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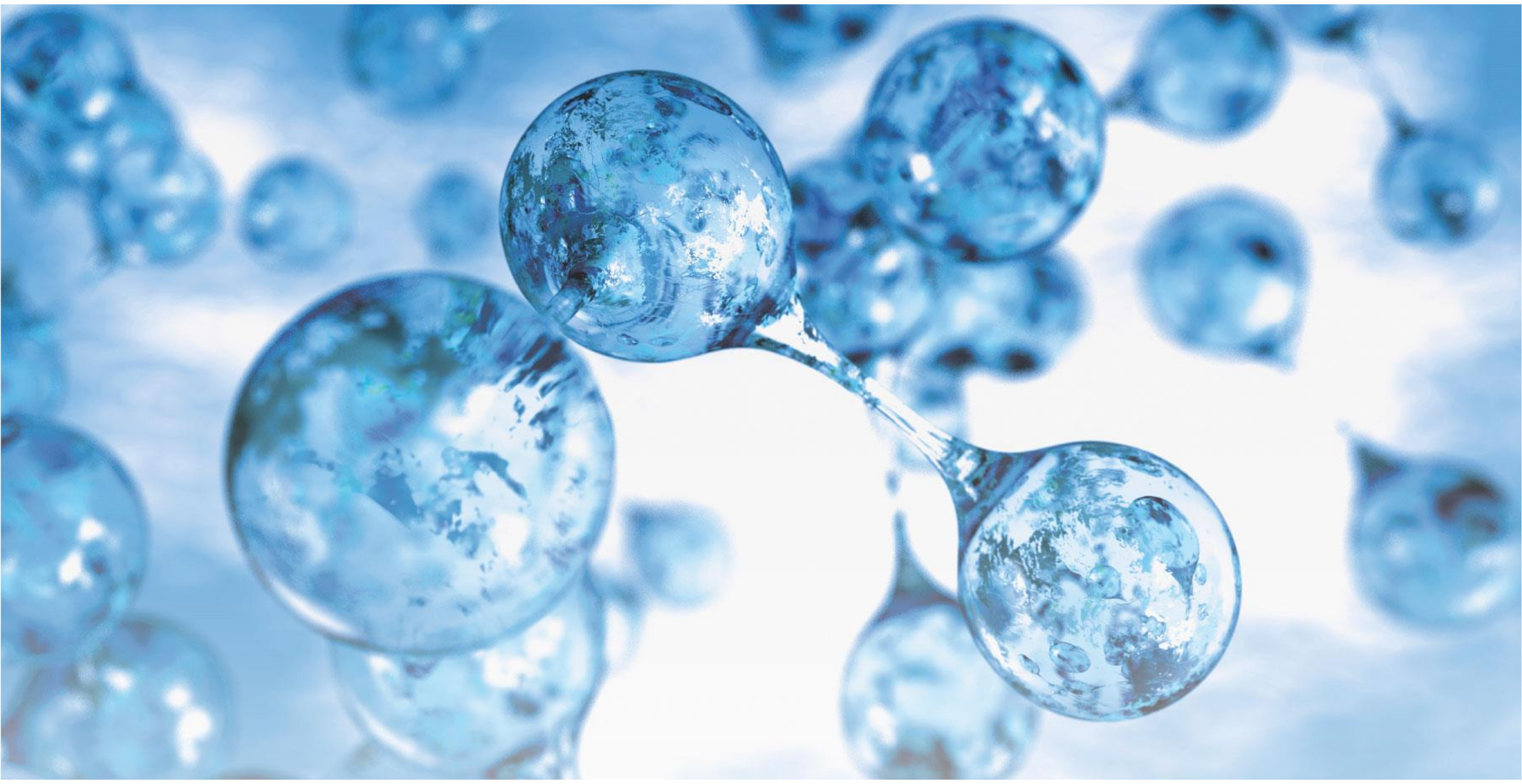

Hydrogen:

A Handbook for Investors and Project Developers

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The aim of this report is to present general relationships in an understandable way. However, the decision for a concrete investment always requires a well-founded and specific examination of all relevant project circumstances. This report cannot and should not replace this. Rather, it represents a starting point for one's own considerations of a specific project. Therefore, neither Fichtner nor the author are liable for decisions made on the basis of this report. However, we will be happy to assist you in developing your specific project ideas.

Table of Contents

1 Introduction

The world has highly ambitious decarbonisation targets to meet. Carbon neutrality by 2050 is a key aim of the Paris Climate Agreement, and some countries have reached beyond this with even more demanding goals. As an example, the European Union is seeking to reduce its CO_2 emissions to 55% below 1990 levels by 2030 – less than a decade from the time of writing. Achieving this reduction (let alone meeting worldwide aims) will require a complete transformation of our current economy, within a generation, into a fully sustainable system.

To understand the scale of this target, it helps to keep in mind where these emissions come from – namely, the burning of fossil fuels. Achieving a 55% reduction in greenhouse gas emissions therefore means fundamentally transforming 55% of fossil fuel supply chains. The size of this change is gigantic: fossil fuel markets are worth many hundreds of billions of euros in the EU alone. But the transformation is not limited solely to what energy is bought and sold. The infrastructure supplying these alternative energy sources – electricity and hydrogen grids, charging points, hydrogen refuelling stations and energy storage – must also be built up, requiring the investment of many more billions. On top of these further costs, the processes that use this energy must adapt. Some existing applications can theoretically use alternative energy sources directly: combustion engines, as an example, can be powered immediately by synthetic, CO_2-neutral fuels. Other uses require some modification, such as boilers, which need to be adapted before they can use hydrogen blends. Finally, there are industries and processes that need to fundamentally change to be climate-friendly (like steel milling). These adaptions and replacements at the consumer level also form a market which, within the EU alone, is billions of euros in size.

Thanks to its flexibility, hydrogen is widely seen as having vast potential as a replacement for fossil fuels in many areas. It is therefore a key element of this global decarbonisation project, in which – to achieve CO_2 targets – truly vast amounts of money will be needed every year. The "rock-star among renewable energies", as EU Commissioner Frans Timmermans calls the smallest molecule in our universe, is by no means a new idea as an energy source. As early as 1870, Jules Verne was predicting that hydrogen would one day supply the world with energy:

"Yes my friend, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. … I believe, then, that when the deposits of coal are exhausted we shall heat and warm ourselves with water. Water will be the coal of the future."
(Jules Verne, "The Mysterious Island")

For investors, a fascinating – and difficult – problem arises in the hydrogen sector. On the one hand, there is a recognisable market, which in its size (and above all, in the pace of development forecasted by politicians) is one of the greatest opportunities in human history. When has any other previous market been created, within a decade, that is likely to be worth hundreds of billions of euros? On the other hand, hydrogen has spent decades being regularly celebrated as "the fuel of the future", only to sink again into obscurity. Investors are therefore faced with the dilemma of betting on the future of hydrogen. Will it once again be a doomed science fiction à la Captain Nemo, or is a worthwhile (and for some, possibly vital) market finally developing? On top of this first and fundamental question, investors must also consider whether the speed of developments in hydrogen and the expansion of the market are in line with the predictions of politics and researchers.

It is therefore a challenging and exciting time for all who deal with energy, decarbonisation, and above all hydrogen. I have the good fortune and privilege to head one of the leading global independent hydrogen consultancy teams in these fascinating times, one with many decades of experience in the practical implementation of hydrogen projects. This has afforded me opportunities, in recent years, for hundreds of conversations with potential hydrogen investors, from private individuals and asset managers to project developers and plant operators. Their interest in hydrogen is not limited by geography; an increasingly global view has enabled me to talk to people from all corners of the world – from Chile to Australia, Norway to South Africa – and exchange views on (and expectations of) hydrogen.

There are common themes to many of the questions I have encountered: Is the technology mature? Will the market for hydrogen in the future be worth investing in? How can I be part of the future of hydrogen? What makes for a viable project and a prudent investment? And, of course, the key question, since hydrogen has often been ascribed great potential but has never managed a breakthrough as an energy carrier. Will it be different this time, and if so, how, and why?

The basic answers to these questions remain constant, even if the project particulars and conditions vary. The drivers of (and the barriers to) hydrogen as an energy source, both internationally and for individual projects, will not change.

Mastering these great challenges – so we not only achieve decarbonization but make it an economic success – will not be possible if we all try to answer the same questions by ourselves. A knowledge deficit in a field, like hydrogen, that is new to so many, can lead to unwise investments, failed projects and, above all, to delayed action. Society can no longer afford this, in view of the increasingly-obvious climate change and the high targets we have set ourselves.

This is why I have decided to write this handbook. Part of my job, and that of my colleagues, is to advise investors on their plans. We have spent years finding solutions for the challenges of hydrogen projects, from political consultation to facility construction. Of course, we have not answered every question! I learn something new in every conversation I have, which is what makes work in the hydrogen sector in these times so fascinating. However, we have certainly heard, thought through and discussed the fundamental, recurring problems and questions that investors ask themselves in the hydrogen sector often enough that we can offer added value here.

Time is of the essence. Climate change is a stark reality, and ever more tipping points are being reached. Society and politicians have set ambitious goals to keep our world both habitable and economically-sustainable; industry and finance must now deliver. Therefore, instead of passing on our knowledge one project at a time, I have decided to make it available to a wider audience through this handbook. It is intended to provide the basic knowledge required to assess project ideas in the field of hydrogen and make successful investments.

I hope that this will allow potential investors to move swiftly and efficiently in their research, development, and decision-making processes. Through this handbook I aim to give you, the reader, the answers to the questions that many other people and organizations have already asked themselves in the same situation. In this way, this handbook is intended to contribute to moving the world forward on its way to sustainability.

Enjoy your reading and good luck with your projects!

2 The investment case for hydrogen

2.1 The challenge of a climate-neutral future

The goal of climate neutrality was agreed in the Paris Climate Agreement. As a result, states (and confederations of states) have developed their own climate targets and have already implemented some of them in laws. What many of them have in common is the goal of striving for climate neutrality by 2050. To support these aims it is crucial that CO_2 emissions be avoided as much as possible, which requires a profound transformation of the economy: As Figure 1 shows, many sectors contribute to today's greenhouse gas emissions. According to the Intergovernmental Panel on Climate Change (IPCC), electricity and heat generation only cause around a quarter of total greenhouse gas emissions. This sector is also the easiest to decarbonise under the existing system. With the steadily increasing electricity production from renewable energies, it has already made good progress on the way to CO_2 neutrality.

For the other major sources of greenhouse gas emissions (agriculture and forestry, transport and industry), which together account for more than 60% of global greenhouse gas emissions, there is still a lack of a strategy and a clear path to decarbonisation. If the states' climate targets are to be achieved in whole or in part, these sectors will be subject to a fundamental transformation (in addition to the electricity and heating sectors).

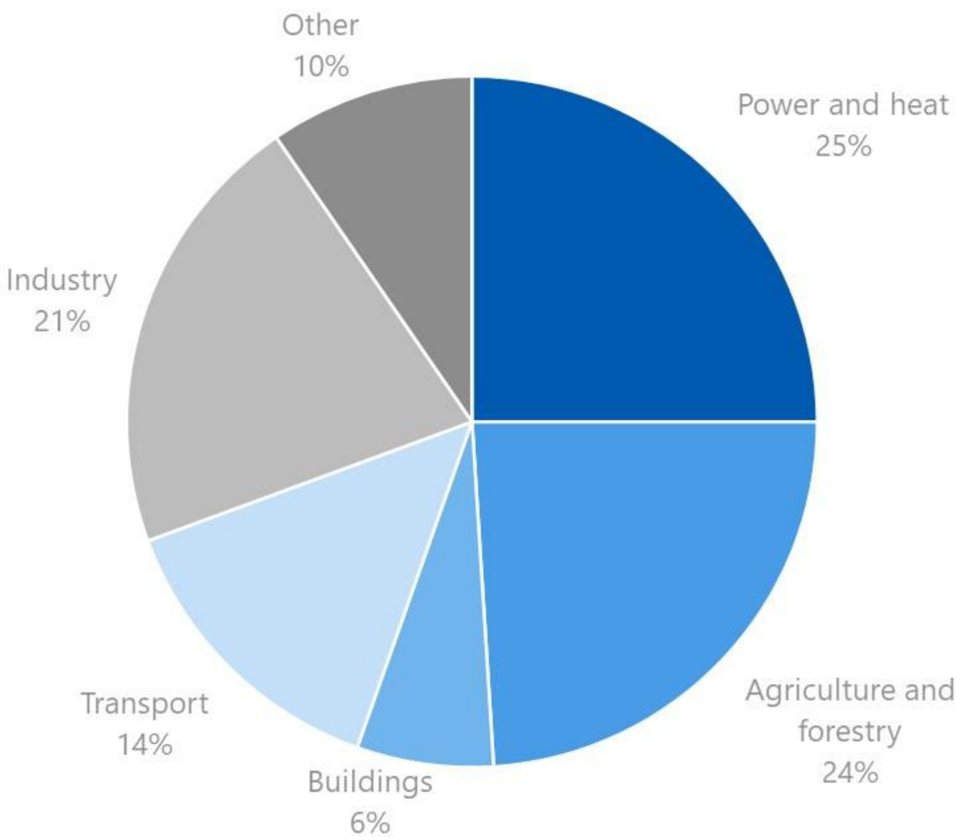

Figure 1: Share of economic sectors in global greenhouse gas emissions (IPCC, 2014)

The goal of sustainable economic activity, like hydrogen as an energy carrier, has often been propagated over the decades. However, the prerequisites are fundamentally different today than they were a decade or two ago. Four factors are driving development today more than ever before in human history:

- Climate change: For a long time, the need to decarbonise was derived from forecasts of global warming. Climate change, and its effects, are now clearly noticeable.
- Public awareness: Society expects industry and politics to act to limit global warming. The pressure on decision-makers is steadily increasing here.
- Inexpensive renewable energies: The costs of generating electricity from wind and solar energy have fallen dramatically in the last two decades. In some places they are already well below the cost of generating electricity from fossil fuels.
- Availability of capital: There is a large amount of money available for sustainable investments. Sustainability aspects also flow into many investment decisions.

The boundary conditions and drives for decarbonising the economy are therefore both favourable and fundamentally different from the last hydrogen hype of the 1990s.

2.2 Why not just use more renewable electricity?

A complete electrification of all sectors of the economy (a so-called "all-electric" scenario) is often discussed as a solution for global decarbonisation. The underlying logic is that the generation of electricity from renewable energy is based on known, market-ready technologies. The goal, then, would be to use this CO_2-neutral electrical energy in all sectors that previously burned fossil fuels. This would result in a path to decarbonisation based on power generation technologies that are ready for the market. An example of this is electromobility: by using battery vehicles, electricity generated from renewable energies replaces crude oil.

If an “all-electric” scenario was to develop, the raw material hydrogen would not be needed far beyond the current level. It is therefore essential to understand how likely it is that an "all-electric" scenario will arise to develop an understanding of the hydrogen market’s future opportunities. To this end, it is important to first develop an understanding of the challenges of a future climate-neutral energy supply – whether hydrogen, "all-electric" or another option. These challenges are:

- Challenge 1: amount of energy
- Challenge 2: form of energy
- Challenge 3: availability of energy

The success of any technology will depend on how well it can meet these challenges. These factors, and their implications for the energy supply of the future, are explained below and their implications for the energy supply of the future are shown. This creates an image from which expectations regarding future developments can be derived.

Challenge 1: amount of energy

Electricity production from renewables corresponded to around 17% of worldwide primary energy consumption in 2020. Science, politics and the public agree that it will increase significantly in the future: for example, the US Energy Information Administration (EIA) expects that between 2020 and 2050

8 Effective project blueprints

As said from the outset, this handbook aims to provide answers to frequently asked questions about the hydrogen sector. From my experience in the field, the most common question investors ask themselves is simply: how do you identify a good project? In a more mature sector, such as wind or solar, developing a project is relatively straightforward, as reasonable framework conditions and project types are well known. In a new sector such as hydrogen, however, many lack a suitable frame of reference for classifying and evaluating opportunities that arise.

To make the handbook as useful as possible, it is therefore important to me to give as general an answer to this question as possible. This inevitably involves some simplification, and certain nuances cannot be addressed. However, my experience suggests that such a general frame of reference is still valuable. For me it offers a good starting point for classification or developing of ideas, and I hope it will also be of valuable support to you in bringing clarity to the world of hydrogen.

A successful product needs to have an edge over its competitors. Therefore, my frame of reference for assessing hydrogen project ideas seeks to find their clearly identifiable, specific advantages over the competition. With an understanding of the three parts of the hydrogen value chain (as seen in Section 4), four project types can be identified. I always check all projects that I come across, in my work or while reading, to see whether they correspond to one of the four project types mentioned. So far, those that do well invariably fit into one of the four categories, and since those categories are based on exploiting specific advantages along the hydrogen value chain, I do not expect this to change until a fundamental shift occurs. Examples of this could include a technology ban in a country, as yet unforeseeable technical innovations, or new regulatory developments such as domestic hydrogen quotas that block imports. From today's perspective, however, I can not see such developments.

The four most promising project types are discussed in the following pages. In addition to a brief description of the framework conditions for each one, I have included explanations of their advantages and success factors. There are now numerous successful hydrogen projects, so for each project type I describe concrete examples that can be traced from public sources. I hope this provides a good understanding of the principles and makes it easier to draw parallels. I also hope it dispels the argument that hydrogen projects are a matter for the future and not the present.