NATIONALER WASSERSTOFFRAT

INFORMATION PAPER 2022-09-16

# The need for research and development into the use of hydrogen in the steel industry

## 1 STATUS

Current blast furnace technology is based on the use of fragmented pieces of iron ores (sinter, pellets, lump ores) and coke as well as injection coal.

In the existing blast furnace process, the only technological option at present is to replace injection coal with hydrogen-rich gases. However, the coke cannot be replaced due to the nature of the process, which means that blast furnace technology for reducing iron ore cannot be operated in a climate-neutral way. When operating a conventional blast furnace in Germany, the metallurgical gases (blast furnace gas, coke oven gas, converter gas) produced are used as efficiently as possible in order to replace other fossil fuels such as natural gas or to utilise the residual energy of the metallurgical gases for electricity or steam production.

A higher blending of hydrogen-rich gases in the blast furnace process is technically feasible and being researched further.

Similar to the blast furnace-converter method, the alternative technology for producing climate-neutral primary steel is two-stage: hydrogen-based direct reduction of the iron ore and melting with electrical energy in the electric arc furnace (EAF) or smelter. The new processes completely dispense with solid coal and coke, and the reducing agents are gaseous.

The transformation task – first and foremost the associated investments but also explicitly the requirements in research and development – is of unprecedented magnitude and requires a timely and strict implementation that cannot be accomplished by individual stakeholders.

## 2 RESEARCH AND DEVELOPMENT REQUIREMENTS

The requirements for research and development include the modification of existing blast furnace processes, further development of direct reduction plants for flexible hydrogen operation, downstream production steps and material issues (both for production technology and for steel as the end product). These issues are to be supported by the digital modelling of the corresponding areas, especially the reduction processes and the integrated operational management. Moreover, circular economy and the large-scale implementation of direct reduction processes are increasingly taking on a special role.

In particular, these are the following topics for research and development:

- **Blast furnace processes**
  - Process gas recirculation
  - Basic research on the industrial use of hydrogen

- **Direct reduction and electric smelter**
  - Alternating mode natural gas/hydrogen in the direct reduction process (to ensure flexibility in the supply of reducing agents)
  - Influence of steam on iron ore reduction in the shaft furnace (sticking) – quality assurance
  - Development of alternative hydrogen-based reducing agents
  - Fundamental technology development of the shaft furnace/fluidised bed process to industrial maturity
  - Research of reduction rates and results with blending of higher hydrogen contents (>50%, and up to 100%) – efficiency and economic consideration
  - Process optimisation with high hydrogen content including fundamental investigations on the influence of the smelting behaviour and different hydrogen contents on productivity – quality assurance and economic consideration
  - Thorough consideration of the smelting technology (EAF and smelter) when using directly reduced iron
  - Behaviour of refractory materials – service life

- **Hydrogen use in downstream processing (heating, heat treatment, etc.)**
  - Investigation of NOx formation and emissions during the combustion of hydrogen
  - Investigations into the thermal load on burners and components
  - Safety technology and handling of hydrogen
  - Influence on product quality
  - Economic considerations

- **Materials, steel quality and by-products**
  - Identification of new materials for production plants – resistance to hydrogen embrittlement
  - Safeguarding the properties of steel and by-products that are produced with low levels of $CO_2$ for quality assurance:
    - Achievable chemical compositions of the steels from the new metallurgical routes
    - Use of biogenic carbon for alloying steels
    - Carburisation of the molten steel for the H2-DR-EAF route and H2-DR-smelter route
    - Adapted applications or conditioning of the new slags for the EAF and smelter route
    - Recycling of metallurgical/residual materials within the transformation process
    - Certification – adaptation of both customer and EU standards to the specifications that can be achieved with the new technologies
    - Challenges due to the use of higher proportions of secondary materials

- **Fundamental research on new processes (for example, plasma-based iron ore reduction)**
  - When looking at a true circular economy, the steel produced in a climate neutral manner needs to be considered – even more than before – a valuable material that can be further processed almost $CO_2$-free. It requires the development of appropriate and currently still novel concepts (consistent labelling, inventory management, return/recycle options, etc.).

Scaling up hydrogen production, the associated electrolysis technology and the transport logistics is essential for decarbonisation of the steel industry from an economic perspective, among other things. This requires further consideration, which is not the scope of this paper.

# 3 SECURING THE SUPPLY OF SKILLED WORKERS

Taking into account the major economic challenges, additional highly qualified professionals who can build the bridge between current and new technologies are needed for the transformation. Consequently, the international search for junior staff is also an important instrument for securing demand, in addition to a qualified higher education landscape with corresponding degree programmes and vocational education and training. We also recommend to develop concepts for increasing the attractiveness of these new, also increasingly sustainable job profiles with corresponding regional future prospects in the area of the green steel industry.

# 4 RECOMMENDATIONS OF ACTION

Based on the research and development needs listed above, the following recommendations for action and questions to be clarified can be derived in order to map the gradual market ramp-up:

## 4.1 CREATE CLEAR FRAMEWORK CONDITIONS

Fundamental clarification of what exactly is recognised as green input material/green steel ASAP.

## 4.2 CREATE A COMMON PLATFORM FOR PRE-COMPETITIVE EXCHANGE

The challenges require a great deal of action and capital. If individual companies and research institutions work on these aspects in parallel, it will only partially lead to the desired goal and delay the establishment of innovative approaches. Although the corresponding framework conditions still need to be defined, we recommend developing a rapid joint approach in the pre-competitive space. To this end, appropriate structures that are legally compliant must be created with the involvement of all stakeholders. The industry must specify the topics for the currently necessary rapid transformation, which are to be implemented quickly. Research supports industrial establishment by providing solutions based on its technological developments. Fundamental approaches should be continuously pursued in parallel to ensure the innovations of the future.

## 4.3 SHAPE FUNDING OPPORTUNITIES QUICKLY AND UNBUREAUCRATICALLY

Currently, the funding does not compensate for the time lost in applying for projects and hinders a transformation at the necessary and desired pace. Support programmes should be concrete, specific and quick to access and implement (reducing them from years to a few months).

The possibility of mandated research (top-down approach) should also be considered. In this way, general and necessary research activities can be put out to tender by the federal government in a competitive procedure with clear definitions. This applies in particular to metastudies and accompanying scientific projects as well as to specialist conferences.

## 4.4 MAKE APPROVAL PROCEDURES FAST AND UNBUREAUCRATIC

Approval processes should be implemented quickly in the case of pilot industrial plants, but also at the level of experimental plants and in the area of cooperation with universities and research institutions. We recommend completion in a few months.

## 4.5 ENSURE THE AVAILABILITY OF SUFFICIENT QUANTITIES OF HYDROGEN AT COMPETITIVE PRICES

In addition to the aforementioned recommendations for action in the area of research and development, it is necessary to also address means to ensure the availability of sufficient quantities of hydrogen at competitive prices. Under current conditions, the in-house production of hydrogen is difficult to realise competitively, but it is essential for building up experience and generating initial results for the transformation of the overall process. Thus, synergies, which should be exploited through coordinated action, arise with the other relevant aspects of the hydrogen value chain, especially in the area of $H_2$ production. Consequently, the necessary upscaled production of green electricity must also be taken into account, as well as the infrastructure for the distribution of hydrogen at the same time.

## 4.6 PROMOTE ACCEPTANCE

Acceptance is another overarching issue. The general public should have better access to information about the importance of hydrogen in industrial use. To this end, a nationwide hydrogen marketing campaign should be considered.

### THE GERMAN NATIONAL HYDROGEN COUNCIL

On 10 June 2020, the German Federal Government adopted the National Hydrogen Strategy and appointed the German National Hydrogen Council. The Council consists of 26 high-ranking experts in the fields of economy, science and civil society. These experts are not part of public administration. The members of the National Hydrogen Council are experts in the fields of production, research and innovation, industrial decarbonisation, transportation and buildings/heating, infrastructure, international partnerships as well as climate and sustainability. The National Hydrogen Council is chaired by former Parliamentary State Secretary Katherina Reiche.

The task of the National Hydrogen Council is to advise and support the State Secretary's Committee for Hydrogen with proposals and recommendations for action in the implementation and further development of Germany's National Hydrogen Strategy.

**Contact: info@leitstelle-nws.de, www.wasserstoffrat.de/en**