be better to have blending, we will not go for it. The reason is that it is not accepted by the EU commission. Therefore, I believe that step by step, along with the increase of hydrogen production, we will switch pipelines grids to 100 percent hydrogen.

- *From the infrastructures you mentioned, what do you believe to be the main opportunities/obstacles that can influence the infrastructure development towards the mainstream of Green Hydrogen?*
  Other things that will need to be changed are power stations, for example, and cars. Nowadays, there are some fuel cell cars provided by Asia, and in Brussels, for example, public means of transports are fuel cell buses. However, the percentage of these sustainable vehicles is very low compared to the "petrol" ones, indeed, it is just around 20/25 percent.

  On the customer side, heating facilities, burners, houses, and industries will need to be adapted as well, and that is a lot of work.
  However, the Germany industry responsible for the production of heaters affirms that, from next year onwards, all new heaters will be able to elaborate at least 20 percent of hydrogen. Then, from 2025 onwards, all new products will be able to be switched easily to a 100 percent of hydrogen. Simultaneously, the end consumers will switch to new technologies that will work with hydrogen as well. It is a process that will be done year by year.

- *Since the pipeline development constitutes a critical point to mainstream Green Hydrogen and requires a high level of international collaboration to develop those infrastructures, how would you predict to be the international collaborations in the future regarding this matter? Do you see possible obstacles related with the international collaboration?*
  I see one obstacle in particular, that is that we are competing with the "old" majors. The big

petroleum companies are obviously on the losing side, and for me it is quite interesting to see what their first moves will be to switch their strategy and enter the hydrogen business. I know that SUS Company and other major companies are going for shale gas, which is of course a product that is competing with hydrogen. Therefore, a key question is “will these companies support such a green energy transition, or will they slow it down?”.

Another issue would be: will countries and governments be willing to accept and support joint ventures and international capitals that will be brought into their territories, despite the big impact this will have on the nature and landscape of their territory? Will these countries' population be able to see the “win” side of this transition?

And of course, we must hope that no new conflicts between countries will occur.

- *What do you believe it will be the role and positioning of DEW21 regarding Green Hydrogen?*

In the retail business, of course, we will be in trading, grid technology, and burning (which means heating stations). What we will not do for sure is electrolysis – because we are too slow – and green production of electricity itself.

- *What do you believe it will be the strategic options and decisions DEW21 will take regarding Green Hydrogen?*

One of the strategic options we are currently discussing is the big alliance and if we be willing to invest money as a start investment to build up the all value chain from the hydrogen in the dessert and switching to ammoniac and shipping to Germany and having then a next station base where will change from ammoniac to hydrogen again. And for this chain huge investments need to be done and it's always a question if we are going be able to investigate this contract before hand to make sure when they start they work that will be able to take hydrogen to a certain price or not. The question is if this action is going to be done by small companies like us, if it is going to be done the government or it will be fully done by big companies and global players.

And other strategic option is to go to contractors and sa that we believe in green hydrogen and we go for it.

Political Stability

- *Reflecting on the war between Russia & Ukraine and considering all the consequences felt in Europe, how do you believe this political event will influence the energetic transition and how can it influence Green Hydrogen infrastructure development?*

  I strongly believe that the Ukraine war has lead to increased prices and therefore the natural gas is more short in efficiencies and as consequence there is a gap to be filled and it will be filled by green sources energies and green hydrogen will be one of the future options.

- *Reflecting now on the political divergencies that have been occurring between the 3 German parties, how do you believe these different visions can somehow affect the state investment & funding decisions and the how it can somehow possibly delay the energetic transition?*

I think the green party will fight for it anyway and they stand for the climate transition. I see that specially the yellow party want to make sure that in the economic point of view this could work and therefore I think that the willingness to spent so much money in only one technology will be very limited, to make sure that we will not have economic collapse and that the industry won't get bankrupt.
Of course that the 3 parties are working really close in this matter.

- *How do you believe the European Union & German Government funding incentives to produce Green Hydrogen will influence the sector in the expansion of this new source of energy?*
  There is of course a big confliction because the European Union is not pushing so hard the green hydrogen future and there are of course a big part of the politicians (for example in Belgium) tat are going for technology that is only electric base and therefore it creates competition, because they believe the is possible to have much more share in electricity in the primary energy weeks.
  In Germany, I think there is a full support for this expansion and new sources and goin for international alliances.

- *Once the energetic sector is a high regulated industry, do you believe that new regulatory l and taxation laws that will arise from the mainstream of Green Hydrogen will drive towards the facilitation of infrastructure development or will constitute a barrier to it?*
  So there was launched recently a new energy directive that is a new upgrade and we see in the 2nd upgrade that is focusing in the gas development. And there, there is a clear distinction where the directive states that you can only have one thing, if you are distribution system operator of natural gas you cannot be in parallel responsible for hydrogen and I see it as big obstacles because I believe that regulation should promote and incentivize new investment in hydrogen infrastructure and not to block it.
  So in my point of view the path would be to copy past the last 15 years accepted regulations in gas matters and do it for green hydrogen.

- *In what manner do you believe the political momentum of shifting towards a reduction of gas dependence will constitute an opportunity to streamline the production of Green Hydrogen?*
  I think the political momentum will not be a big barrier so I see highly motivated companies that are today in the value chain of natural gas to shift it to green hydrogen. The only barrier is the companies that are responsible for the extraction and production of natural gas so the long-term investment they did (from example from companies that are doing business in America as gas producer) and of course has a complexity that can somehow affect the all industry.

- *How do you predict to be the evolution of political stability worldwide within the next decade?*
  My big hope is that in the end, within the next 12 months Russia will be separated and isolated and that the war will stopped. This is the best case scenario and after this end or

either we have been competing against Russia and promoting Ukraine and that we are standing together much closer than before and therefore we will be able to have the transformation to neutrality much faster.
The worst case would be entering nuclear catastrophe and we would be entering the 3rd world war and that we wouldn't be able to be carbon neutrality for 2050.

- *How do you believe the political stability situation will impact the import options regarding the energy sector?*
  Wht we see is that we are getting situation that we need to be prepared for sabotage initiatives and is an extreme risk to have only an option and that was easily to kill one or two pipelines. And with one action you can destroy 60 billion investment and this is one of the most important energy transmission systems in the world and therefore is important to reach political stability to make sure the future energy and hydrogen tunnels, hydrogen pipelines and production facilities won't be hit by sabotage.
  So I believe political stability is key to achieve energetic neutrality and transformation.

- *How do you believe the threat on pipeline attacks will evolve?*
  What I see is that are a lot of investments are done and investigations to protect critical infrastructure so in Germany we have really for the power stations but I believe that is key to have situations where freedom is possible and that we are going against terrorism.
  But is not possible to supervise all the infrastructures.

- *And how do you believe political stability will affect Germany's and DEW21 strategic options regarding the importation of energy sources?*
  I think it is going to be affect as we are not going to do international investment and we will not be investing in Qatar and we won't be spending our money. But in Dortmund as the local perspective is that the investment need to have a strong relation to our town and our business and a consequence will be to have a strong focus on import and besides to have own electricity to use 3rd class for electrification or hydrogen production.

Appendix 3: Interview with Dr. Jens Kanacher (Head of Asset Steering of DEW21)

Energy sector evolution towards Carbon Neutrality

- *How would you describe to be the energetic sector paradigm by 2035 worldwide, at the European level and at German level?*
  So I think the most significant change is that we continue to see a steady shift away from fossil fuels, which are being replaced piece by piece by renewables.
  We also see a shift worldwide, where we have always made electricity from some energy source at the moment, in the future, we will create energy sources from electricity. So now we are talking about molecules, which is a worldwide trend.
  So we will continue to have a global energy trade as we have today, as we had 50 years ago. The forms of energy that we transport will change, so where we transported coal, oil and gas today or in the past, we will transport other energy sources worldwide in the future, and we will undoubtedly see further networking, also on the electric rail, so worldwide transport will not take place in the form of electricity, but in the form of green molecules, yes

hydrogen, synthetic methane, methanol, ammonia, whatever is being discussed. I believe, by the way, that there will not be just one of these energy carriers then, but several.
But at the end of the day, hydrogen or hydrogen derivatives.
And I think that we will then see here in Germany, that was also your question, that we will expand as much as possible renewable energies, that will not be enough, we will continue to be an import country for energy and will then get this energy from other regions, possibly than in the past. The areas from which we get energy are called the sweet spots for renewable energies, that is where I have renewable electricity available very, very cheaply and also with a very, very favourable profile because I don't bring the electricity directly to Germany, I have to convert this electricity first, and for that, I need plants, for example, an electrolyser, and if I can load it as well as possible, it's cheaper than if I can only operate it for 1000 or 2000 hours a year.
And another trend that I see pretty clearly, at least for Germany, is that the system as a whole is becoming more decentralised than it used to be, that we are getting more flexibility. But, still, we also need, for example, from the area of heat pumps from the area of mobility. So I believe that integrating them into the system in a meaningful way will be one of the most exciting steps in the next 10 or 15 years. Unfortunately, the current market design doesn't provide for that yet, i.e. fluctuations in demand, which are always, so to speak. Demand does not have a major impact on the price, but the production side essentially determines the price at the moment. And I believe that in the future the price will be determined more and more by the demand side.
That's maybe if you don't have an energy economic background, not all clear, but then please open fire for enquiries, yes, so that's not a problem at all.

- *Do you believe it will be possible to achieve Germany's strategic goal of achieving carbon neutrality by 2045?*

Well, from a technical perspective, first of all, we have to say that we have everything we need.
So is it technically possible? Yes.
So I don't need an invention, a miracle or anything like that. Still, with what I have today, I can realise a climate-neutral energy supply for Germany and Dortmund in the periods mentioned.
The question is: Are there other reasons why this could fail?
Yes, there definitely are.
So there is an almost infinite range. It starts locally, so to speak, that certain things are perhaps not accepted enough. Renewable or If you do renewable heat supply, for example, also via district heating, construction site issues that are very local now.
You've probably heard all about the power line issue. Somehow they are trying to bring the electricity in Germany from the north to the south.
To put it cautiously, the expansion is not quite as rapid as one would hope. That may well be an obstacle.
If we look at the current political and global economic situation, then of course, at some point, we may have to say that climate protection is all well and good, but now it's about other things and then you say, as long as we still have highly cheap fossil energy, we'll just use it not out of conviction, but out of sheer necessity.
So maybe an extreme example, but if I was in one of the crisis areas, let's say in Ukraine, I wouldn't care how warm it would get. The main thing is that it gets warm and if you look at that.

Maybe it's not so present in Lisbon, but here in Germany, there are definitely thoughts that this winter could be a challenge, and when you talk to the people here, then suddenly, the topic of climate protection and environmental protection are forgotten.
Then no matter what, you do here, somehow you store a bit of electricity for an emergency generator.
I don't want to devote too much attention to this one point, but I just wanted to say that there is a whole range of possibilities as to why this cannot work as quickly as we have planned in Germany. So it's nice that you said you are more optimistic in Dortmund.
I think it's a mixture of optimism and ambition, so you set yourself an ambitious goal, but you also have to, and that's why I thought it was very good and rare that people put it that way You have to have a good dose of optimism to conclude that we'll get there in time.

- *What do you believe that are the steps that DEW21 and Dortmund are taking towards this direction?*
I'll start with DEW 21. What we've just done or what we've done this year is we've considered in great detail the steps and the necessities to get Dortmund climate neutral quickly. Basically, 3 points were identified. One is we need a power generation or a power supply in Dortmund that is renewable.
That means we have thought about how we can achieve this. It's relatively easy in Dortmund because Dortmund will always be an energy sink, so the wind is not a big solution because of the dense development. I don't think I need to explain that much; it's just not rural enough. Photovoltaics potential in Dortmund is limited, so we always have to import electricity there. Our proposal is to exploit the potential on-site as much as possible for rooftop PV and ground-mounted PV. There is potential in Dortmund. But that will not be enough. That's why we have said that we need a portfolio of renewable plants, above all wind, but also PV, which is then available in Germany, which can at least supply Dortmund with green electricity.
Dortmund with at least a balance of green electricity. That is the electricity side. The heat side is straightforward. We need a triad of further expanded district heating by 2035, which will be climate neutral by then.
We need a substantial expansion of heat pumps, and by 2035 gas infrastructure will remain and will have to remain for various reasons. I don't want to go into that in detail. That's why we need to be able to fall back on green gases by then, which we will most likely have to import from somewhere.
That on the issue of heat in a nutshell, on the issue of mobility we have considered is our contribution. We cannot force anyone to switch to a green form of mobility. But we can make a change possible. Making it possible means providing the necessary infrastructure. It means providing an electricity grid that can withstand the fact that every household has a charging option. It means that we also have charging infrastructure in public spaces. In Dortmund, we are in the special situation that we only have about 30 percent of households that correspond to this classic idyll. House, carport next to the house, PV system on it and I can then install a wallbox somewhere and charge.
As a rule, in Dortmund, we have many households in apartment buildings, where it's not so easy to do that, where you have to think about public charging infrastructure even under tight building conditions. Creating offers for this is the contribution that DEW21 can make.

Perhaps a step back, once again to DEW21 - that's the plan, so to speak. But we are already working on this plan, which means we are actively involved.
To give you some examples: On the electricity side, we're doing ground-mounted PV, and we've currently launched another photovoltaic offensive through our sales department in cooperation with another company to be able to offer simple and highly available rooftop solutions for private customers, but also commercial customers.
We are in the process of implementing renewable energy projects in Germany and PV self-developed and purchased in the field of mobility.
That's exactly what we're doing; we're looking at our grid, we're analysing it or have analysed it, we know how much we have to invest again in which places in order to make the grid fit for the future.
And are also in the area of public charging infrastructure that we are starting to build public charging infrastructure there on a larger scale.
We are also doing a huge district heating project in Dortmund. This district heating conversion in the area of heat pumps and, so to speak, conversion to green gases. We are, I would say, still in a preparatory phase, to put it positively.
The main possibility I see is that we can collect renewable energy worldwide and bring it to Germany at a low cost. Unfortunately, we are not a very attractive country in Germany, neither in terms of wind profiles nor in terms of photovoltaic profiles.
In the case of PV, yes, I don't need to tell you in Lisbon that the sun shines there just a little bit longer and more intensively, and it's precisely these advantages of certain locations that can be tapped very well via hydrogen, also for Germany.
Hydrogen has the big advantage that it is a green molecule and the big difference to green electrons if you want to put it that way, is that you can store a green molecule much, much better on a much larger scale. So this means that green hydrogen gives us a chance to bring a very high degree of flexibility into the German or European system.
But maybe to share a thought with you.
If we have a system, and that's what everybody dreams of, which basically consists of wind and photovoltaics, I would like to supply the world with energy in the future. Then it must be clear to everyone that photovoltaics actually has relatively stable production throughout the year. With wind, however, we see very large fluctuations, so in a bad wind year we easily have 30 percent less than average and in a good wind year 30 percent more than average. This means that the big challenge, which is often seen or written about, is how do I get the electricity that I have produced with photovoltaics, how do I actually get the electricity into the winter? However, the bigger challenge is how to compensate for years when I might have bad wind year.
And hydrogen and all derivatives of hydrogen, so if I'm talking about hydrogen now, then take that as a synonym for hydrogen methane, methanol, ammonia, everything that I can also make from it, so to speak.
Hydrogen has the great possibility to lift a worldwide, global portfolio effect. That means that if it is freezing in Europe, it might be surprisingly warm in Asia, North America or somewhere else. And then I have the possibility to bring green molecules or hydrogen worldwide in the direction where I have more demand than production and can thus leverage a great efficiency advantage. So that is a very, very big advantage of green hydrogen.

Obstacles, I think are always very specific. So hydrogen itself, of course, is not particularly easy and particularly convenient to transport. That's why we often talk about the derivatives, the derivatives also all have their challenges for methane and for methanol I need carbon.
So, there are certain challenges to get the carbon and then it has to be somehow renewable for methane methanol, that's difficult with ammonia.
Do I possibly have certain safety challenges when I transport ammonia by ship?
An Israeli colleague once said it's unimaginable that an ammonia tanker could dock in a harbour somewhere in Israel and if a bomb were to go off, half the harbour city would be destroyed, so in that respect, there are particular challenges. But I believe these challenges can all be solved in the long run. The question is rather how quickly will we have this available and does that fit in with the timeframes that we have just discussed as ambition levels? Does that fit with 2035? Does that fit with 2045?
My assessment is probably more towards 2045 than 2035.
The whole thing has to be scaled up very much. You really need very, very much renewable energy. Then I have to put very large or very much installed capacity of electrolysers there as well.
If we have the classic images, yes, a desert somewhere, I'll put photovoltaics there. It's a great story, but I somehow have to get to the water. So I need water extraction and water treatment to create an infrastructure capable of transporting such large amounts of energy over long distances. I think it will take time, so I see the time rail as the biggest risk in this topic, but the clear message for me is more a question of when than if we will see reasonable solutions around the case of green hydrogen.

Green Hydrogen Considerations and Infrastructure Development

- *Since road transport and other things will be transported again, there are still some obstacles with green hydrogen as a dangerous good. That means you probably need another pipeline expansion to be able to tap into the whole of Europe. I can see that there are really a lot of players who really have to work together in different areas and of course also geographically, which I think is a big obstacle or a big challenge, of course, coupled with the huge investment sums of billions that are needed for this. How realistic do you think it is that this can work in such a feasible way?*

I think it's totally realistic, I just think it takes more time than some people imagine. So I'll give you a concrete example of why I think it's very realistic.
You rightly said I have a broad value chain because I start somewhere with renewable energy. I then possibly convert the hydrogen into some derivative, and then I have to transport it, land it somewhere, and distribute it again. Let's take Germany as an example. I have to develop a corresponding application technology here.
I think it all takes more time than we can imagine at the moment. Nevertheless, I am confident that it will emerge. Why? Because there are very concrete application examples where I have a large anchor customer, so to speak. The word doesn't fit, but I'll explain it using this example.
Let's take green methanol as an example.
Green methanol will become very important in the shipping industry. Yes, you can research that on the internet, so to speak, from Maersk to others who are now converting to methanol because they simply say that this is the most suitable derivative for shipping in the future.

So the shipping industry already has excellent methanol logistics anyway, so you also have to know that methanol is the third most transported commodity worldwide after coal and oil, so the barriers to entry are relatively small.
So that means you can manage quite well.
Not even green methanol but hydrogen then is the classic example that we always have here in Germany. Something like Krupp at the Duisburg site simply consume such an incredible amount of hydrogen when they use hydrogen to produce steel. I can finance the logistics for this huge amount of hydrogen without any problems. It's not so noticeable because they simply have such a sales volume and then I have this anchor there, and then you can develop other things around it. For me, the same applies to the topic of power plants. I can probably convert turbines relatively easily at some point; it's already a requirement of politics today. When new gas-fired power plants are usually built, that are normally gas turbines, they are also hydrogen ready.
The moment I directly convert a turbine like that, I'm simply talking about hydrogen quantities the can city of Dortmund probably won't even burn in a year. So it's definitely a very big story in terms of points.
And I believe that this chain will develop bit by bit, starting from individual applications.
And then more and more of these individual applications will emerge, they will network better and better and so a global commodity market will slowly emerge and I'm firmly convinced that when we talk in 20 years, hopefully shortly before I retire or something, that we will then be looking at a global commodity market for hydrogen for green methane, for green methanol, for green ammonia as we are today simply looking at the global commodity market for hard coal, oil, gas, fossil natural gas.
And I am pretty confident that we will get there. So these are the starting points, the large individual applications.

- *If we now see that this international cooperation and the maturation will of course take a lot of time, then perhaps the focus is also a bit on local hydrogen production for the time being. We have now also noticed this project in Holzwickede, where somehow for the first time one hundred percent green hydrogen was distributed through a natural gas pipeline. Do you have any insights about this project or what is your perception of this project?*
You're just going to get an answer in Ruhr typical openness.
Maybe already to the first part of your question. I don't think we will be faster and more successful with a local hydrogen production.
On the contrary, local hydrogen production will always be too expensive. It will always be subsidised projects and what we see in Holzwickede.
I really don't want to rub the Westnetz colleagues' noses in it, but it's a joke; they took a small line somewhere, converted three customers, and built a new gas infrastructure in parallel as a backup so that they could use the old infrastructure as a hydrogen infrastructure. That's not proper research, but we don't really have time for that anymore, if we want to have big solutions in Dortmund in 2035, then that's the wrong way to go. From an industrial policy point of view, I can appreciate the idea, which is also anchored in Germany's hydrogen strategy, that we also want to build up corresponding electrolyser capacities in Germany. But exclusively out of this industrial political thought.
I don't see any energy economic sense at all, because at the moment we simply don't have a situation in Germany where we are throwing electricity out of the window, so to speak,

but in Europe conventional power plants are always running, and that means that if I now switch on an electrolyser. Then I always increase the share of fossil-fuelled power plants that run for an electrolyser. And even if I say I'll combine it with some PV plant or a wind plant that's right next to it. But if I didn't have the electrolyser next to it, then the electricity from that wind or PV plant would just displace fossil fuel generation, which is much more intelligent. So from an energy, economic point of view, I don't think it's genius. From an industrial and political perspective, as I said, I can understand why people say that if we want to become prominent in this electrolyser market with the players, we have, i.e. ThyssenKrupp, Siemens and others. The fact that we are demonstrating, promoting and scaling this here in Germany is the crucial thing at the moment with electrolysers.
We don't have any big electrolysers available at the moment, so not only us but worldwide, there are no big ones that are available and at least not the more modern ones, but alkaline ones are.
Yes, but that would be the answer so Holzwickede, yes is PR and a bit of f and E but honestly not that serious.
And a domestic generation will be a marginal phenomenon. So, by the way, all energy economic studies in Germany say that.

- *But they say production here is too expensive. Now that's referring to the green, to the green energy generated by PW or wind, because the electrolyser plants themselves are not necessarily going to be cheaper now in Australia, are they?*
  That's totally right, so, the Capex for electrolysers and also for downstream synthesis and if you go any derivatives. So, the costs are roughly comparable worldwide.
  The biggest differences, so to speak, are the risk factors that have to be applied in the individual countries and their corresponding interest rates. We often talk about the Levelized cost of energy. So if I invest in something, what is the cost of the individual end product?
  It's mainly renewable energy, which is much cheaper in other countries. But, in all fairness, it has to be said that here in Germany, there is a relatively high burden of grid usage fees, levies, surcharges, taxes and so on. This means that we are not cost-competitive. So it's essentially the production costs, so to speak, for renewable energies that are significantly more expensive here than in good locations abroad.

- *What do you think, which infrastructures have to be changed in order to put the production of green hydrogen on a broad basis and about transport possibilities, i.e. a little bit in the direction of maybe converting existing gas networks to work for hydrogen?*
  Exactly, so I think the entry into the topic of hydrogen will probably not be via hydrogen. That's a bit strange, but that's basically because I can transport hydrogen very badly in ships, and I think the entry will only work via ships.
  Because all other things mean too significant an investment. This investment is only worthwhile when I already have a market on one side, so to speak, on the generation and demand sides, which has already been significantly ramped up.
  Why hydrogen is not good to transport, I probably don't need to explain that to you. So very volatile, I don't need to go into it much. That's why I think that in the first step, we will see, and this is also the current publication, that we believe either about ammonia. Ammonia has a significant advantage in that I only need nitrogen.

There's a lot of nitrogen in the air, so I can quickly get at it. The synthesis is of course, not so optimal for ammonia via the Haber Bosch process, which is the current standard procedure.
Methane and methanol are very attractive because I have access to excellent infrastructures. Still, they have the disadvantage that I need carbon from somewhere, which I have to put into this synthesis.
It's a solvable problem but it's not easy.
Nevertheless, I think these are the things being discussed at the moment, essentially methanol and ammonia. We will see in the first step, they come to Germany by ship, and the question is, what do I do with them?
And there are different ideas, either to use ammonia directly or to do cracking, which means to reverse the process step here and separating the hydrogen from the nitrogen again.
If we actually move in this direction, then we have the challenge in Germany that we need an infrastructure to transport hydrogen. I see a great willingness on the part of both the transmission system operators and the distribution system operators to move in precisely this direction, i.e. Open Grid Europe, and Thyssen Gas, they are doing basically nothing else in terms of communication other than saying at the moment that we are switching to hydrogen.
So but they don't have any other option; otherwise, their business model is dead for the foreseeable future.
You need quite a lot of infrastructure, but it's surprising how much you can use and how little effort you need to keep using it, even if you convert it to hydrogen. These are all estimates at the moment.
That's why it's good that there are projects like the one in Holzwickede, for example, where you at least look at a few hundred metres and say, "What does it look like in this particular case, what do you have to pay attention to? And of course, you can take the findings with you and scale them up for further application.
Now I'm not sure if that conclusively answers your question about what infrastructure do we need, but what is definitely still a huge issue from a German perspective is the issue of application technology, what do I do with the hydrogen when I already have it there?
When I use it? And that is certainly due to the fact that you are also talking to DEW 21 and DoNetz, the distribution network operators behind it.
So if I then use the hydrogen to generate heat, just as I have gas heating systems today, then of course, 200,000 end devices have to be replaced here in Dortmund alone, I think.
That's a challenge.
It's tough to change that over, I can't just say I'll do it when the customers feel like it, but it has to be done in a coordinated manner, so to speak.
There is no legal framework for that yet, which means that at the moment I can't say to anyone, "Look at your pipeline that's in your street, it's going to be converted to hydrogen.
That's why you won't get any more natural gas; that's not even legally possible at the moment.
And that, I believe, is a very, very big hurdle.
That's why I'm sticking to what I said earlier. I believe that we only start at the places where we have a relatively large demand at once, which I can see here in Dortmund, that these are our central heating plants for district heating, where we are talking directly about more than

100 somehow installed capacity are for me power plant locations. These are chemical plants, sites or even steel. Locations like I just mentioned with the example of Thyssenkrupp.

- *Yes, what I have taken away from you now is that you say that, at least for the time being, transport, at least international transport, will be more via ships and not via huge pipelines, as was the case with gas with Nord Stream etc. Do you think this could play a role in the future because it would be more scalable, I say now, than with ships? Do you think that this could play a role in the future, because it would be more scalable,?*
  I think that there are two aspects that always give it a certain limit. One factor is that I will never be able to achieve the worldwide exchange that I outlined at the beginning. The second aspect is that such a grid-based infrastructure is always quite vulnerable. We have seen it quite wonderfully with the example of Nord Stream, where there was an attack at one point and the entire system was paralysed, which is much more diversified with ships. So the risk is that if I have a hundred boats and one is somehow destroyed, that's annoying but not bad.
  But if I have one pipeline and this one pipeline or three pipelines and one of them is broken, that's bad.
  Then I have a real problem and I think those are the limitations. But the economic advantage of pipelines is enormous if I want to transport large quantities steadily, especially with hydrogen. That's why I'm convinced that this will develop downstream.

- *What do you think are the strategic decisions of DEW21 specifically, which you now realistically see in the next few years concerning green hydrogen? So what role does DEW21 play there? How do you try to get a slice of the cake regarding imports, or do you perhaps also rely a little on local production?*
  How do you position yourself strategically in the next few years regarding green hydrogen?
  I think there are two questions to clarify; the first question you want to clarify is whether we believe in transforming the gas grid towards hydrogen.
  But regardless of the answer to that question, there is a second question.
  Independently, I said earlier that we, for example, our central heating plants for district heating, which are really huge plants, can also produce very high demand for hydrogen. So then the question, I think, is whether we should wait for hydrogen to become a commodity that we can buy, also in a structured way, i.e. delivered in the same time sequence as natural gas today.
  Or do we want to be active before there is such a commodity market, where I try to establish a supply chain through partnerships that end in Dortmund?
  Simple example You like to drink cola, you can wait until the local beverage dealer offers cola somehow. You always take it and use it for whatever you want to use the cola for, or do you say no, well, I would like to have cola now, before the beverage trade is here, then I have to somehow get in touch with probably Coca Cola myself and think about how I can maybe import it here? I believe this is precisely the question you have to ask yourself.

Political Stability

- *Now, we're looking at the war in Eastern Europe. What do you think in general in terms of time, but also from a technological point of view and how that affects the, the energy transition?*

Also with the ulterior motive, green hydrogen or green hydrogen derivatives accelerate that or does that present us with more concrete challenges? Is it maybe also harsh judgement but not so bad that it is now accelerating and opening people's eyes a bit? How would you judge that?
I think it will be partly, so partly it is an acceleration. We are now seeing massive demand on the customer side for heat pumps or for photovoltaic systems. Everyone wants to become a bit more efficient, preferably a bit more self-sufficient, i.e. storage. Of course, there is also extreme demand. On the other hand, this may also be due to a difficult economic situation, perhaps even an economic recession.
This can clearly put the brakes on what will clearly put the brakes on are currently rising interest rates.
We have renewable energies, but also electrolysis plants, where the main cost block is Capex and not Opex, and Capex is very sensitive, so if the interest rate rises, the economic viability is ruined very quickly.
This is better for technologies that are Opex driven, and that are fossil fuels, so if I build a fossil fuel power plant, it's much, much cheaper in terms of Capex than if I somehow try to do the same thing in a renewable way. But then I always have the fuel costs that I no longer have with renewables.
So that's definitely economically, I think, a possibility where you can say it's also really becoming more difficult.
But what I would definitely like to say, even though that wasn't really part of your question. I think that we are in for a renewable world that also includes hydrogen imports.
You often have that in the discussions that then many say yes, there we have again such dependencies and then we have again this geopolitical conflict potential and I think that's completely wrong. Why is that completely wrong? It's super great if we can, so to speak, produce hydrogen at the best renewable location in the world.
If it doesn't work there, then we go to the second best.
If it doesn't work there, we go to the third best.
Until we are somewhere where it just works.
This means that we are not limited to the countries, as is the case today, where there is gas and oil in the ground, but we can cover the whole spectrum.
And we have perfect locations in many countries where we would say that they are quite stable from today's perspective - let's take Australia. Let's perhaps take Scandinavia, let's take Canada as a good example. We have locations that have not been thought about very much. Greenland, so it's not a bad joke about climate change, but in the meantime you can put wind turbines in many places there very, very well, no one has done that in the past, for good reason, but the wind conditions there are gigantic, great.
If I simply produce hydrogen there and distribute it worldwide from there.
At least from today's perspective, one will say politically not very sensitive location, but the essential statement is we simply have a variety of location possibilities that we don't have today based on fossil fuels. And so I think the potential for geopolitical tensions over energy issues with the shift towards, renewables and sort of from gas and oil to hydrogen, methane, methanol, ammonia so that's going to be a significant improvement in the situation and I think will be very good for the world overall.

- *We now have 3 parties in government, the Greens had the best election result in their history, which is of course good maybe for renewable energies, but of course also difficult to agree with 3 parties we see how much is discussed. In general we have seen now green hydrogen and also other renewable energies are extremely dependent in Germany also on large state investments that promote these consortia and more.*

  Again with investment and also regulatory decisions that might facilitate local production here and also create incentives.

  So I think in any case that the current political situation in Germany is basically quite good for the progress of the energy transition.

  On the one hand, we have a party that preaches openness to technology very strongly, I think that's very, very important.

  We have on the other side, I mean the Liberals, we have on the other side the Greens, who with the Minister of Economy or with the Ministry of Economy and Climate occupy a place where you can definitely observe that they are currently working with a commitment that you could not observe in the past.

  With the selection of the state secretaries, especially Patrick Graichen, you also have people there who think in a very renewable, progressive way, in the direction of electrification and rapid energy transition, and also smart people. I think that's good for you, but I'm not sure how stable the current government will be, so to speak, with external influences. So it's one thing to motivate a country: Let's do more energy transition and the other is to look in crisis mode, will the flat fall cold in January or in February or not?

  What I perceive is that a lot of momentum has fallen by the wayside. However, I would perhaps want to attribute that less to the current government than really it is a very clear external shock. Or rather, we have several of them here.

  That makes it really difficult right now, but if we had spoken in the middle of the year or maybe even a little earlier, I would have said that, regardless of other political convictions, this boy group, with Habeck, Graichen, Müller, Krischer, who was still there at the time and is now the Minister of the Environment in North Rhine-Westphalia, they have already pushed things forward and made a lot of progress, not only in the sense of announcements, but have also become very active very quickly. That has definitely been good for the energy transition, but in my opinion it has now evaporated.

Appendix 4: Interview with Maximilian Blum (city of Dortmund's climate technologies Coordinator)

Energy sector evolution towards Carbon Neutrality

- *How would you describe to be the energetic sector paradigm by 2035 worldwide, at the European level and at German level?*

  I think that is achievable, depends of course on many parts and also on the national developments. So again, in Dortmund, we will not be able to produce all renewable electricity. So we will depend on just enough renewable electricity coming from outside.

  The renewable hydrogen that we would need to be climate-neutral will also come from outside.

We won't be able to produce it in Dortmund, so we'll have to rely on energy supplies. Therefore, there are many fields that Dortmund does not directly influence, and I think it could be critical in the area of hydrogen that would be good until then to get enough imports to Dortmund. So, that depends significantly on the national conditions simply.

- *Do you believe it will be possible to achieve Germany's strategic goal of achieving carbon neutrality by 2045?*
  I don't think the city of Dortmund will be able to go it alone, but I believe 2035 is now the target for not allowing any new combustion cars.

- *What do you believe that are the steps that DEW21and the city of Dortmund are taking towards this direction?~*
  DEW21, I would say, has two essential building blocks, on the one hand, the power supply. I think in the electricity sector, which DEW21 also does within Dortmund, but also outside of there and to build plants for the production of renewable energies or renewable electricity and in the gas sector, of course, then to find alternatives, i.e. district heating supply or local heating, networks or then also perspectively, since hydrogen will be used. But there are also considerations and strategies at DEW21, so I would say they are the two main fields of action.
  The city can also influence the transport sector in some way. Because the city is also the owner of the municipal utility, it can control it strategically.
  And apart from that, what I can do there from my point of view?
  In any case, what I can do there is to practically take on an exemplary role, i.e. also to convert one's real estate to renewable energies and to use one's areas for PV, and so on.

Green Hydrogen considerations

- *What do you believe to be the greatest advantages and opportunities, and the greatest obstacles for Green Hydrogen?*
  So the advantage is definitely that it makes renewable energies storable. And above all exportable or importable.
  The main problem with renewable electricity is that there is always a discrepancy between the generation and use sides.
  That's why we have to make sure that we can store the electricity when there is more renewable energy available or in regions of the world with a lot of renewable electricity available.
  In order to make the current electricity then, at another place of the world and then on the other hand with the other time usable. In any case, this is a great advantage and practically all energy sources that we use now can be substituted by hydrogen or hydrogen derivatives in the future.
  A big obstacle is undoubtedly the expansion of renewable energy capacities to be able to produce hydrogen.

- *Up to which level would believe that Green Hydrogen can be a substitute energy resource to what are today's main sources of energy?*

Well, technically, hydrogen could be used to operate every area directly, so we could convert the natural gas boilers at home and the natural gas networks. We could use hydrogen in mobility and use it to generate electricity. So in principle, we can use hydrogen everywhere, but we have to ask ourselves which efficiencies we work in each case. Because often it will be that in many areas, the use of electricity directly is probably the more economical variant, for example, electric cars, because we have much lower energy losses when we use electricity directly.

- *What do you believe should be the key considerations to take into account when considering the expansion of Green Hydrogen as energy source?*
  Well, I think that from Germany's point of view and also from Dortmund's point of view, we definitely have to create an ecosystem for the companies that are somehow involved in the value chain. And, of course, to somehow keep value creation in Dortmund, but also to get the costs down for the systems.
  So that is, I think, a huge point that we offer support for the companies that are now building electrolysers. Still, maybe also some are sometimes quite banal and components, some seals or so, are then needed for the new hydrogen systems and supports

- *Do you think that hydrogen can be profitable as an energy carrier?*
  I think that we can't get around hydrogen at all. So hydrogen is certainly not always the better option for transport, and there may be other options like methanol or ammonia. Still, hydrogen is always the only option we have so far from a technical point of view to go from hydrogen to other energy carriers, and electrolysis is always the first step

Green Hydrogen considerations

- *You had already mentioned the case of pipelines, that they can be converted.But what infrastructure would have to be changed in your opinion, to put green hydrogen production on a broader basis? What would have to happen there?*
  Yes, exactly in any case the electrolysis must be provided. Of course, you must not forget - the renewable electricity capacities that we also need to produce all the electricity and infrastructure for transport. Pipelines will certainly play a role within Europe.
  But then, of course also terminals for transport by ship. Whether it's directly with methanol, ammonia, or hydrogen remains to be seen,

- *What do you think will happen first in the time sequence? So will they try to import via ships first or via pipelines? What is your assessment there?*
  I can imagine that transport via ship is practically the simpler one. First, because you don't have big infrastructure projects like pipelines that have to be laid through some countries?
  And if you are now so smart and also the LNG terminals are already hydrogen ready or ammonia ready designed, I think that's one of the first ways we will go.

- *How do you see international cooperation in the whole topic? So how important do you think that is, especially when you think about pipelines that go across several continents because you have higher electricity capacities in Andalusia, Morocco or Australia. So how important would you rate that?*
  As enormously important on the one hand because then of course, we have to build the pipelines.
  Germany is currently also an importing country for energy sources and we have numerous cooperations with other countries that supply us with energy, and that's exactly what we need to do with regard to green hydrogen and find partner countries that supply us with hydrogen.

- *That will probably not change, and Dortmund will continue to act as an importer and therefore be dependent on imports. In your opinion, what are the strategic decisions or options that the city of Dortmund has concerning green hydrogen?*
  I think strategic decisions, especially regarding the conversion of infrastructure, because we have the municipal utility itself as a local supplier here. Then certain areas might be converted to hydrogen. That one worries at an early stage about where the hydrogen comes from, i.e. looks regionally, where there are perhaps areas where hydrogen can be produced or is sufficiently available through import possibilities.

Political Stability

- *With the current war between Russia and Ukraine, if you think about the consequences for Europe, maybe that with the Nord Stream 1 pipeline in mind.*
- *How do you think this political event will influence the energy transition, and can it significantly influence the development of green hydrogen?*
  So as bad as the events are, I think they will have a positive effect in terms of our energy consumption and our CO_2 emissions, I have to say.
  Simply because we are now, first of all saving energy and then, of course, we are also trying to become independent of energy supplies from Russia as quickly as possible.
  Yes, and I think that this can result in a considerable acceleration also for hydrogen supplies.
  Above all, I think this has taught us that we should not be so dependent on an importing country in the future.

- *How do you see the current political situation in Germany? Well, I mean, currently, we have a three-party government consisting of the SPD, the Greens and the FDP. The Greens had the best result in their history. But, nevertheless, one sees again and again that within this coalition to, quarrels comes. How do you assess how capable this government is of implementing its policies and bringing the issue of hydrogen forward*
  I think the government or the governments before it have a tough time with such far-reaching strategic decisions on the energy level.
  And that is certainly something that has slowed down the expansion of renewables in the past, which could have been faster.
  And I suspect that something similar will also arise with hydrogen, that it will take a long time to agree on specific details, such as the declaration of green hydrogen.

And whether or not additional renewable capacity needs to be built. And I think that's the kind of out how to slow down the development.

- *And what do you estimate how important financing incentives from the European Union or the German government are now at the beginning?*
  That's essential in any case because green hydrogen is of course, not yet competitive. Even with the enormous natural gas prices that we have at the moment, it's still cheaper to produce your hydrogen, if you have any, from gray hydrogen, i.e. from steam reforming with natural gas, or to use other energy sources from the outset, so without funding it won't work.

- *Okay, where should this funding most likely goes, or where would the financial budget be most targeted?*
  Above all, the technology should be supported in Dortmund and Germany.
  You have incentives, or companies have incentives to build electrolysis plants here and produce renewable hydrogen. And then the technology is developed.
  So one is also part of creating value again with us in Germany.

- *so there is a strong regulation in the energy sector with hydrogen because it is also potentially dangerous to transport. Do you think that law can hinder that?*
  The main thing that comes to mind about regulation is that the gas pipeline network operators are regulated differently from the natural gas and the hydrogen networks. That the revenues from the operation of the natural gas infrastructure may not go into the process of hydrogen infrastructure.
  That is certainly something that one wants to deal with politically and does one want to somehow promote the operation of the natural gas infrastructure or does one on the other hand make the compromise that the expansion of the hydrogen infrastructure can perhaps be slowed down if one regulates that separately is certainly a big question.
  But I believe, as far as the safety of hydrogen transport is concerned, we now have our procedures in place.

- *To what extent do you think that the political momentum to reduce natural gas contributes to hydrogen scaling up?*
  For the time being, we can't avoid using natural gas in certain areas. For example, we simply can't provide alternatives overnight in the building sector.
  We also do not have the hydrogen from overnight, which we then bring in the corner line.
  And of course, even if we shut down nuclear and coal-fired power plants, we still need backup when the wind doesn't blow, and the sun doesn't shine somewhere to operate the gas-fired power plants, which will then be operated with hydrogen in the future.
  So I'm afraid that hydrogen now is not a short-term solution that reduces natural gas consumption.

- *How will political stability affect import opportunities in the energy sector? The city of Dortmund will always be an energy importer due to the dense development and because you don't have that capacity.*

That's an important point because I think 10 or 20 years ago, there was already the consideration to build huge solar power plants north of the Sahara in Africa, which ultimately also failed in many cases because of the political stability there on the ground or instability. So I think, next to the factor of renewable energies, I believe is the most crucial factor that you have to look at, when it comes to who will export hydrogen to us in the future.

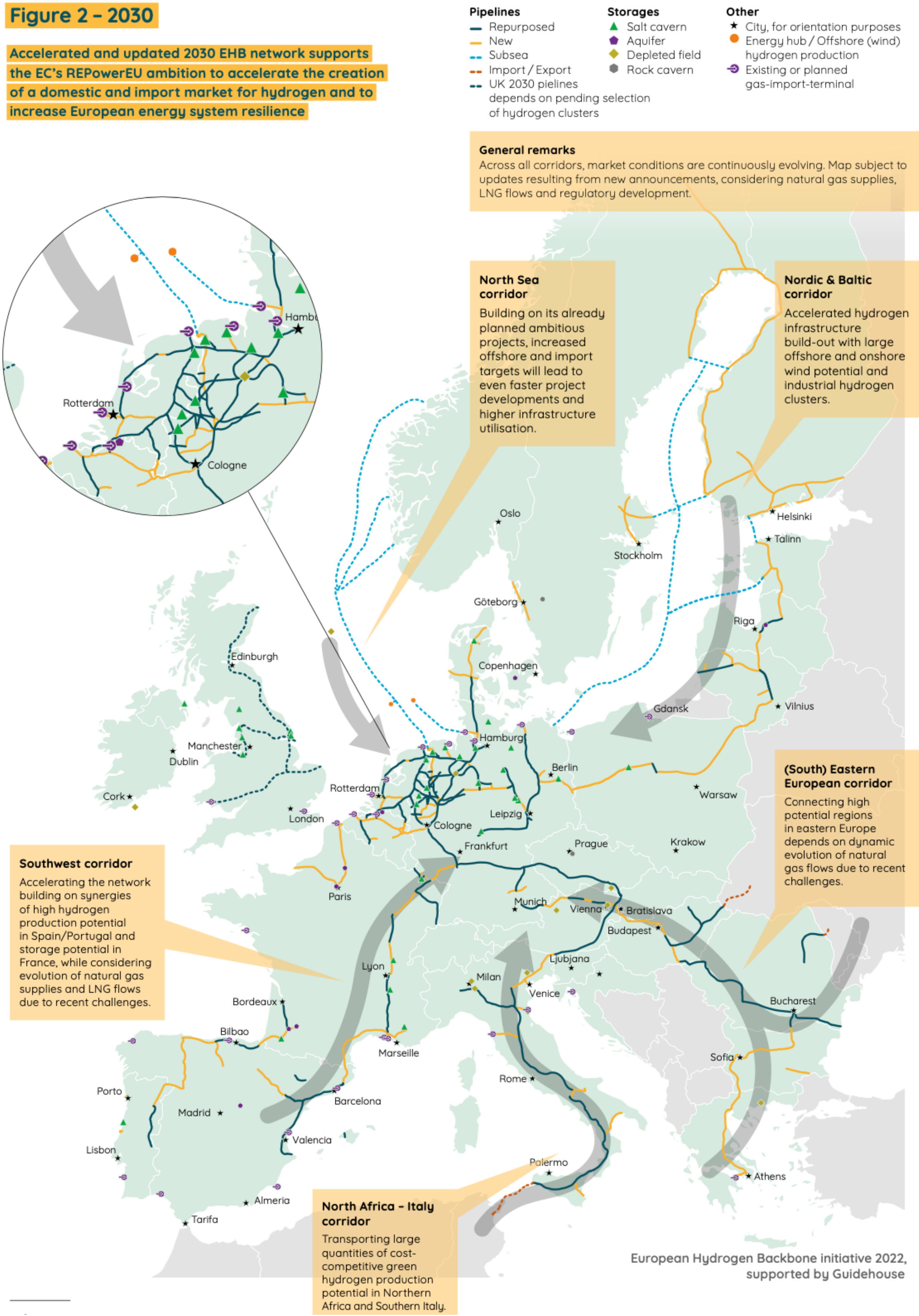
Appendix 5: Uncertainties End-States

Extreme 1	**Uncertainty Name**	**Extreme 2**
Competitive viability	*Economic Viability*	Economic impracticability
Fast implementation of laws and regulations	*Regulations for* H_2 *transport and green* H_2 *production*	Slow implementation of laws and regulations
Compressed hydrogen pipelines' distribution	*Hydrogen transport options*	Chemical carriers' distribution
Public sourcing funds	*Funding*	Private sourcing funds
High Political Stability	*Political Stability*	Low Political Stability
High Infrastructure Development	*Infrastructure development*	Low Infrastructure development

Appendix 6: Uncertainty Mapping Scale

Scale	Uncertainty Level	Impact Level
0	Certain to predict	Impactless
1	Extremely Likely to predict	Insignificant Impact
2	Very Likely to predict	Minor Impact
3	Likely to predict	Very Low Impact
4	Somewhat likely to predict	Low Impact
5	Neither likely or unlikely to predict	Moderate Impact
6	Somewhat uncertian to predict	Serious Impact
7	Likely uncertain to predict	High Impact
8	Extremely uncertain to predict	Very High Impact
9	Unconclusive to predict	Severe Impact
10	Unpredictable	Transformational Impact

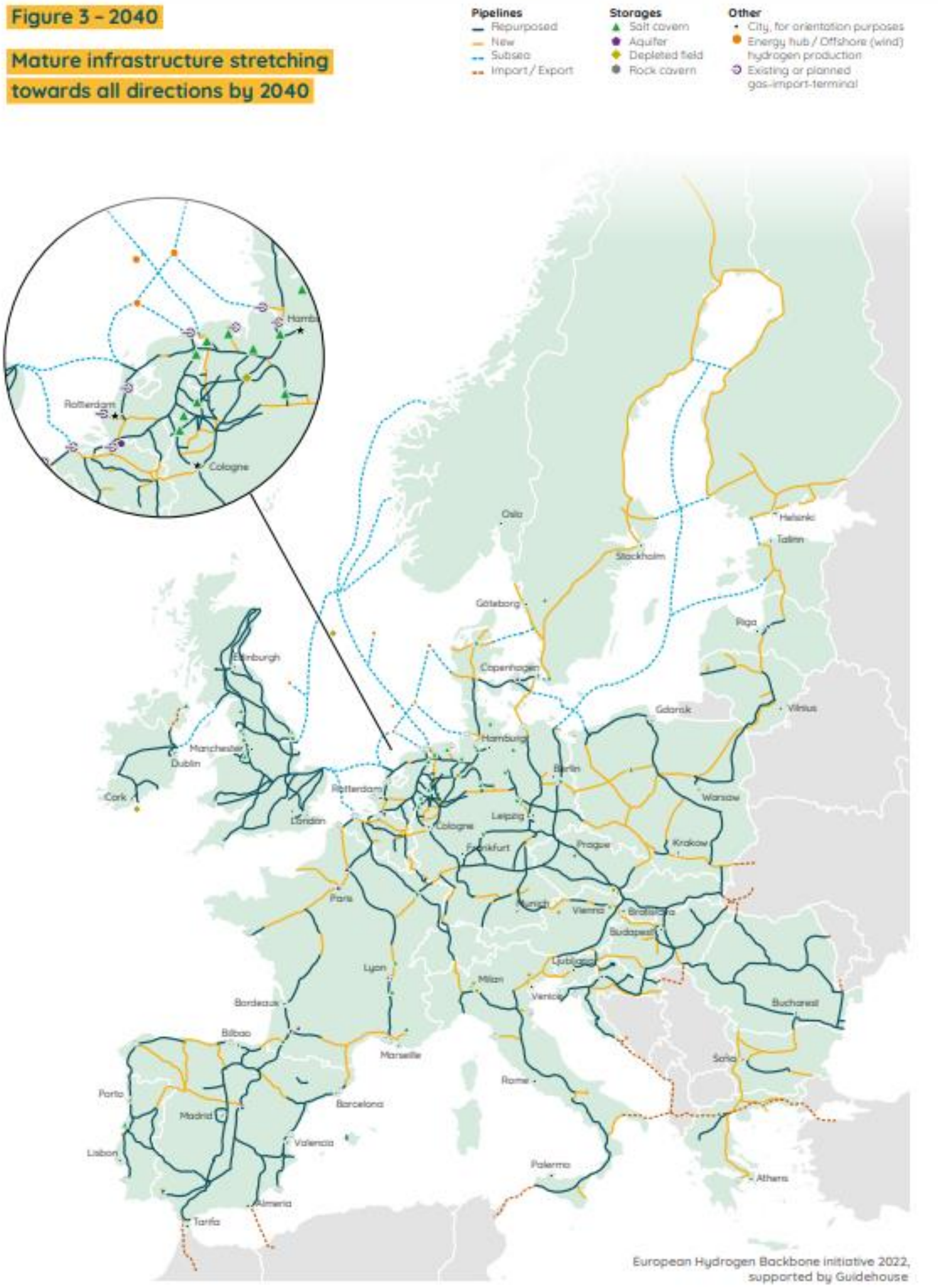
Appendix 7: European Hydrogen Backbone by 2030



Appendix 8: European Hydrogen Backbone by 2040

Figure 3 – 2040

Mature infrastructure stretching towards all directions by 2040



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Appendix 12: Australia – Germany route planned by the project “Shipping the Sunshine” – souce: Germany Embassy