
# Electrolysers: opportunities for the Dutch manufacturing industry

Regional opportunity map and recommendations for the development of a Dutch production chain for electrolysers


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# Colophon


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# List of technical abbreviations

| | |
|---|---|
| AE | Alkaline Electrolyser |
| AEM(E) | Anion Exchange Membrane Electrolyser |
| BoP | Balance of Plant (electrolyser component group) |
| BPP | BiPolar Plate (electrolyser component) |
| GDL | Gas Diffusion Layer (electrolyser component) |
| MEA | Membrane Electrode Assembly (electrolyser component) |
| PEM(E) | Proton Exchange Membrane (Electrolyser) |
| PTL | Porous Transport Layer (electrolyser component) |
| SOE | Solid Oxide Electrolyser |
| WE | Water Electrolyser (electrolysis system composed of multiple stacks and BoP) |

# 1. Introduction

# Electrolysis: key to the energy transition and potential growth market for the Dutch manufacturing industry

In almost all possible scenarios, the production of 'green' hydrogen plays an essential role in a climate-neutral economy. This can be produced through the use of water electrolysers, among other things.

In a water electrolyser, water is split into oxygen and hydrogen using (renewable) electricity and without releasing any $CO_2$. This technology is still relatively expensive compared to fossil alternatives and is not yet available on a large scale. Nevertheless, the demand for electrolysers is expected to increase enormously between now and 2030.

This offers opportunities for Dutch companies with knowledge and experience in the field of materials, components, assembly and integration. At the same time, there is serious international competition.

The aim of this study is therefore to help the Dutch manufacturing industry to pre-empt the expected scaling up.

**Terminology:** For the rest of the document, we will refer to 'electrolyser' or 'electrolysis' instead of using the full term 'water electrolyser' or 'water electrolysis' (abbreviated to WE). By this, we mean the electrolysis of pure water into hydrogen and oxygen.

# The intended impact is to help the technological industry in the Netherlands, including many SMEs, to pre-empt the opportunities that will arise when scaling up the production process for electrolysers.

The main objective of this study is to accelerate the energy transition through a joint effort by knowledge institutions, provinces and the manufacturing industry; at the same time, it intends to help and stimulate the Dutch manufacturing industry to pre-empt the economic opportunities that this will bring.

The result is twofold:

- A national opportunity map. This is focused on the companies and their (intended) position in the supply chain.

- A strategic innovation agenda. This offers a view of actions aimed (among other things) at knowledge development, chain integration and market activation, which are necessary to realise these opportunities.

Results will be highlighted at the level of four regions but the final analysis is particularly relevant at the supra-regional level.

By the Dutch technological (manufacturing) industry, we primarily mean innovative companies - young and old, from both the new and traditional sectors - which have the ambition and capacity to seize the new market opportunities.

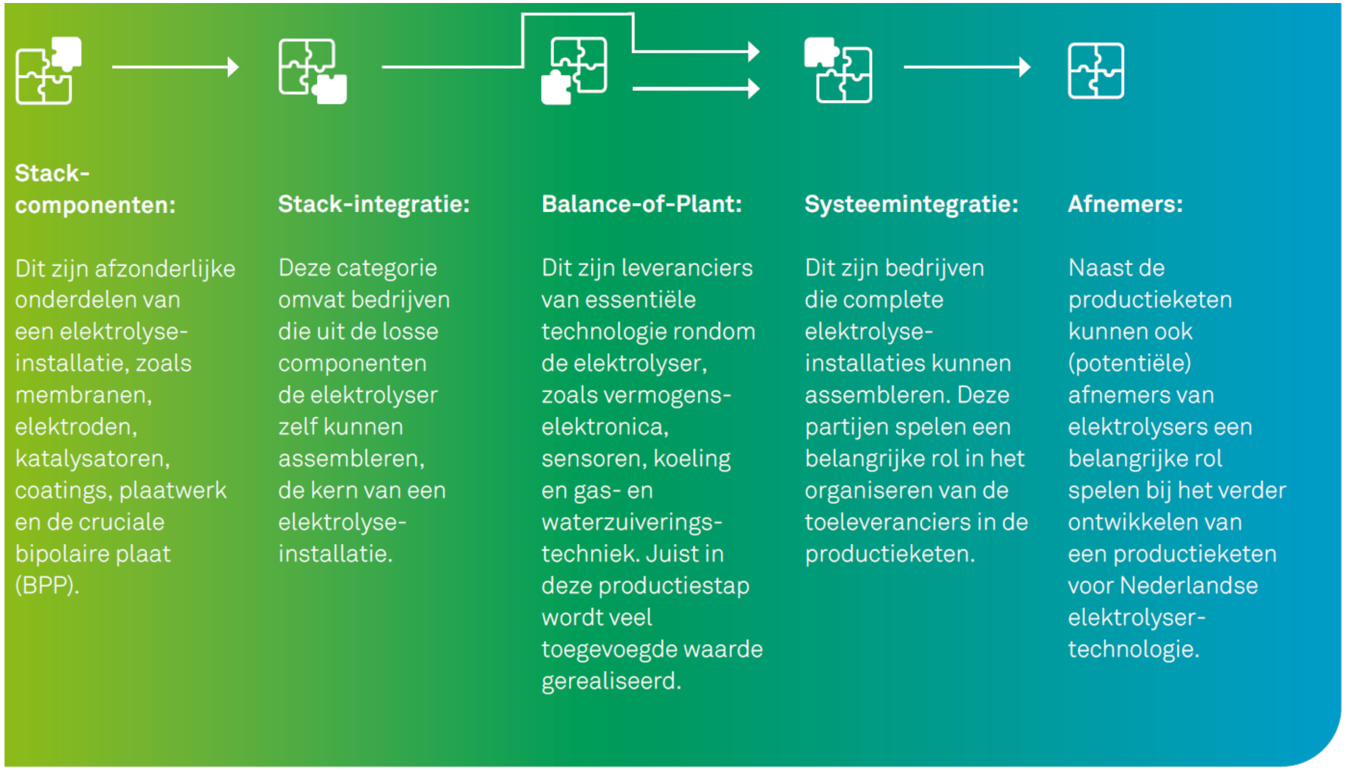
# Target group

The target groups of this study are:

- Businesses, particularly SMEs and potential new entrants.
- Companies that want to act as a system integrator for the large-scale production of (components for) electrolysers and are looking for partners to build up their supply chain.
- Public authorities with an ambition to link regional and national initiatives.

# Scoping (1/2): focus on a (potential) production chain in the Netherlands

In this study, we have opted for a full focus on the electrolyser production chain. The diagram below provides insights into the structure of the production chain.




The focus of the study is on companies based in the Netherlands and therefore does not offer a perspective on the international context. This is important because innovation and the scaling up of electrolysis technology will be determined to a large extent by developments at an international level. In this sense, this study should be seen as a starting point for international positioning.

This study can be seen as a follow-up to the Dutch study ‘Hydrogen: Opportunities for Dutch Industry'. This publication states that one of the opportunities for Dutch manufacturing industry production lies in the field of electrolyser components.

**Source:** Hydrogen: opportunities for Dutch industry. Via the following link:

https://www.fme.nl/system/files/publicaties/import/Waterstof%20Kansen%20voor%20de%20Nederlandse%20industrie_HR_0.pdf

Various electrolysis technologies are available. For the purposes of this study, we will only focus on the technologies which will be suitable for scaling up over the next five to ten years, especially in terms of production (in large series) and scale (large industrial systems).

This concerns the so-called Proton Exchange Membrane (PEM) Electrolyser and the Alkaline Electrolyser (AE). The table provides insights into the relative performance of the various technologies.

The PEME and AE are commercially available and ready for large-scale application. Other technologies, such as the Solid Oxide Electrolyser (SOE) or the Anion Exchange Membrane (AEM) Electrolyser, are still at the R&D stage. These are also relevant in the longer term, but large-scale implementation is still far beyond the investment horizon for most companies.

**For a further explanation of the technique, see Section 3.**


PEM stacks

Photo source: Hydron Energy

Alkaline electrolyser

Photo source: ThyssenKrupp

# Scoping (2/2): focus on scaling up market-ready technology

**Relative performance of Alkaline, PEM and SO elektrolysers**

| | 1st | 2nd | 3rd |
|---|---|---|---|
| Technological maturity | **AE** | **PEM** | **SOE** |
| Efficiency | **SOE** | **AE** | **PEM** |
| Lifespan | **AE** | **PEM** | **SOE** |
| Response time (fast to slow) | **PEM** | **AE** | **SOE** |
| Safety | **PEM / AE** | | **SOE** |
| Physical 'footprint' (from small to large) | **PEM** | **AE** | **SOE** |
| Cost of capital (from low to high) | **AE** | **PEM** | **SOE** |

Source: TNO, 2020

# Approach

### Step 1: Survey

For the study, a survey was conducted which was aimed at companies that could potentially play a role in the production of electrolysers. This survey was broadly distributed via FME and TNO, as well as the provinces and the Regional Development Agencies involved. Of course, Ekinetix's earlier research has also been factored in.

### Step 2: Interviews

The outcome of the survey was a longlist of 150+ companies. Based on desk research and additional input from experts (TNO and FME), this list was reduced to a selection of some 80+ companies that were considered for an interview. We interviewed almost all of these companies (the exceptions were companies which we already knew so well that an interview would not add anything). In addition to companies, we carried out discussions with knowledge hubs and large (potential) users of electrolysers.

### Step 3: Opportunity map

Based on the interviews and additional discussions with experts, a list has been drawn up of the companies which have a relevant knowledge position AND ambitions in the field of electrolyser production. This list solely concerns (potential) producers and some initial customers, ultimately comprising 72 companies. A distinction has been made between the various elements of the production chain, among other things. On the basis of this overview and the insights and experiences gained, an opportunity map and strategic innovation agenda have been drawn up.

### Step 4: Validation

The results presented in this study were tested at various points by submitting them to experts, both within and outside of FME and TNO and, in particular, in the context of four regional meetings at which companies and public authorities from the regions involved were present. The conclusions and recommendations were discussed with both internal and external experts and were refined where necessary.

# Disclaimer

The list of companies in this report has been compiled on the basis of an extensive survey and input from experts from various organisations. The list has formed the basis for the analysis and recommendations, for the creation of an overview and for the gathering of insights and experiences from companies.

However, we do not want to suggest that the list is complete. We need to be cautious when it comes to statements on the relative representation of certain types of company per province. The methodology used and the total figures do not lend themselves to such claims.

It goes without saying that there are more companies than those currently included in this study. For this group of companies, the invitation to approach us remains open. Please refer to the contact information in the colophon.

# Reading guide

Section 2 sets out, in general terms, the ongoing development of the market for electrolysers and the parties which are the dominant players within this.

Section 3 provides basic insights into the operation of the electrolyser and provides an overview of the most important materials and components. This information was important during the research as part of the survey for companies and is relevant as background information when it comes to understanding the opportunity map and strategic innovation agenda.

Sections 4 and 5 present the main results of the study, the opportunity map and the strategic innovation agenda:

- The opportunity map provides an overview of Dutch companies which can play a role in the production of electrolysers, together with an analysis of the various Dutch regions.

- The strategic innovation agenda sets out, in concrete terms, what is needed to capitalise on the opportunities for the Dutch manufacturing industry.

Finally, conclusions and recommendations are set out in Section 6.

An appendix containing the list of companies can be found at the end of this publication.

# 2. Market perspective

This section sets out, in general terms, the ongoing development of the market for electrolysers and the parties which are the dominant players within this.

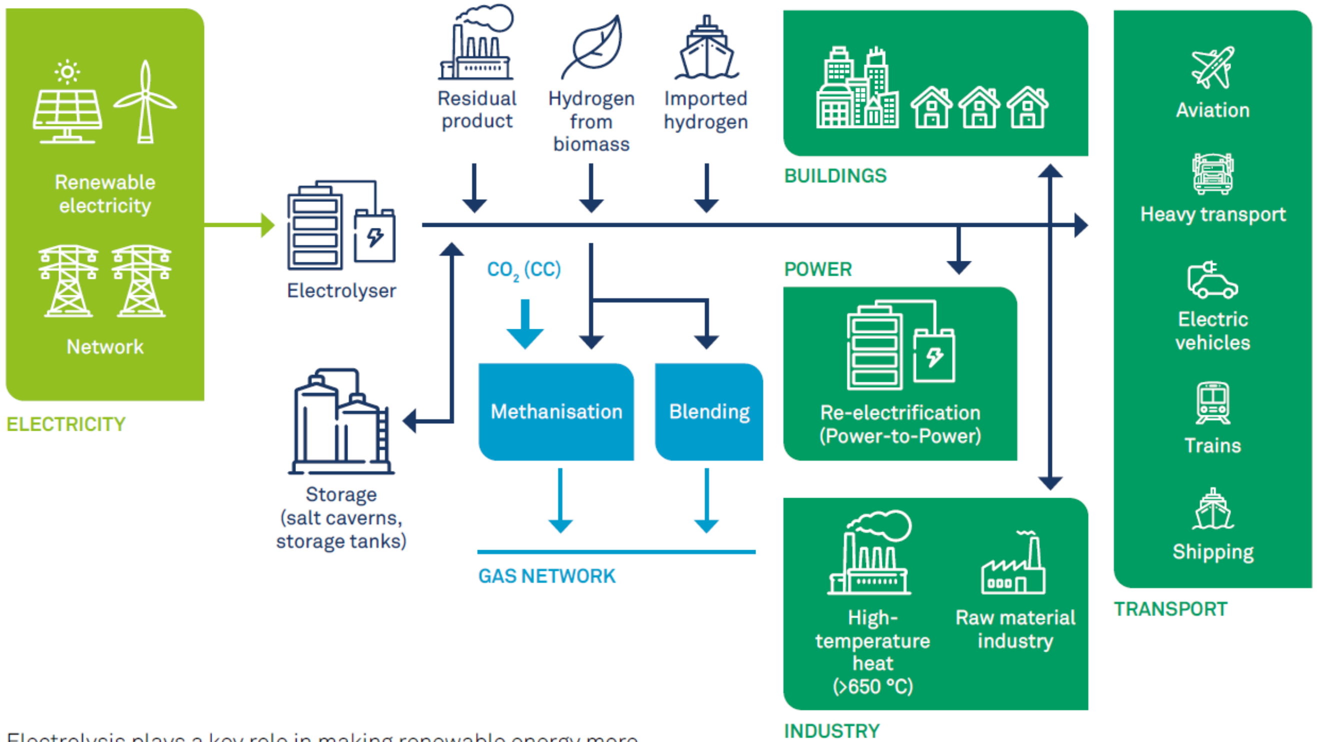
# Why hydrogen and why electrolysers?

Text source: TNO Position Paper. Reaction of TNO to the Cabinet's hydrogen vision.

https://www.tno.nl/nl/aandachtsgebieden/energietransitie/roadmaps/naar-co2-neutrale-brand-en-grondstoffen/waterstof-voor-een-duurzame-energievoorziening/tno-over-kabinetsvisie-waterstof-begin-nu/

Hydrogen plays a central role in the energy transition for several reasons:

- The splitting of water using renewable electricity, whereby energy is captured in the hydrogen gas, offers the possibility for the large-scale storage of renewable electricity.
- Electrolysis technology provides a source of adjustable demand that facilitates the far-reaching integration of the variable supply of renewable electricity from wind and the sun.
- Besides the production of electricity, hydrogen can be used as a substitute for natural gas, as a raw material for the chemical industry and for the production of fuels.
- As it is storable and easier and cheaper to transport over long distances, hydrogen will play a role in future imports and exports of wind and solar energy as a replacement for fossil energy imports and exports.




Electrolysis plays a key role in making renewable energy more widely usable. Source: IRENA.

# Ambitions and expectations

The developments surrounding (green) hydrogen are characterised worldwide by high expectations and great ambitions. These ambitions and expectations are currently being translated into policy plans and legislation. In its Hydrogen Strategy, for instance, the European Commission presents an objective of 6 GW by 2024 and 40 GW by 2030. By way of comparison, there is currently no more than 200 MW of electrolyser capacity installed worldwide and the increase is still below 1 GW per year. In order to help achieve these ambitions, the European Commission is pledging tens of billions to stimulate the development of water electrolysers and hundreds of billions to develop solar and wind farms.

In the Netherlands too, expectations have been picked up and translated into objectives. The Climate Agreement refers to scaling up electrolysis capacity to 500 MW by 2020. The aim for 2030 is 3-4 GW. Other European countries also have quantified targets for electrolysers, e.g. 5 GW by 2030 in Germany according to the German National Hydrogen Strategy.

**How much is one gigawatt?**

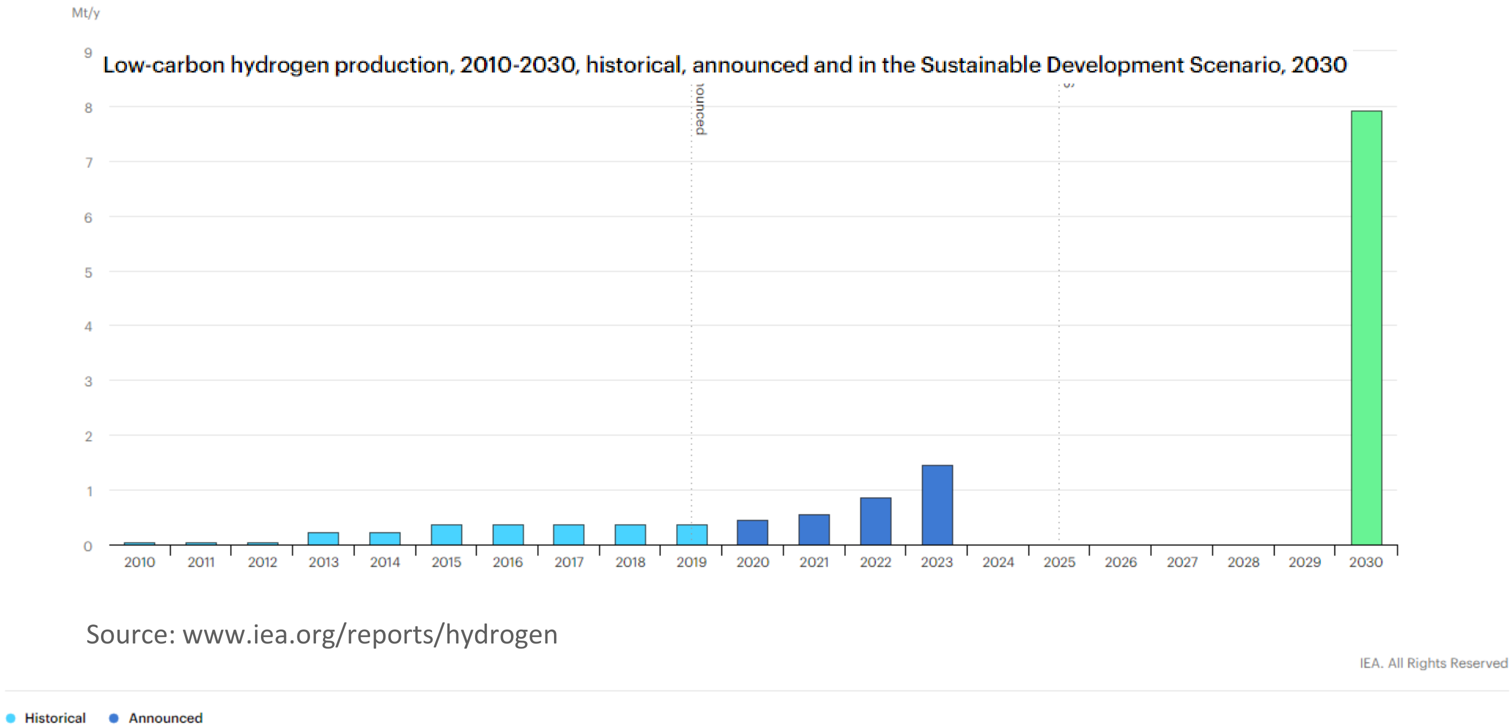
A capacity of one gigawatt is comparable to:

- A large offshore wind farm with hundreds of the largest wind turbines available
- An Internet data centre (1-5 GW)
- The electricity consumption of households in five to ten major cities

A GW electrolyser can produce about 150 kt of hydrogen. In comparison, a petrochemical cluster in the Netherlands consumes hundreds of kilotonnes of hydrogen per year. Industrial demand in the Netherlands is around 1500 kt.

# Electrolyser market perspective

Current European demand for hydrogen amounts to some 7 Mton. 80% of this is determined by the production of ammonia for fertiliser and oil refining. As a result of global climate policy, demand for hydrogen is expected to increase rapidly. This demand will eventually have to be met with $CO_2$-neutral hydrogen.




Source: www.iea.org/reports/hydrogen

In terms of electrolysis capacity, this means scaling up to dozens of gigawatts over the next ten years. In the run-up to 2050, this will go to hundreds of gigawatts according to current plans. At present, annual capacity growth is less than a GW. The growth potential for electrolysers is therefore enormous. The European market for electrolysers alone is expected to be worth tens of billions of euros over the next ten years. This estimate relates solely to electrolysers and is independent of the indirect economic effects that the development of a hydrogen production system (with its associated ecosystem of economic activities) will have.

**Relevant sources:**

- Hydrogen roadmap Europe
- Power roadmap Frontier
- Infrastructure Outlook Tennet
- Dutch Climate Agreement
- Hydrogen demand, Gasunie
- Certifhy report 2015
- IEA hydrogen future, 2020
- EU hydrogen strategy, 2020
- IRENA outlook, 2020

# Application of green Hydrogen: first in mobility, mostly in industry

In terms of application, most scenarios point to industry (the largest market) and the mobility sector (the initial market) as the most important domains. The highest willingness to pay is in mobility, but this market is limited due to a lack of infrastructure and competition from alternatives in the form of electric vehicles.

When applied in industry as a raw material, the willingness to pay is lower (currently below the cost price of green hydrogen) but the potential can be unlocked more easily because the necessary infrastructure is already largely in place.

For all applications, blue hydrogen - produced from natural gas in combination with Carbon Capture & Storage (CCS) technology - is an important 'competitive' technology. According to CE Delft's scenarios, the cost price of blue hydrogen will certainly remain below that of green hydrogen for the next 10-20 years.

However, both techniques are still largely dependent on subsidies and policy choices for large-scale implementation, so a purely economic comparison is of limited value here.

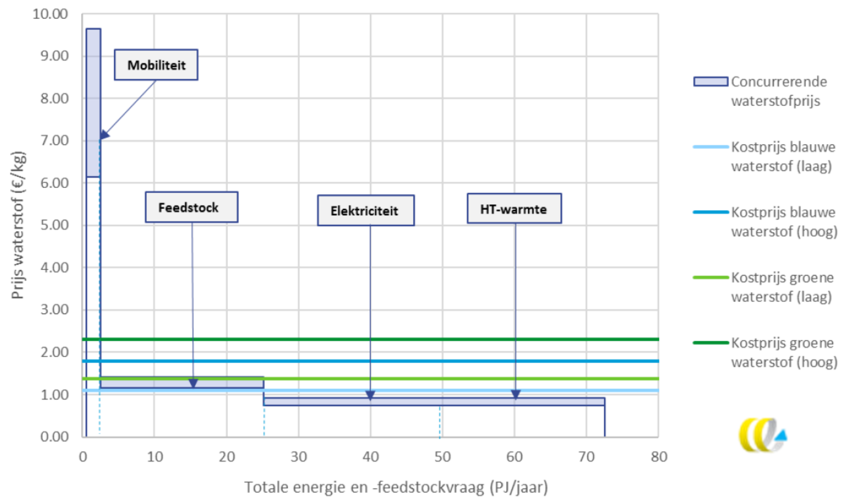



Figure: Estimation of the merit order for the feasible potential of hydrogen applications and marginal chain costs for blue and green hydrogen in 2030

Image source: CE Delft - Hydrogen routes for the Netherlands. 2018

Sources:

CE Delft – Hydrogen routes for the Netherlands

# The current production of electrolysers is in the hands of a small group of companies

The system for the development and automated production of electrolysers is still in an early stage of development. Market volumes are low (MW scale) and there is only (space for) a handful of companies producing electrolysers. The table provides insights into the system integrators which are currently responsible for the lion's share of all production. These are currently not located in the Netherlands.

| Company | Country | Type of technology |
|---|---|---|
| Asahi Kasei | Japan | Alkaline |
| Hydrogenics (Air Liquide) | US & Belgium | PEM & Alkaline |
| HydrogenPro / Tianjin H2 Equipment | Norway + China | Alkaline |
| ITM Power (Linde Engineering) | UK | PEM |
| McPhy | France | Alkaline |
| Nel | Norway | Alkaline & PEM |
| Siemens | Germany | PEM |

Production processes are not (yet) automated (a lot of manual work) and the production chain is not yet organised. In order to realise the necessary cost reduction and to bring the production volumes to the GW scale, a stroke of innovation is needed at both the technical level and in the automation and optimisation in the chain level. There is thus no talk whatsoever of a 'done deal'. The situation offers opportunities for the companies, supported by public authorities and other parties, that are prepared to invest now and pre-empt a frontrunner position.

At the same time, there are risks. First of all, competitors are not standing still. There is also the need to develop infrastructure and new (regulated) markets. National and regional public authorities have a task here in creating appropriate framework conditions and facilities.

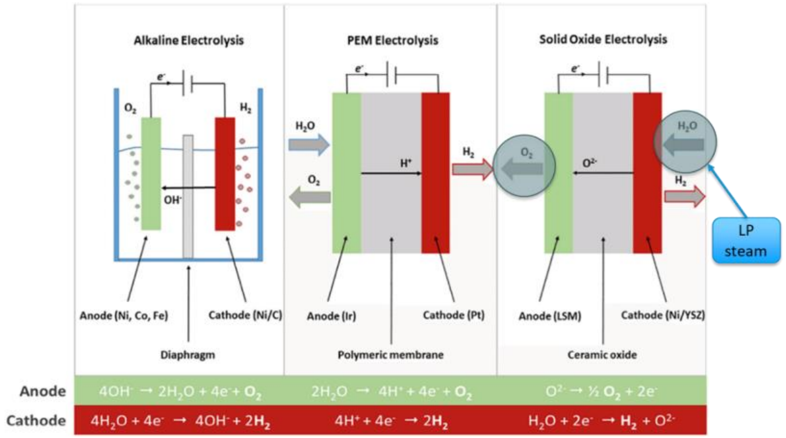
# 3. Technology

This section provides basic insights into the operation of the electrolyser and provides an overview of the most important materials and components. This information was important during the research as part of the survey for companies and is relevant as background information when it comes to understanding the opportunity map and strategic innovation agenda.

# The technologies which can be scaled up within five to ten years are Alkaline and PEM.

**Source: DNV-GL, TNO - Technology Assessment of Green Hydrogen. 2018**

- In electrolysis, water is separated into hydrogen ($H_2$) and oxygen ($O_2$) under the influence of electric voltage. The hydrogen is deposited at the cathode while oxygen is formed at the anode. Conductive membranes or diaphragms are used to exchange the electric charge.



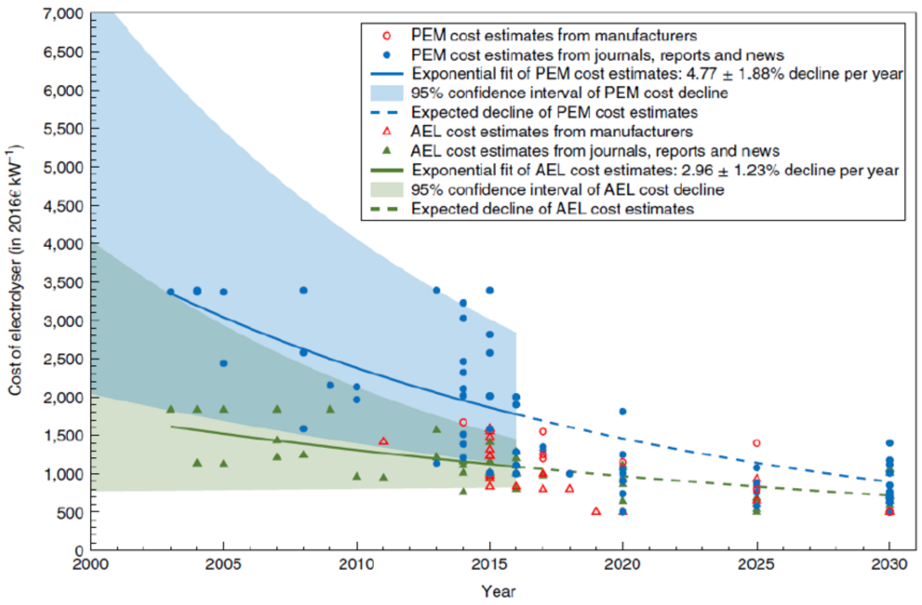

Picture source: P. Millet, S. Grigoriev, 2013, Water Electrolysis Technologies, in Renewable Hydrogen Technologies

- Currently, only Alkaline and PEM electrolysers are considered market-ready technologies. SO and AEM electrolysers are other promising systems which are, however, still at the research stage of development. They therefore fall outside the scope of this study.
- Alkaline systems have been applied on a large scale (6-100 MW) for many years, most recently in the production of chlorine. The installed systems are large, slow to turn on and off, require a lot of power and are less efficient than PEM systems.
- PEM systems are relatively new and have a number of advantages. They have a smaller physical footprint, produce hydrogen under pressure and are suitable for connection to a fluctuating energy source such as a wind farm. The largest systems currently have a capacity of approx. 10 MW.
- For flexibility and integration with renewable energy generation, the PEM electrolyser appears to be the most suitable solution. Alkaline technology would be ideally suited  to large, continuously running industrial applications. Both systems are undergoing further development. Time will tell which position they can occupy and to what extent there will be one or more dominant techniques.

# The expectation is that the cost price of PEM and Alkaline electrolysers could fall substantially in the coming years as a result of industrialisation. This is also necessary to enable their large-scale introduction.

The price of an electrolyser stack is currently between 100 and 400 Euro/kW for Alkaline systems and between 300 and 800 Euro/kW for PEM systems. For the total system, this is between 1000 and 2000 Euro/kW. The resulting cost price of green hydrogen is not (yet) competitive with fossil alternatives.

The costs of capital for both technologies are expected to converge over the coming years. The expected cost of a stack in 2030 is around 100 Euro/kW. To achieve this goal, major steps need to be taken in the areas of design, materials, components and subsystems.




Source: Nature Energy 4, 216-222 (2019)

# Structure of an electrolyser (1/2)

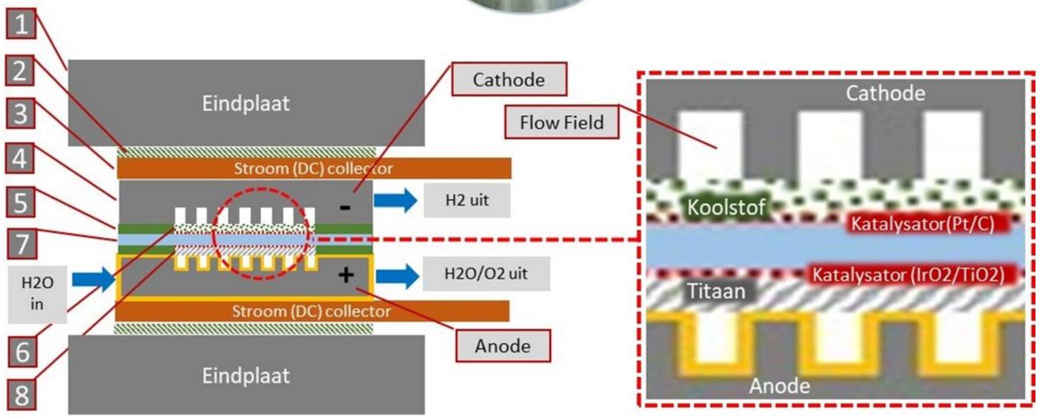
An electrolyser consists of a set of stacked basic units, so-called cells, each of which can perform the basic function: electrolysis. The heart of the cell is formed by the membrane with electrodes encapsulated between two metal plates through which water and reaction gases can be passed. As a whole, this is subject to electric voltage and high mechanical pressure. Several stacked cells together form a stack. As multiple larger cells are stacked on top of each other, the capacity of the electrolyser stack increases.

See the diagram below for the names of the most important parts within the PEM cell. The structure of an Alkaline cell is by no means the same. The differences are often not relevant to the objectives and level of detail of this study. Whenever this is the case, it will be stated in the analysis.

1. End plate
2. Separator
3. Current collector
4. Bipolar plate
5. Sealing
6. GDL (Anode)
7. Membrane + catalyst layers
8. GDL (Cathode)

**PEM cell** (sketch)

**MEA detail** (sketch)



# Structure of an electrolyser (2/2)

An electrolyser consists of a (PEM or Alkaline) stack, embedded in a system of so-called Balance of Plant (BoP) components. In this study, we focus on the following BoP components/functions:

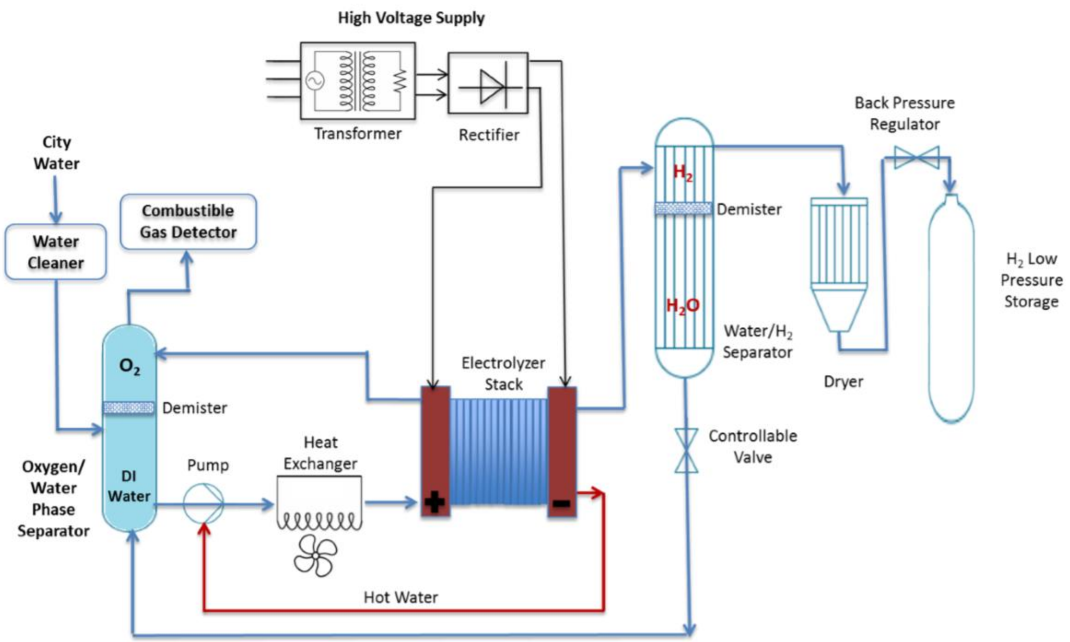
**WE system:**

**Stack**

1. Electrolyser stack

**Balance of Plant (BoP)**

2. Power electronics
3. Water treatment
4. Gas treatment
5. Cooling
6. Sensors
7. Pipelines




Again, the differences between BoP systems for PEM and Alkaline systems are not relevant to the objectives and level of detail of this study. Whenever they are, this will be mentioned in the analysis.

## The critical components can be seen as a focal point for innovation. The companies which can contribute to performance improvements and cost reductions for these components over the coming years have a chance of being successful in this new market.

Critical components represent the elements in the electrolyser with the:

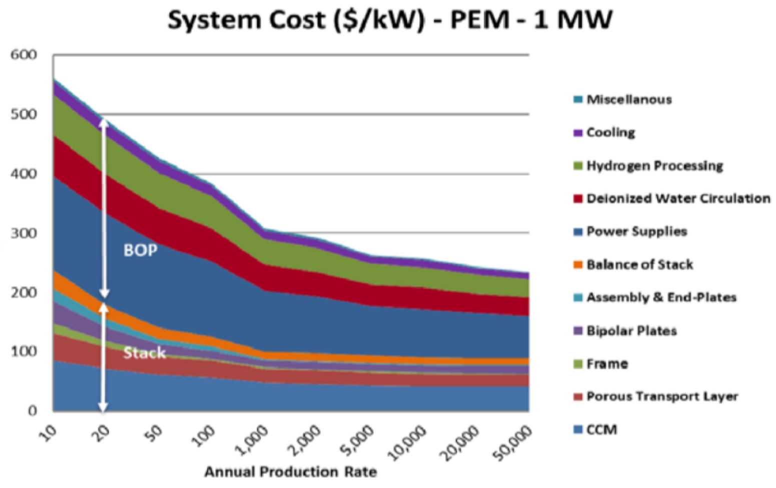
- greatest value

AND/OR

- biggest technological bottleneck

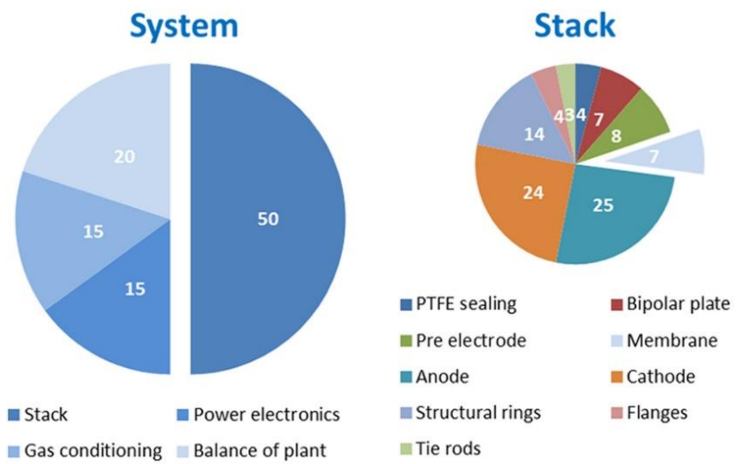
The costs of PEM systems are determined by the following components:

- PEM stack (40%) with membrane, electrodes/catalysts, GDL and the bipolar plates as the most cost-determining components.
- Power electronics (25-30%).
- Water treatment (10-15%).
- Gas treatment (10-15%).
- Some of these components contain rare metals, which further increases costs and poses a potential problem for sustainability.




**Source**: NREL, 2019

The cost structure of the Alkaline electrolyser is different. The most expensive components are the electrodes as well as the mechanical components needed to hold the heavy structure together. As a comparison, the typical size of an Alkaline diaphragm is 2 to 4 $m^2$. In the case of PEM systems, this is smaller by a factor of 10!




**Source:** E4TEch, 2014. Development of water electrolysis in the European Union.

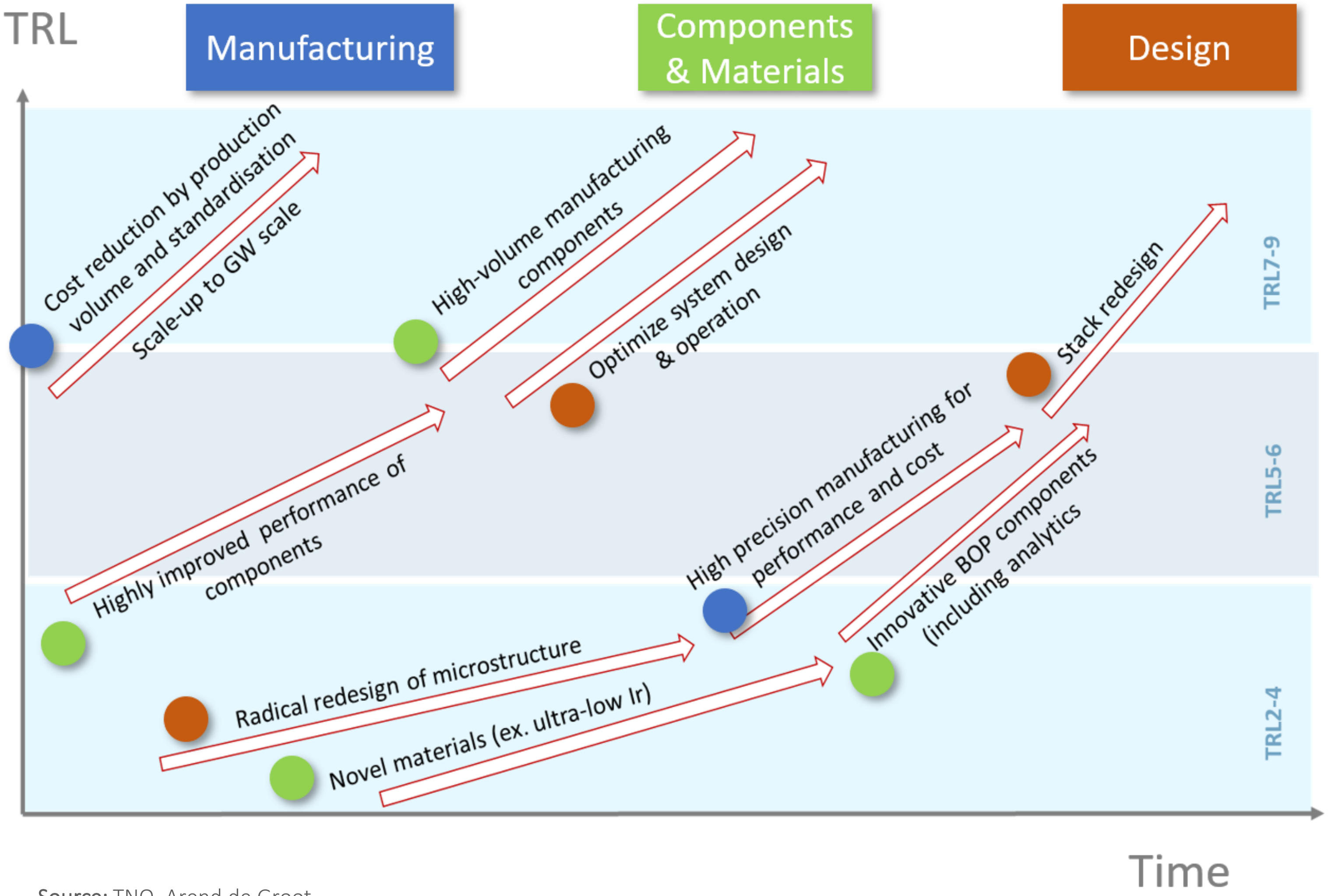
For both PEM and Alkaline, we can distinguish between important innovation directions which will contribute to the success of water electrolysis:

- The first direction assumes cost reduction through increasing volumes, increasing standardisation and component (function) integration.

- The second direction revolves around improving quality at the level of materials and components.

- The third direction focuses on more efficient and flexible WE systems which are better suited to the needs of future energy systems.

# Innovation directions




Source: TNO, Arend de Groot.

# Specific innovation tasks for Alkaline and PEM systems

| Domain | Alkaline | PEM |
|---|---|---|
| WE cell design and materials | Better catalysts (RuOx, IrOx) that can increase the current density (>0.5A/cm$^2$).<br>Electrolyte at higher temperatures.<br>Ion-conducting membranes instead of passive diaphragms. | Higher current density (>5A/cm$^2$) due to optimal cell design.<br>Better (nano) catalysts (Sb, Te).<br>Reduction in Pt/Ir use due to better evaporation and coating techniques.<br>Alternative membranes, thinner, better conductivity. |
| Stack | Larger stacks (more cells on top of each other).<br>Higher working pressure.<br>Increased stack density due to reduced cell thickness (0-gap design). | Larger, longer stacks, smaller footprint.<br>Higher operating pressure (>100 bar).<br>Low-cost bipolar plate, stainless steel instead of Ti as substrate, high-tech coatings for optimal mass-transfer behaviour. |
| WE system/BOP components | Improvement to thermal behaviour.<br>Optimisation of KOH circulation.<br>Faster turning on/off (better integration in the e-grid). | Autonomous, coordinated, self-monitoring (sensory) systems.<br>Bankability/risk-free operation.<br>Integration into the electricity and gas networks.<br>Better $H_2O$ quality, less Me+ residues. |
| Lifespan | Durable electrodes through smarter materials and coatings.<br>Better water quality, elimination of Me+ contaminants. | New electrode/coatings that improve the lifespan of electrocatalysts.<br>Better protection of the bipolar plate against erosion. |
| Efficiency | Smarter power electronics are estimated to deliver 2-3% efficiency. | Thinner membranes, lower resistance.<br>More efficient AC/DC conversion. |
| | Higher operating temperature (<200 degrees Celsius) | Higher operating temperature/pressure. |
| | Optimisation of transport (ions, water) processes in the Alkaline cells. | More efficient gas scrubbers. |
| Industrialisation | In time, manual work will be largely automated, but the impact will be smaller than with PEM. | Standardisation, mass production and more competition are particularly beneficial for PEM, which will be produced in many large quantities. |

# 4. Opportunity map

## The opportunity map gives an overview of Dutch companies which can play a role in the production of electrolysers. To be placed on the map, a company must meet the following criteria:

- The company falls within the scope of the study. See Section 1 for an explanation of the scope.
- The company has a relevant knowledge base - in terms of technology and expertise - for the production of (components or stacks for) electrolysers.
- The company has ambitions in the field of development and/or manufacturing focused on the production of (components or stacks for) electrolysers.

Per company, the following are then identified:

- The location in the Netherlands
- The technology focus (Alkaline, PEM, generic)
- Specific position(s) within the production chain for which the company has ambitions
- Specific position(s) within the production chain in which the company is already active, specifically regarding the development and/or manufacturing of electrolysers

The following slides give an overview of the current situation in the Netherlands with specific attention to the particularities within regions. The regional view also mentions the relationship with regional policy, relevant demonstration projects and research & innovation infrastructure.

The regions are defined as follows. This classification, based on the provinces involved in the study, is somewhat arbitrary but can be explained to some extent as centres of existing administrative cooperation. Only the west region is an exception.

| | | |
|---|---|---|
| North | > | Groningen, Friesland, Drenthe (New Energy Coalition) |
| East | > | Gelderland, Overijssel (OostNL) |
| South | > | Zeeland, Noord-Brabant, Limburg (ENZuid) |
| West | > | Noord-Holland, Zuid-Holland, Utrecht |

# Electrolyser production chain

**Stack components:**

These are separate components of an electrolysis installation, such as membranes, electrodes, catalysts, coatings, sheeting and the crucial bipolar plate (BPP).

**Stack integration:**

This category includes companies which can assemble the electrolyser from the separate components, the core of an electrolysis installation.

**Balance-of-Plant:**

These are suppliers of essential technologies relating to the electrolyser, such as power electronics, sensors, cooling and gas and water purification technology. A great deal of added value is created at this stage of production.

**System integration:**

These are companies which can assemble complete electrolysis installations. These parties play an important role in organising the suppliers in the production chain.

**Customers:**

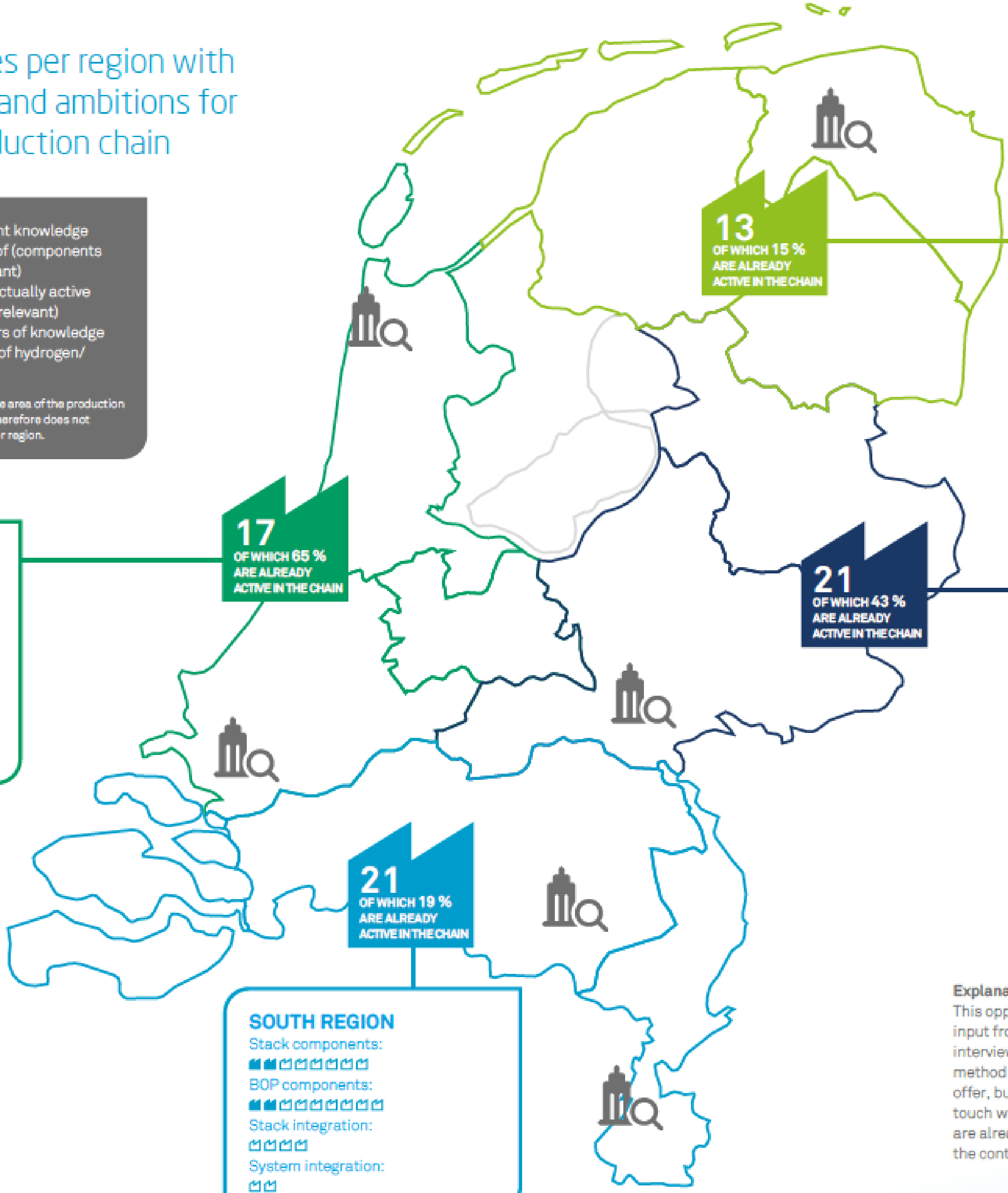
In addition to the production chain, (potential) electrolyser customers can also play an important role in the further development of a production chain for Dutch electrolyser technology.

# Opportunity map for electrolysers

## Number of companies per region with relevant knowledge and ambitions for the electrolyser production chain

□ Number of companies with relevant knowledge and ambitions for the production of (components of) electrolysers (potentially relevant)
■ Number of companies which are actually active in the production chain (currently relevant)
Research institutes and/or clusters of knowledge and (research) activity in the field of hydrogen/ electrolysis

NB Several companies are active in more than one area of the production chain. the sum total for the various categories therefore does not correspond to the total number of companies per region.




**NORTH REGION**
Stack components:
■□□□
BOP components:
□□□□□□□□
Stack integration:
■□
System integration:
■□□
Electrolyser customers:
■

**WEST REGION**
Stack components:
■■■
BOP components:
■■■■□□□
Stack integration:
■■
System integration:
■■□□□
Electrolyser customers:
■■□□

**EAST REGION**
Stack components:
■□□□□□□□
BOP components:
■■■■□□□
Stack integration:
■■□
System integration:
■■■□□
Electrolyser customers:
■■■□□

**SOUTH REGION**
Stack components:
■■□□□□□□
BOP components:
■■□□□□□□□
Stack integration:
□□□□
System integration:
□□

**Explanation**
This opportunity map was created on the basis of an extensive survey, input from experts from various organisations and more than 80 interviews with relevant companies throughout the country. This working method has provided a solid impression of what the Netherlands has to offer, but we do not pretend that it is complete. We would like to get in touch with any companies that are missing from this overview but which are already active in the chain or are considering becoming so. Please see the contact details in the colophon.

# Explanation

Hotspots for the (potential) development and production of stack components can be found in Gelderland, Overijssel and Noord-Brabant.

In the other provinces, too, companies with relevant knowledge and expertise can be found throughout the entire production chain.

In general terms, we can state the following: the entire value chain for electrolysers is represented in the Netherlands. The regions with relatively large manufacturing industries stand out when it comes to the (potential) development and production of components.

- For the east of the Netherlands, the centre of gravity is around Arnhem (hydrogen technology cluster) but also in Overijssel, where many companies specialise in materials technology.
- In Brabant, it is mainly the companies around the Eindhoven HTSM cluster which are strongly represented.

For the (potential) development and production of BoP components and system integration, we can see that relevant companies are located throughout the country, particularly around the existing industrial clusters.

It is also notable that the potential stack and system integrators are spread throughout the Netherlands.

The following slide provides an analysis for the different segments of the value chain.

**Technology breakdown**

In addition to the geographical spread, this study also looked at the technologies with which the companies involved are active.. The table below shows how many companies per segment of the production chain work with Alkaline, PEM or generic technology and what percentage of these are already active in the chain.

| | Stack-componenten | | BOP-componenten | | Stack-integratie | | Systeemintegratie | | Afnemers | | Totaal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alkaline | 2 | 50% | 3 | 0% | 3 | 100% | 2 | 100% | 1 | 100% | 6 | 67% |
| PEM | 9 | 33% | 4 | 50% | 6 | 33% | 5 | 80% | 5 | 80% | 22 | 45% |
| Generiek | 12 | 25% | 24 | 33% | 2 | 0% | 8 | 0% | 4 | 25% | 44 | 27% |
| **Totaal** | **23** | 30% | **31** | 32% | **11** | 45% | **15** | 40% | **10** | 60% | **72** | 36% |

# Opportunity map - explanation per chain segment

**Stack components**
The Netherlands has the required companies which can make stack components, almost a third of which are already active in the production chain. The emphasis here is on PEM and generic technology. The dominant regions in this area are the east and the south. The latter is also interesting because of the presence of companies which can play a role in the automation and mass production of components. The west region is also interesting because the companies there are already active in existing production chains.

Stack integration
Several companies have the technical means to produce stacks in the short term. At the moment, a small number are already active as developers and/or producers, especially of PEM systems. It is notable that the south region, in particular, is not yet active in the market even though its potential is in no way inferior to that of the other regions.

BoP components
This is a relatively large category with a remarkably good spread throughout the Netherlands. A substantial number of these companies are already active in existing production chains for electrolysers. This is particularly true in the east and the west. The other two regions have manufacturing industries that work predominantly for other markets, such as fuel cells or the automotive sector.

System integration
(Potential) system integrators are active throughout the Netherlands and are generally large companies. A handful are already active in this market, but mainly as developers and manufacturers of small systems. Series production is not yet ongoing in the Netherlands. An important conclusion is that there is a potential manufacturer of electrolysers in almost every province. The question is if and how such parties will also become active.

Customers
Several companies in the Netherlands are already using electrolysers for the production of hydrogen on a pilot scale or plan to do so in the near future. These are currently concentrated predominantly in the west and east regions but all industrial clusters have potentially interesting application areas, including the north (Eemshaven) and the south (Chemelot).

# Opportunity map

# Regional view

In the regional view, outlines of the relevant companies and their (potential) position in the production chain are provided separately for four regions. Notable characteristics, opportunities and challenges are identified. For each region, an overview is given of regional policy, relevant demonstration projects and research & innovation infrastructure. The regions are defined as follows:

| | | |
|---|---|---|
| North | > | Groningen, Friesland, Drenthe (New Energy Coalition) |
| East | > | Gelderland, Overijssel (OostNL) |
| South | > | Zeeland, Noord-Brabant, Limburg (ENZuid) |
| West | > | Noord-Holland, Zuid-Holland, Utrecht |

# North region

| Company | Province | Region | Stack components | BOP components | Stack integration | System integration | WE user | Technology |
|---|---|---|---|---|---|---|---|---|
| Ampulz | DR | North | | ■ | | | | PEM |
| Eekels Technology | GRO | North | | ■ | | | | Generic |
| FINN | GRO | North | | ■ | | | | Alkaline |
| FMI additive manufacturing | FR | North | ■ | | | | | PEM |
| Gasunie | GRO | North | | | | ■ | ■ | Generic |
| ICH B.V. | DR | North | | ■ | | | | Generic |
| Masevon | FR | North | | | ■ | | | PEM |
| Metal Membranes | FR | North | ■ | ■ | | | | Alkaline |
| Oreel | FR | North | | ■ | | | | Generic |
| Resato | DR | North | | ■ | | | | Generic |
| Stork | GRO | North | | | | ■ | | Generic |
| SuwoTec | GRO | North | ■ | | | | | Generic |
| Tieluk | FR | North | ■ | ■ | ■ | ■ | | Alkaline |

# North region (1/2)

### Highlights

The manufacturing industry for electrolysers is underrepresented in the north of the Netherlands. Nevertheless, there are good opportunities for a diverse group of companies ranging from suppliers of electrodes (SuWoTec, Tieluk) and power electronics (Ampulz) to (potential) developers and producers of stacks (Masevon, Tieluk) and system integrators (Stork, Gasunie).

- Above all, the the north of the Netherlands is characterised by a powerful energy and industry cluster with Eemshaven and the (planned) offshore wind farms as an important application area for green hydrogen.
- The traditional position in the field of natural gas and the related assets (capital, skills) also provide a good starting point for building up a regional hydrogen hub and launching large-scale experiments.
- Also unique in the region is the so-called Hydrohub, an open test facility in which knowledge institutes and companies can test (components of) electrolysers on a semi-industrial scale. Partners include Gasunie, ISPT, TNO and Hanze University of Applied Sciences.

### Ambitions and policies

- The province of Groningen has a leading role in the development of hydrogen technologies in the region. A hydrogen vision exists and substantial investments have already been made in projects, infrastructure and research facilities.
- The provinces of Drenthe and Friesland are currently more in the position of followers. Friesland is still working on a hydrogen vision; in Drenthe, the college plans to release five million euros for a broad scheme aimed at energy innovation.
- Collaboration between the northern provinces is going well. Supra-regional coordination is mainly taking place within the New Energy Coalition network.
- Very recently, the northern provinces - in collaboration with Gasunie - translated their ambitions into an investment plan aimed at building up a regional hydrogen economy.

# North region (2/2)

## Projects

- A consortium of Gasunie, Groningen Seaports and Shell has begun a feasibility study regarding an electrolyser in Eemshaven linked to a 3-4 GW wind farm. The time horizon for the realisation is 2027 (NorthH2 project).
- Gasunie and Nouryon, together with other partners, are working on plans for a 20 MW electrolyser in Delfzijl (Nouryon, Gasunie). Funding (11 million euros) comes from the European partnership Fuel Cells and Hydrogen Joint Undertaking (FCHU).
- The Heavenn project is another FCHU project. The goal is to set up a fully integrated hydrogen hub in the north of the Netherlands. A 20 million euro subsidy is available, plus another 90 million euros of co-funding.
- At the GZI site in Emmen (at the initiative of NAM and Gasunie, among others), a 2 MW electrolyser is planned in order to produce hydrogen to replace natural gas for industry (Emmtec) and public transport (QBUZZ). In 2021, the first step will consist of installing 2-4 MW of electrolysis and realising a tank facility for the hydrogen buses in this region. Before 2023-2025, there are plans to expand to 20-50 MW of electrolysis (and even up to 100-250 MW after 2025).
- A hydrogen district is being planned in Hoogeveen, where a site of approximately 16 homes is to be fitted with a central electrolyser and fuel cell in order to provide the homes with heat and electricity.
- Within the framework of the Green Shipping Wadden Sea Programme, the production and application of green hydrogen is being demonstrated in the port of Den Helder. This includes the construction of a solar park, electrolyser and public hydrogen filling station. An electric-powered vessel with a hydrogen fuel cell will also be developed with which various maritime service providers and knowledge institutes can gain experience. The programme is coordinated by FME and is aimed at supporting industry, knowledge institutes and ports in regard to the innovations for $CO_2$-neutral and fossil-free shipping and facilities in the Wadden ports. The total programme costs amount to 25.9 million euros. The Wadden Fund provides a subsidy of 8 million euros. The provinces of Friesland and Noord-Holland also support the programme.

## Opportunities and challenges

- In the Netherlands, and even in Europe, the region is in a leading position when it comes to (plans for) the large-scale application of electrolysers. Gasunie and Nouryon are important parties in this respect.
- At the same time, none of these projects involve cooperation with suppliers from the region or even from the Netherlands. The demonstrations are aimed at learning and experimenting with the application of the electrolyser in the context of the energy system, not at (learning to) build and improve the electrolyser.
- Companies which may already be able to produce electrolysers are currently hardly involved in existing production chains. For the group of BoP suppliers in particular, the gap between the existing potential (8) and actually active companies (0) is striking.
- The administrative cooperation of Groningen, Drenthe and Friesland with other Dutch regions is limited. In particular, there is room for improvement in regard to the available facilities and infrastructure.

# Research facilities in the north region


## Hydrohub

### Groningen

**Objective:** The goal is to produce cost-efficient, large-scale and $CO_2$-free hydrogen in the Netherlands before 2030. MW-scale stress tests of water electrolysis.

**Scope:**

- TRL: 4 - 5
- Technology: PEM (250 kW) and Alkaline
- Particularities: design, efficiency and balance of plants

**Offer:** Activities are aimed at testing MW-scale electrolysis systems in a simulated application environment. The focus is on the development of new stack designs, new components and BoP efficiency. Non-partners can also use the installations and test their own (sub)systems. As soon as this works well in the Hydrohub, it can be translated into an electrolysis installation on an industrial scale (GW).

**Partners:** Consortium with ISPT, Gasunie, Yara, Shell, Nouryon, TNO and Hanze University of Applied Sciences.

# West region

| Company | Province | Region | Stack components | BOP components | Stack integration | System integration | WE user | Technology |
|---|---|---|---|---|---|---|---|---|
| ABB | ZH | West | | X | | X | X | Generic |
| Althen | ZH | West | | X | | | | Generic |
| Bosal | UT | West | | X | | | | Generic |
| Cryoworld | NH | West | | X | | | | Generic |
| Delft IMP | ZH | West | X | | | | | Generic |
| Demaco | NH | West | | X | | | | Generic |
| Evides | ZH | West | | X | | | | Generic |
| Frames Group | ZH | West | | | | X | | PEM |
| GP Groot | NH | West | | | | | X | PEM |
| Hydron Energy | ZH | West | X | | X | | | PEM |
| Hygro | NH | West | | | | X | X | PEM |
| Magneto | ZH | West | X | | | | | Generic |
| Mourik | ZH | West | | | | X | | Generic |
| Port of Rotterdam | ZH | West | | | | | X | Generic |
| Yokogawa | UT | West | | X | | | | Generic |
| ZEPP solutions | ZH | West | | | | X | | Generic |
| Zero Emission Fuels | ZH | West | | | X | | | Alkaline |

# West region (1/2)

## Highlights

- The region has a relatively large number of companies that are active in the field of BoP components but also a large number of (potential) system integrators such as Frames, Zepp and Hygro. In the field of stack components, the number of relevant companies is limited, but those that are present (Hydron and Magneto) are already active in the existing production chain for electrolysers.
- The companies Hydron Energy and Frames are interesting in terms of stack and system integration. They have built, together with TNO, a 50 KW electrolyser for research purposes. As part of the Hydrohub test centre (Groningen), they are now working on a 250 kW PEM system. Design and construction has been done entirely by Dutch parties. The components come from various international suppliers.
- The region is further characterised by the presence of large potential end-users, particularly the chemical industry in Rotterdam and steel production in IJmuiden. This offers opportunities for the demonstration and ultimately large-scale application of electrolysers.
- Offshore wind provides prospects for large quantities of sustainable electricity. The existing hydrogen infrastructure is a strong starting point for the import, export and transit of green hydrogen.
- What is also unique in the region is the strong knowledge infrastructure, including the Faraday lab (NH) and the Fieldlab Industrial Electrification (ZH), a facility designed to develop, test and accelerate the application of electrolysis systems, among other things. Demonstration on an industrial scale is one of the most important objectives.
- Also worth mentioning is Investa's experimental centre in Alkmaar, focused on R&D concerning green gas.

## Ambitions and policy

- The province of Zuid-Holland has the ambition to realise 1-2 GW of electrolysis capacity by 2030. This is in line with the national objective of 3-4 GW, as set out in the Climate Agreement. In collaboration with the Port of Rotterdam Authority and other partners, the province is investing in the development of a hydrogen infrastructure through various projects. The generation of green hydrogen is one element of this.
- For Noord-Holland, the hydrogen strategy is still under development. A vision on energy infrastructure already exists, of which hydrogen forms a part.
- In terms of hydrogen technology, the province of Utrecht is particularly active in terms of application in mobility. There is (as of yet) no integral hydrogen vision in which the production of hydrogen or electrolysis play a role.

# West region (2/2)

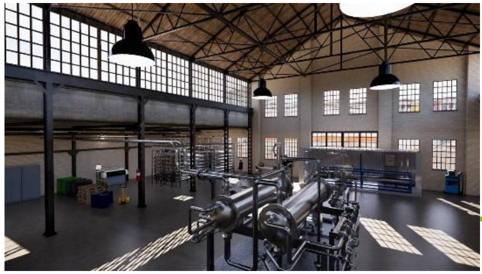
## Project

- As part of the H2ermes project, Nouryon, Tata Steel and the Port of Amsterdam are investigating the establishment of a 100 MW hydrogen plant on the Tata Steel site in IJmuiden.
- In Rotterdam, two electrolysers are planned of 250 MW each: one by Shell (for 2023) and one by Nouryon, BP and the Port of Rotterdam Authority (2025).
- In Wieringermeer, HYGRO is realising a 4.8 MW wind turbine with an integrated 2 MW electrolyser for the production of hydrogen.
- In Anna Paulowna, ENGIE is realising a 1 MW electrolyser at a Liander substation.
- Vattenfall will build a 10 MW electrolyser on the Hemweg in the next two to three years and wants to scale up to 100 MW by 2030.

## Opportunities and challenges

- With a wide range of large-scale end-users, the region is an ideal pilot area for the first electrolysis applications. Plans for the development of electrolysers are plentiful but at the moment, these are mainly projects for which the technical and economic feasibility has yet to be determined.
- As a pilot area for the development of electrolysis technologies, the region is currently being utilised to only a limited extent. Only proven technologies are used in the existing demonstration programmes. The Dutch (potential) suppliers, who are less well positioned in the current market, are not benefiting from the initial market demand partly because of this.
- The challenge is to establish a connection - and interaction - between this type of project and the intended component suppliers, including those from elsewhere in the Netherlands. The aim is to stimulate innovation in all parts of the chain.
- The testing capacity and demonstration possibilities of the Faraday lab and the Fieldlab Industrial Electrification in particular could be the bridge here between the development of new technology and production methods and the implementation of what is available in this region, particularly in industry.

# Research facilities in the west region



## Fieldlab Industrial Electrification
Rotterdam

**Objective:** Industrial incorporation of electrolysers into industrial practice

**Scope:**
- TRL: 4 – 8
- Technology: flexible electrolysers in industrial practice.
- Particularities: focus on electrification technologies for the process industry with an important focus on decarbonisation of industry, sustainability, energy and resource efficiency and energy transition vision.

**Offer:** Solution centre, experiment and test site, demo location (on-site) at relevant industrial scale (>MW).

**Partners:** FME, Deltalinqs, TNO, Innovation Quarter, Port of Rotterdam.


## Faraday Lab
Petten

**Objective:** Optimising and scaling up electrolysis technology; Gigawatt Electrolysis Plant design.

**Scope:**
- TRL: 2 – 7
- Technology: PEM, Alkaline, SOE and AEM.
- Particularities: interdisciplinary approach together with the process industry.
- Focus on the development of next-generation electrolysers (TRL 3-5) in collaboration with research centres on the High Tech Campus (Holst Centre, Solliance, TNO Material Solutions).

**Offer:** Research and development focused on materials and components with specific attention to industrialisation, cost reduction, prolonging lifecycles and better system integration.

**Partners:** TNO collaborates in projects with Hydron Energy, Magneto, PTGe, Delft IMP, Frames, Fujifilm and others.

# East region

| Company | Province | Region | Stack components | BOP components | Stack integration | System integration | WE user | Technology |
|---|---|---|---|---|---|---|---|---|
| Boessenkool | OV | East | | X | | | | Generic |
| Bredenoord | GLD | East | | | | | X | PEM |
| Bronckhorst | GLD | East | | X | | | | Generic |
| Contour | GLD | East | | X | | | | Generic |
| Demcon | OV | East | | X | | | | PEM |
| Dufor | GLD | East | X | | | | | Generic |
| Eurekite | OV | East | X | | | | | PEM |
| Ferro Techniek | GLD | East | | X | | | | Generic |
| HFI Hartman | GLD | East | X | | | | | Generic |
| Hyet Hydrogen | GLD | East | | | X | X | | PEM |
| HyGear | GLD | East | | | | X | X | PEM |
| Koolen Industries | OV | East | | | | | X | Generic |
| MTSA Technopower | GLD | East | | X | | X | X | PEM |
| MX Polymers | GLD | East | X | | | | | PEM |
| Nedstack | GLD | East | X | | | | | Generic |
| Nouryon | OV | East | | | | | X | Alkaline |
| NTS Norma | OV | East | X | | X | | | PEM |
| Teljin Aramid | GLD | East | X | X | | | | Generic |
| Veco Precision | GLD | East | X | | | | | PEM |
| Xintc Global | GLD | East | | | X | X | | Alkaline |
| Zeton | OV | East | | | | X | | Generic |

# East region (1/2)

## Highlights

- The region has a particularly high concentration of companies specialising in the development and production of materials and components. A large part of the activities are clustered at Industriepark Kleefse Waard (IPKW) in Arnhem. The strong position of these companies can be explained through the knowledge and experience built up over the past 20 years regarding fuel cell technology. In Overijssel, relevant knowledge lies mainly in the field of materials (e.g. ceramics) and mechanical engineering.
- In the field of stack and system integration as well, several companies are well-equipped to play a role in development and production. In fact, companies are already active, albeit on a modest scale, in the existing production chain for electrolysers - both PEM and Alkaline.
- Business Cluster H2 Technology is an initiative of Hymove which is aimed at strengthening the hydrogen technology export position from the Netherlands to China. The scope is national and offers room for companies that can add something to the consortium.
- In particular, the HAN University of Applied Sciences in Arnhem and Nijmegen is a regional leader in the field of knowledge development. The HAN offers an experimental environment in which students work together with companies on small-scale tests.

## Ambitions and policy

- In terms of economic and industrial policy, the province of Gelderland is joining forces with the cities of Arnhem and Nijmegen. The province's policy is aimed at forming and strengthening 'innovation clusters' of companies. A step has recently been taken in this direction by establishing an H2 lab linked to HAN, for instance.
- The province of Overijssel is still in the process of forming a vision and strategy. The idea is to use electrolysis for the development of small-scale decentralised applications, such as for filling stations and residential areas. The region should become a living lab for matching technologies.
- The collaboration between public authorities and regional development organisations (OostNL, KIEMT) is regulated in the east of the Netherlands through the HyEast network.

# East region (2/2)

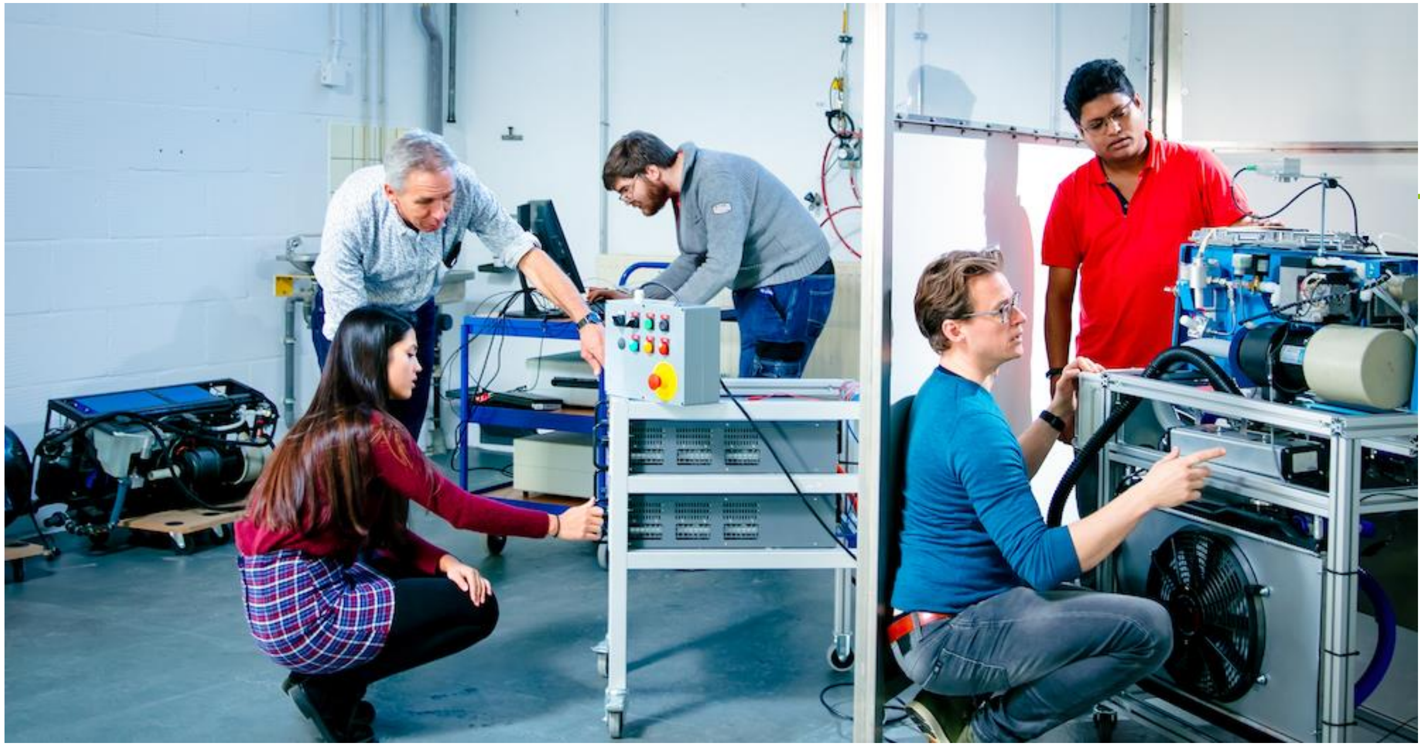
## Projects

- Together with regional partners, MTSA is building a power-to-power installation at the IPKW demo and test location (living lab), partly to explore various functions.
- Furthermore, in terms of projects, the emphasis is on applications, particularly in the field of fuel cells. For example, Hymove - together with regional companies and knowledge institutions - built a hydrogen powertrain for heavier vehicles in 2016, with demonstrations in two Syntus buses in 2019-2020.

## Opportunities and challenges

- The region is relatively highly developed in terms of collaboration between companies with relevant and complementary knowledge positions. The cluster in Arnhem, with HAN as the public knowledge carrier, forms an important regional centre in relation to this.
- In terms of policy and ambition, it is also notable that the region mainly focuses on the development and deployment of small-scale electrolyser systems. A few companies themselves have also indicated that they see opportunities here, particularly in being able to create a unique international offer. A focus on (the series production of) small-scale electrolyser systems could possibly be an interesting USP for the Netherlands. This direction has not yet/barely been translated into concrete experiments and projects.
- Here, as in other regions, there is a complete lack of connection between the existing manufacturing industry and demonstration plans. If the region wants to develop as a living lab, this should include a pilot for the manufacturing industry.
- As far as public policy is concerned, it is important to note that the currently planned use of subsidies within the region is limited to generic funds to support innovation. Entrepreneurs also note that the range of subsidies and schemes on offer is unclear. If the region is to build up a position as a pilot area, a more coordinated policy is needed.
- In line with the aforementioned points, there is an opportunity to link regional ambitions (and resources) to supra-regional initiatives and developments. There are opportunities for companies in the region to collaborate with companies elsewhere in the Netherlands. The link with test infrastructure in the north and west regions offers companies the opportunity to validate their products. The link with the High Tech cluster in the south offers opportunities to focus on automation and series production.

# Research facilities in the east region



## HAN H2Lab
### Arnhem

**Objective:** The HAN H2Lab carries out practice-oriented research into hydrogen applications for small and medium-sized hydrogen systems..

**Scope:**
- TRL: 3 - 5
- Technology: SOE, PEMFC, Alkaline (small scale).
- Researchers, teachers and students from the HAN work together with companies on projects here. These parties design, model, construct and test various hydrogen systems for mobile applications, energy storage and grid stability.

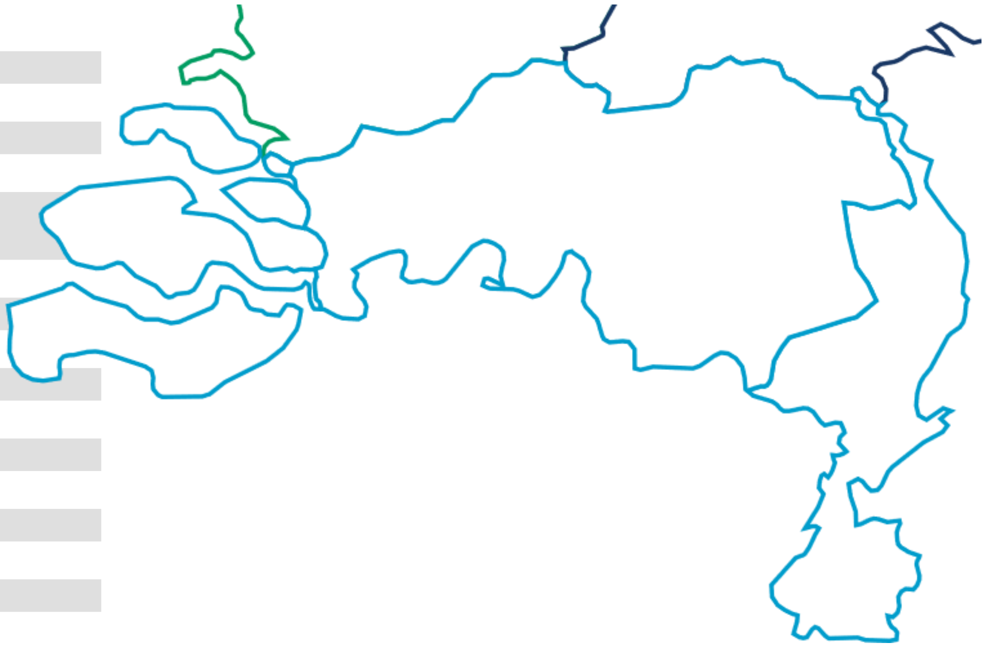
**Offer:** The lab is equipped with infrastructure aimed at developing and testing hydrogen systems. In addition to the hydrogen facilities, this includes a workplace, test spaces, test stations, electrochemical testing equipment and associated safety systems.

**Partners:** SEECE (Sustainable Electrical Energy Centre of Expertise).

Photo source: https://www.han.nl/onderzoek/kennismaken/technologie-en-samenleving/lectoraat/duurzame-energie/faciliteiten/hanh2lab

# South region

| Company | Province | Region | Stack components | BOP components | Stack integration | System integration | WE user | Technology |
|---|---|---|---|---|---|---|---|---|
| Additive Industries | NB | South | ■ | | | | | PEM |
| Admatec | NB | South | ■ | | | | | PEM |
| Adsensys | NB | South | | ■ | | | | Generic |
| Blue Engineering | LI | South | | | ■ | | | Generic |
| Bosch Transmission Technologies | NB | South | | | ■ | | | PEM |
| Coorstek | NB | South | | ■ | | | | PEM |
| D&M Vacuumsystems | LI | South | | ■ | | | | Generic |
| Delmeco | ZE | South | | | | ■ | | Generic |
| Diffutherm | NB | South | | ■ | | | | Generic |
| Exotech | ZE | South | | ■ | | | | Generic |
| Fluidwell | NB | South | | ■ | | | | Generic |
| Fuji Film Europe | NB | South | ■ | | | | | PEM |
| Hauzer | LI | South | ■ | | | | | Generic |
| Ionbond | LI | South | ■ | | | | | Generic |
| Kepser Pro Metaal | NB | South | | ■ | | | | Generic |
| KMWE | NB | South | ■ | | | | | Generic |
| Lumileds | ZE | South | | | ■ | | | PEM |
| Nproxx | LI | South | | ■ | | | | Generic |
| Prodrive Technologies | NB | South | | ■ | | | | Generic |
| PTG | NB | South | ■ | | | | | Generic |
| VDL | NB | South | ■ | | ■ | ■ | | Generic |



# South region (1/2)

## Highlights

- The region is particularly well-positioned in terms of advanced materials - coatings, membranes and ceramics. There are also various parties in the region that see a role for themselves as stack or system integrators. It is notable, however, that only a small proportion of these companies are actually active. These are mainly potential new entrants.
- Zeeland is already the largest consumer of (fossil) hydrogen, with DOW, Yara and Zeeland Refinery as major consumers. Moreover, this is the location at which a hydrogen connection has been running since 2018 via a Gasunie pipeline. Zeeland is also the region in which large-scale wind power will first become available. All in all, this is an attractive location for the first large-scale electrolyser demonstrations.
- The application of hydrogen also plays an important role in Limburg, particularly for the Chemelot industry cluster with OCI Nitrogen as a major producer of fertilisers. In terms of future infrastructure requirements, Limburg still has a major task ahead of it, particularly in regard to the connection to high-voltage power lines.
- The knowledge infrastructure in the region is strong due to the presence of Brainport/TU Eindhoven and the Brightlands Chemelot Campus, which is a particular spearhead in the development of new materials.

## Ambitions and policy

- The province of Noord-Brabant is committed to the broad development of the technology needed to improve the business case for hydrogen storage and conversion. Various initiatives are underway in order to flesh this out in concrete terms. The main thrust is to link up the HTSM manufacturing industry.
- The province of Zeeland has the ambition of remaining the largest hydrogen cluster in the Netherlands as part of the industrial hydrogen economy, with the Smart Delta Resources (SDR) network as a powerful triple-helix collaboration platform. At an early stage, the SDR region opted to develop a transition path regarding hydrogen and this was made concrete in the Hydrogen Delta programme.
- The province of Limburg has recently launched a hydrogen agenda. In doing so, it sees a role for itself as a director focused on collecting knowledge, bringing plans together and making choices. A budget of €500,000 has been made available for a number of projects which are mainly focused on the application of hydrogen in industry and pumping stations.
- Within the framework of ENZuid, the three provinces are working together to make the southern provinces more sustainable. An explicit ambition is to link the manufacturing industry to innovations within the chemical and energy sectors. Work is underway on defining initial projects.

# South region (2/2)

### Projects

- The Hydrogen Delta programme of SDR is aimed at a 100 MW pilot electrolyser in 2025 and a GW system around 2030. In the short term, blue hydrogen will be used in the transition to green. In addition, a hydrogen grid will be developed for connection to the national grid.
- A regional study was carried out into the implementation of an electrolyser on a 1 GW scale. The participants were SDR, Dow, Yara, Zeeland Refinery, PZEM, ArcelorMIttal, ENGIE, offshore wind company Ørsted and port company North Sea Port. The study was carried out by Arthur D. Little.
- The ENSouth programme is working on concrete, investment-ready cases. For one of these cases, the aim is to develop an electrolyser system in close collaboration between industrial customer(s) and the Dutch manufacturing industry.
- A consortium of VDL, TU Eindhoven, DIFFER and Nouryon is working on a new electrolyser design, including a focus on second-generation Alkaline technology (AEM). The goal is to achieve a far-reaching reduction in the cost of capital.
- Force Renewable Energy is working with BOM (the Brabant Development Agency) and partners on the realisation of so-called GreenH2UBs. A unique feature is that electrons from wind and solar energy are converted into green hydrogen molecules which can then be used for mobility and grid balancing.

### Opportunities and challenges

- The south region is characterised by large potential due to relevant companies with ambitions in the field of electrolysis technology. This applies in particular to the companies that can play a role in enabling the mass production (of materials and components) and series production of systems.
- It is also interesting to see that the region is already specifically committed to linking the knowledge and skills of the manufacturing industry to developments in the chemical and energy sectors. This is being coordinated - and funded - through the ENZuid supra-regional collaboration, among other things.
- It is notable, however, that there are relatively few companies in the region that are already active in the existing production chains, partly because these are companies that do not yet have a role to play. After all, a volume market does not yet exist for the development of series production and the associated investments of millions.
- Besides the necessary funding, machine builders currently have insufficient insights into the specifications of the electrolysers to be produced. Product standards are still lacking.
- Nevertheless, there is an opportunity for the region, and the Netherlands, to build up a position here based on the unique knowledge and skills in the field of HTSM and mechanical engineering. However, this can only succeed if there is (even) more investment over the coming years in collaboration between the HTSM sector (machine builders, component manufacturers) on the one hand and the chemical industry (customers, system integrators, stack integrators) on the other.
- As in the other regions, a lot is happening in the hydrogen field in terms of programmes, platforms, projects and schemes. It is difficult for companies to maintain an overview. There is a need for an overview and coordination.
- As in the other regions, there is generally no strong link between developments in the manufacturing industry (production of electrolysers) and major demonstration plans.

# Research facilities in the south region

## Eindhoven Institute for Renewable Energy Systems (EIRES)

Eindhoven

Photo source: https://architectenweb.nl/nieuws/artikel.aspx?ID=48064

**Objective:** The ambition is to use the existing knowledge position in the field of high-tech systems, materials and manufacturing to design relatively small-scale components and systems that can be produced in large volumes.

Scope:

- TRL: 3 (AEM) – 9 (Alkaline)
- Technology: Alkaline, AEM
- Particularities: modular design - ambitious up-scaling plans, so the focus is not on large installations but large sales figures.

**Offer:** EIRES is directed by the various departments of Eindhoven University of Technology: Applied Physics, Built Environment, Chemical Engineering and Chemistry, Electrical Engineering, Mechanical Engineering and Industrial Engineering & Innovation Sciences..

**Projects**: The First Dutch Electrolyser project focuses on a design, prototyping and development roadmap for Alkaline systems. A special feature of this is the involvement of the manufacturing industry and potential system integrator VDL.

**Partners:** Metalot, VDL, Nouryon, DIFFER, TNO, DENS, Vertoro.

## Brightlands Chemelot Campus

Geleen

Photo source: https://www.insittardgeleen.nl/nl-nl/5/114/chemelot.aspx

**Objective:** The Chemelot Campus focuses on the development of expertise and business in sustainable chemical processes. The focus is on chemical recycling, hydrogen production and electrification, among other things.

Scope:

- TRL: lab-scale, with extensive possibilities for scaling up on Chemelot's chemical site
- Technology: special mini-plant facilities for bio-based processes; facilities for electric cracking
- Particularities: expertise in the field of renewable processes; expertise in the field of green hydrogen initiatives.

**Offer:** Brightlands Chemelot Campus has all the facilities for researchers, entrepreneurs and students to work on innovative smart materials, bio-medicines and sustainable chemical processes. Flexible workplaces can be rented by companies and knowledge institutes, as can laboratories, clean rooms and (mini) pilot plants.

**Partners:** > 100, including Chemelot, TNO and SABIC

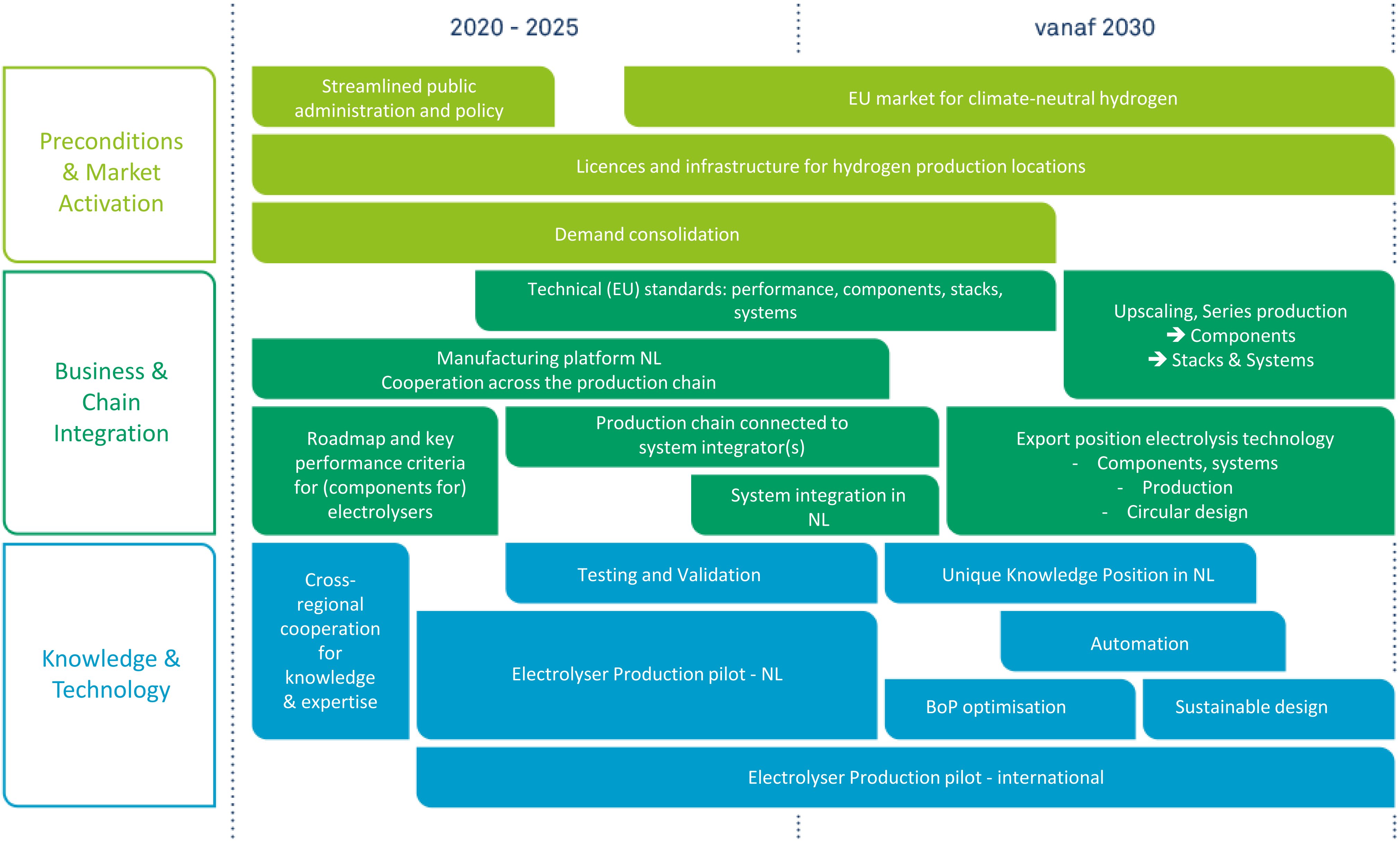
# 5. Strategic Innovation Agenda

The strategic innovation agenda indicates what is needed to capitalise on the opportunities for the Dutch manufacturing industry. It outlines development steps in the fields of:

**Knowledge & Technology:** focused on stimulating research and technological innovation.

**Business & Chain Integration:** focused on chain collaboration, standardisation, automation and up-scaling of production.

**Preconditions & Market Activation:** focused on the wider system environment of the electrolyser.




Actions needed for the realisation of a Dutch electrolysers production chain

# Knowledge & Technology explanation

## Starting point

- Companies based in the Netherlands have the relevant knowledge and experience in the field of electrolysis technology. Together, these parties are able to supply advanced materials and components and assemble them into stacks or systems.
- At the same time, the playing field is currently fragmented. Too much knowledge development and innovation takes place in isolation. As a result, the whole is not greater than the sum of its parts. It does not help that only a fraction of the potentially relevant companies are already active in the existing production chain for (components of) electrolysers.
- A plus point is the fact that there is still a huge international innovation challenge related to both components and stack and system integration. This is an opportunity for the companies that are able to create a unique knowledge position. This is also a prerequisite for Dutch companies to eventually be able to (continue to) play a substantial role.
- The Dutch knowledge infrastructure is well-equipped to provide Dutch industry with the knowledge, know-how and facilities to build up this position. Labs and test environments have been set up all over the Netherlands that make it possible to validate components and systems.

## What is needed? > Dutch Production Pilot for Electrolysis

- It is important that a Dutch Production Pilot for Electrolysis be set up with the aim of facilitating knowledge and technology development in the chain of Dutch production companies. The essence of this pilot is not learning about the application but rather the production of electrolysers.
- It is explicitly not the intention that this pilot be given a physical location. What is more important is that the existing initiatives are linked together at a national level and given direction through an integrated research and innovation programme.
- Of course, links with real-life testing grounds can be concentrated in regions. For example, applications for small-scale systems could be embedded in logistics hubs. For large-scale systems, the coastal provinces - where large demonstrations are already being planned but where links with the manufacturing industry are still lacking - are particularly relevant.
- In all cases, the existing lab and pilot infrastructure (Faraday, Hydrohub, FLIE, EIRES, HAN and others) should be exploited and, where necessary, business access should be facilitated.
- The innovation focus of these pilots must be on building up a distinctive knowledge position. This is crucial in order to be able to compete with established players. Some important spearheads are sustainability, recyclability, lifecycle components and the scalability of production techniques.
- The aim is to give a national kickstart to research and innovation. Ultimately, however, developments must also be linked to international R&D networks at an early stage. Healthy competition and a joint European knowledge roadmap is a prerequisite.

# Business & Chain Integration explanation

## Starting point

- In the long term, there is a real opportunity for Dutch companies to build up an export position for (components of) electrolysers. For a substantial proportion of the relevant companies, however, they will still have to make an enormous leap forward in terms of innovation. This task is more within reach for companies in the BoP segment than for new entrants in the field of stack components or integrators.
- Nevertheless, the results of this study do not give cause to exclude routes. The starting point is that the Netherlands has a chance to build up a market position in all parts of the production chain through targeted innovation. By working together on a joint, chain-oriented approach, it is possible to create an innovation ecosystem that increases the chances of success across all segments.
- Collaboration within the chain of (potential) production companies is still too infrequent. Of course, companies are reluctant to share competition-sensitive information. But in many cases, the willingness to collaborate is there but they do not know where to find one another. As a result, international profiling is also sub-optimal.
- Partly as a result of the above, there are insufficient insights into the relevant specifications of (components for) electrolysers. It is difficult for potential innovative suppliers to match their offer to the exact demand. The same applies to companies focused on automation.
- Currently, SMEs are still insufficiently on board with large WE users and system integrators. This is a chicken-and-egg story as large producers are insisting on the incorporation of technology with a proven track record, given the large investments and loans associated with these large demonstration projects.

## What is needed? > Electrolysis manufacturing platform

- In order to realise the existing business potential in terms of concrete economic and social value, it is important for Dutch parties to collaborate more and organise themselves. Companies need to know where to find one another, what they have to offer and what they need.
- In order to give direction to relevant innovation tasks, it is important to develop a joint technical roadmap in which companies from various parts of the production chain work on their own innovation objectives. These are inspired and substantiated by the results of the activities in the production pilot.
- The innovation objectives include quality criteria in the fields of sustainability, circularity and use of materials. The definition of quality criteria helps to set a standard for Dutch industry and sends a signal to potential international partners, including potential system integrators/customers.
- The innovations, validated in the lab and pilot facilities, form the basis for the establishment of a track record of Dutch companies that wish to enter a now largely closed market for (components for) electrolysers.
- For a stack or system integrator, this development provides a basis of trust to make investments that benefit the entire chain and are possibly supported by state or EU funds. Whether this will ultimately be a Dutch party cannot be answered for now. In any case, it is a good idea to focus on an attractive ecosystem and business climate.
- The standardisation of components and products (dimensions, settings for temperature, pressure, voltage levels, etc.) is crucial to enabling series production. It is particularly important to connect with the relevant European networks. This is ultimately a great opportunity for the HTSM sector.

# Preconditions & Market Activation explanation

## Starting point

- There is currently no mature market demand for green hydrogen. The starting point for this study is that this will change in the short term, initially through the funding (with public resources) of various demonstration projects.
- If capital becomes available for demonstration projects aimed at the manufacturing industry, the Netherlands can grow rapidly as an expert and exporter of components, stacks and possibly even systems.
- However, the pilots and demos that are currently planned do not offer sufficient prospects for Dutch industry. There is no link between the manufacturing industry and the existing plans for pilots and demonstrations, both for industrial applications and decentralised applications.
- This situation is undesirable from the perspective of both European innovation and climate policy and the Dutch innovation (eco)system as it does not sufficiently stimulate innovation in the production chain and does not make use of the potential contribution of Dutch companies.
- An additional problem is that administrative fragmentation (both within different layers of government and across the Netherlands) results in the ineffective deployment of resources and a lack of direction. This also manifests itself in messy decision-making in the fields of infrastructure, licences, storage and safety, among other things.

## What is needed? > Industrial policy and demand consolidation

- In order to stimulate innovation in the manufacturing industry, industry-specific innovation policies are needed. An essential part of this policy is the creation of an initial market demand. This could be done, for example, by consolidating the demand for electrolyser capacity as this is currently spread over various regional projects.
- The customers of the first electrolysers must then be prepared to take a little more risk. This could be covered by subsidies for experimental industrial research. These subsidies will then be channelled back into the Dutch manufacturing industry and economy.
- Such demand consolidation should be linked to a limited number of use-cases. A different model stack with different specifications will be developed for small-scale systems as opposed to those for large-scale applications in wind farms or industry. In this way, a standard product can be defined per use-case on which the Dutch manufacturing industry can focus. Use-cases can be linked to applications with minimal demand volume: logistics hubs, industry clusters and wind farms.
- As far as regional and national policy is concerned, the pooling of regional resources for national chain integration and demand consolidation will contribute to the position of the Netherlands. Agreements on licences and exemptions should also be taken up by a national working group as much as possible.

## Stack components > what is needed?

As far as the stack components are concerned, the market is still small despite positive prospects. Only a limited number of companies established in the Netherlands have a position. In terms of knowledge and experience, however, there is considerable potential, especially in the east and south. A characteristic of these components is the enormous potential for cost reduction through the automation of production. At the moment, the manufacturing industry is still involved in this task to a limited extent because there are still insufficient insights into the specifications of the components to be produced. The big task now is to convert this chicken-egg problem into an innovation programme in which manufacturing and prototyping go hand in hand.

A few particularities per component:

*Membranes*

- Innovation aimed at optimising the existing PFSA properties in regard to proton-conducting properties, chemical stability and uniformity. Lifespan improvement through the application of nanoparticles, multilayers and structural reinforcement via composites. Scaling up in order to achieve accelerated cost reductions.
- The existing market is dominated by a limited group of pre-existing large companies. New materials (such as ceramics and composites) offer the necessary advantages (no need for rare metals) and new application opportunities. An innovative company with the right product can potentially play an important role. This requires a long-term commitment and a willingness to engage in high-risk entrepreneurship. However, the chance of success can be increased by connecting with other component developers and developers of advanced production techniques.

*Bipolar plate (BPP)*

- The innovation around the BPP focuses on the following areas: choice of materials (metal, ceramics, composites), cost reduction (thinner plates, lower weight, reduction in the use of PGMs in coatings). Here, too, the potential for improvement lies not only in the technology but also in chain integration.

*Electrochemical catalysts (ECCs)*

- Innovation includes optimising the chemical and microcrystalline structure of the ECCs, eliminating rare elements such as Pt, Ir and Au. Active surface enlargement through the application of nano-tubes/fibres, improvement of chemical/electric/mechanical stability and uniformity.
- A great deal of knowledge development is taking place at Dutch research institutes or in the field of ECCs in close collaboration with companies from Germany and Belgium, among others. The challenge is to valorise this knowledge to the benefit of electrochemical components. Suppliers in the ECC segment have to work very closely with membrane manufacturers in order to achieve an optimally functioning product.

*Gas diffusion layer*

- Innovation in the areas of shape (felt, gauze, ...), material (metals, ceramics) and technology (3D/sintering, PVD, VPS). Optimisation of electrical conductivity, contact resistance, porosity and corrosion resistance. Process integration with ECCs/membranes.

### BoP components > what is needed?

- BoP suppliers in the Netherlands often owe their current knowledge and market position to the development of infrastructure for the oil and gas sector. This includes control and power electronics, water processing, gas processing, cooling, measurement and control systems and safety systems.
- BoP suppliers are already active in electrolysis markets, i.e. those characterised by higher TRLs with a proven track record based on standards already in place. Their customer portfolio is varied rather than linked to one specific technology. They are often extremely specialised in their specific market.
- The step to the production of electrolyser systems is relatively small. Indeed, there are many similarities between different forms of electrolysis in terms of sensor and power electronics. In terms of innovation, it is important to focus on footprint reduction, cost reduction, standardisation and multi-deployability.
- In order to build up their position, BOP producers are heavily dependent on developments further down the value chain. With increasing demand and more investment capital, this market can still grow enormously. If these conditions are met, Dutch companies can certainly acquire a leading position in the field of BoP components.

### Stack integration > what is needed?

- There are several candidates present in the Netherlands who can take on the role of stack integrator.
- Among Dutch component suppliers, there is a need for a party that can take on this role because this company - as an important link to the end customers - can remove the uncertainty regarding the technical specifications and the (expected) market volume. Strictly speaking, this company could also be a foreign player that works closely with Dutch suppliers.
- However, despite the limited offer, there is a realistic chance that Dutch companies will be able to take on the role of stack integration. Currently, the focus of companies is on the development and production of stacks for small-scale applications (mobility, built environment). This is not to say that these stacks and the knowledge developed for them cannot ultimately be used for GW-scale electrolysers.
- At the moment, there is no series production of stacks. The challenge is to be at the forefront of this. The business case for the production of stacks improves as the number of parts is reduced and the design is optimised. As a result, final series production will come into view with the stack as a modular component for electrolysis systems in various use-cases. The Netherlands can stand out in this respect. The manufacturing industry is good at harnessing complex production lines with high reliability and efficiency.

System integration > what is needed?
Situation/observations (facts/direct evidence companies):

- At present, the Netherlands barely has a position in the assembly of total electrolyser systems. However, the map does show a large number of companies that could potentially play this role. As in the case of BOP components, the Netherlands has a highly developed infrastructure for electrolyser system integration. Both design and engineering as well as the construction, installation and maintenance of electrolyser systems fits well in the areas of expertise which are being developed for the chemical or oil and gas industry, for instance.
- By setting up a Dutch WE system integration chain, we can benefit from a highly developed BOP base as well as the high standard of quality, service and reliability for which Dutch industry is renowned.
- Companies indicate that the market for small-scale systems and the necessary stacks is very interesting for Dutch companies because the established players are not that far ahead of them.

# Conclusions: Opportunity map

On the basis of the study, we can conclude that the entire value chain for (the production of) electrolysers is represented in the Netherlands. The particularities for the various parts of the production chain are:

**Stack components:** The Netherlands has the required companies which can make stack components, almost a third of which are already active in the production chain. The emphasis here is on PEM and generic technology. The dominant regions in this area are the east and the south. The latter is also interesting because of the presence of companies which can play a role in the automation and mass production of components. The west region is also interesting because the companies there are already active in existing production chains.

**Stack integration:** Several companies have the technical means to produce stacks in the short term. At the moment, a small number are already active as developers and/or producers, especially of PEM systems. It is notable that the south region, in particular, is not yet active in the market even though its potential is in no way inferior to that of the other regions.

**BoP components:** This is a relatively large category with a remarkably good spread throughout the Netherlands. A substantial number of these companies are already active in existing production chains for electrolysers. This is particularly true in the east and the west. The other two regions have manufacturing industries that work predominantly for other markets, such as fuel cells or the automotive sector.

**Systeem integration:** (Potential) system integrators are active throughout the Netherlands and are generally large companies. A handful are already active in this market, but mainly as developers and manufacturers of small systems. Series production is not yet ongoing in the Netherlands. An important conclusion is that there is a potential manufacturer of electrolysers in almost every province. The question is if and how such parties will also become active.

Dutch knowledge and innovative strength (including fuel cell technology, the automotive industry and mechanical engineering) can be deployed and further developed to create and scale up electrolyser production chains in the Netherlands. After all, new technologies still require a great deal of development. Extensive applied knowledge of gas infrastructure, assembly and membrane technology etc. provides the Netherlands with great potential.

# Conclusions: Strategic Innovation Agenda

| | 2020 - 2025 | vanaf 2030 |
|---|---|---|
| Preconditions & Market Activation | • To support innovation in the manufacturing industry, industry policy is required. One essential piece of such policy is **the creation of market demand** for experimental electrolyser capacity.<br>• **Cross-government cooperation** across regions, with national government involved, should aim to build up a healthy national innovation ecosystem. | |
| Business & Chain Integration | • Organise cross-regional cooperation amongst manufacturing companies in the form of a **manufacuring platform NL**.<br>• Develop shared standards for quality and specifications of components, stacks, systems. Seek cooperation and agreement within the framework of international networks. | |
| Knowledge & Technology | • Focus on **developing a unique knowledge position** for the Netherlands in order to become and/ or stay an attractive international partner.<br>• To achieve this, an **Electrolyser Production Pilot NL** should be initiated, aimed to facilitate innovation across the production chain. | |

Actions needed for the realisation of a Dutch electrolysers production chain

A visual roadmap of the strategic innovation agenda is shown in Section 5.

# Recommendation 1

Accelerate innovation through a combination of demand consolidation and a Dutch Electrolyser Production Pilot

## Stimulate development and innovation in the production chain

**Motivation:** Dutch parties are ready to develop materials, components and systems. A quick learning curve is also possible, provided that materials and component developers in the Netherlands can gain the confidence of large customers.

**Action:** Develop a Production Pilot aimed at experimenting with the production of (components for) electrolysers. Link this to (consolidated) demand from (initial) customers. The goal is to give momentum to innovation so that Dutch industry can tap into the upcoming market demand in a timely manner. Speed is of the essence; foreign producers of electrolysers are not sitting still.

**Need**: Regulation / financing through demand consolidation / links with regional use-cases / pooling of provincial resources

**Who:** National government in collaboration with provinces/EU. Knowledge institutes and sector organisations as coordinators. Funding via a party such as InvestNL.

## Measuring is knowing: facilitate testing and validation of Dutch products

**Motivation:** Many companies active at the top of the production chain are looking for a launching customer. SMEs, in particular, do not easily reach OEMs. Their technology has not yet been proven and they usually do not have a track record. Testing and validation is an important way to cover these risks.

**Action:** Use existing lab infrastructure (Faraday, Hydrohub, EIRES, HAN). A voucher scheme could enable SMEs to have their products tested and validated.

**Need:** Coordination action must be subsidised.

**Who:** Knowledge institutions make use of the existing knowledge infrastructure. Funding partly from the government.

# Recommendation 2

Towards a national

Electrolyser

Manufacturing Platform

## Establish a national ‘Electrolyser Manufacturing Platform’

**Motivation**: Dutch manufacturing companies still do not find one another often enough. Moreover, SMEs (in particular) do not easily reach the established players who are currently doing the system integration. This puts a brake on innovation. In addition, it is important to act collectively in order to create the direction and preconditions for successful innovation throughout the chain.

**Action:** Forming a network and managing a community aimed at connecting Dutch manufacturing companies and making them internationally visible. Facilitating accelerated development by linking supply and demand.

**Need:** Funding of process, website, periodic meetings, a marketplace where supply and demand meet.

**Who:** TNO and FME see a role for themselves in taking the lead on this. The connection will be made with existing networks and communities, e.g. Metallot, VoltaChem and ENZuid. Potential customers and system integrators can participate as ambassadors.

# Recommendation 3

Focus on a unique knowledge position for the Dutch manufacturing industry

## Give shared direction to innovation and standardisation

**Motivation:** In order to build up and maintain a unique (or at least competitive) knowledge position, it is important to choose a common direction in a chain context.

**Action:** Develop a chain-oriented electrolyser technology roadmap focused on all materials and components. Do this explicitly in coordination with HTSM sectors. Ensure coordination with European networks, particularly the FCHJU network and Hydrogen Europe and especially where standards are concerned.

**Need**: More R&D and capital.

**Who:** Knowledge institutions, sector organisations, public authorities (by means of subsidies)

## Collaborating on standardisation

**Motivation:** Companies indicate that there is hardly any standardisation in the field of electrolysers and critical components.

**Action:** The development of a universal norm or standardisation for electrolysers will strongly promote collaboration and chain integration and will also improve the (joint) position in the market.

Initially, however, the commitment must be to accelerating innovation. Later on, more emphasis will be placed on defining technical standards that enable series production.

**Need:** Connection to international networks in regard to standards.

**Who:** Government, sector organisations, industry, industry-supported decision on enforcement via legislation and regulations if necessary. Coordination at a European level..

# Recommendation 4

Streamline administrative processes

## Organise regular supra-regional policy consultations

**Motivation:** Too little coordination is currently taking place between the regions. Strategies and resources need to be better coordinated in order to pursue a more integrated policy.

**Action:** Initiate a national hydrogen consultation through which policy officers from the provinces, central government and possibly municipalities can regularly coordinate current policy procedures.

**Need:** Deployment and commitment at multiple levels in the relevant organisations, both administrative and political. It is also important to involve substantive experts in order to bring in the relevant knowledge on technology and the state of the art within industry.

**Who:** Initiative of provinces/regional development agencies. Role for knowledge institutions.

## Simplify and shorten the process of (licensing) applications for hydrogen applications.

**Motivation:** Applications for licences for the decentralised generation of hydrogen in the built environment and mobility are time-consuming.

**Action:** Clarify the vision of local, decentralised, storage, generation and use of green hydrogen, adjust the licensing procedures for this and shorten the lead time of these procedures. These legal obstacles can be disastrous for the business case.

**Need:** Simplification, clarification and explanation of the application for licences for the use and/or generation of green hydrogen.

**Who:** Role for government/provinces/municipalities.

# Recommendation 5

Develop a Dutch hydrogen proposition aimed at international collaboration

## Invest in international collaboration and a Dutch proposition

**Motivation**: A stimulus for innovation within the Dutch manufacturing industry is needed. The deployment of an entirely Dutch electrolyser, however, should not be an end in and of itself but a springboard for companies that will ultimately have to compete internationally.

**Action:** Develop a Dutch hydrogen proposition aimed at international collaboration. Work towards a strong national position in collaboration and particularly in coordination with international networks. This applies to all of the above recommendations, particularly for knowledge development, standardisation and the ultimately a necessary market stimulus.

**Need:** The real opportunities will ultimately come about within the framework of a European playing field. Dutch companies, knowledge institutions and public authorities would do well to coordinate their regional or Dutch influence and use it to the benefit of their contribution to this larger ecosystem.

**Who:** Various parties are already working on this, especially companies. The central government is focusing on international profiling in the direction of the EU but also Japan and California. TNO and FME are orienting themselves towards a follow-up to this study focusing on France, Belgium and Germany.

# Financing

## Financing

In order to achieve the stated ambitions, an investment fund is needed to finance the unprofitable side of large-scale projects. It is also important to create the necessary preconditions. These support both the Dutch climate ambitions and the national earning power. This is in view of the large international export potential of electrolysers but also because the Netherlands can become an international pilot for electrolysers by creating a sales market.

# Appendix 1: List of companies

| Company | Province | Region | Stack components | BOP components | Stack integration | Systeem integration | WE user | Technology |
|---|---|---|---|---|---|---|---|---|
| ABB | ZH | West | | X | | X | X | Generic |
| Additive Industries | NB | South | X | | | | | PEM |
| Admatec | NB | South | X | | | | | PEM |
| Adsensys | NB | South | | X | | | | Generic |
| Althen | ZH | West | | X | | | | Generic |
| Ampulz | DR | North | | X | | | | PEM |
| Blue Engineering | LI | South | | | X | | | Generic |
| Boessenkool | OV | East | | X | | | | Generic |
| Bosal | UT | West | | X | | | | Generic |
| Bosch Transmission | NB | South | | | X | | | PEM |
| Bredenoord | GLD | East | | | | | X | PEM |
| Bronckhorst | GLD | East | | X | | | | Generic |
| Contour | GLD | East | | X | | | | Generic |
| Coorstek | NB | South | | X | | | | PEM |
| Cryoworld | NH | West | | X | | | | Generic |
| D&M Vacuumsystems | LI | South | | X | | | | Generic |
| Delft IMP | ZH | West | X | | | | | Generic |
| Delmeco | ZE | South | | | | X | | Generic |
| Demaco | NH | West | | X | | | | Generic |
| Demcon | OV | East | | X | | | | PEM |
| Diffutherm | NB | South | | X | | | | Generic |
| Dufor | GLD | East | X | | | | | Generic |
| Eekels Technology | GRO | North | | X | | | | Generic |
| Eurekite | OV | East | X | | | | | PEM |
| Evides | ZH | West | | X | | | | Generic |
| Exotech | ZE | South | | X | | | | Generic |
| Ferro Techniek | GLD | East | | X | | | | Generic |
| FINN | GRO | North | | X | | | | Alkaline |
| Fluidwell | NB | South | | X | | | | Generic |
| FMI manufacturing | FR | North | X | | | | | PEM |
| Frames Group | ZH | West | | | | X | | PEM |
| Fuji Film Europe | NB | South | X | | | | | PEM |
| Gasunie | GRO | North | | | | X | X | Generic |
| GP Groot | NH | West | | | | | X | PEM |
| Hauzer | LI | South | X | | | | | Generic |
| HFI Hartman | GLD | East | X | | | | | Generic |

| Company | Province | Region | Stack components | BOP components | Stack integration | Systeem integration | WE user | Technology |
|---|---|---|---|---|---|---|---|---|
| Hydron Energy | ZH | West | X | | X | | | PEM |
| Hyet Hydrogen | GLD | East | | | X | X | | PEM |
| HyGear | GLD | East | | | | X | X | PEM |
| Hygro | NH | West | | | | X | X | PEM |
| ICH B.V. | DR | North | | X | | | | Generic |
| Ionbond | LI | South | X | | | | | Generic |
| Kepser Pro Metaal | NB | South | | X | | | | Generic |
| KMWE | NB | South | X | | | | | Generic |
| Koolen Industries | OV | East | | | | | X | Generic |
| Lumileds | ZE | South | | | X | | | PEM |
| Magneto | ZH | West | X | | | | | Generic |
| Masevon | FR | North | | | X | | | PEM |
| Metal Membranes | FR | North | X | X | | | | Alkaline |
| Mourik | ZH | West | | | | X | | Generic |
| MTSA Technopower | GLD | East | | X | | X | X | PEM |
| MX Polymers | GLD | East | X | | | | | PEM |
| Nedstack | GLD | East | X | | | | | Generic |
| Nouryon | OV | East | | | | | X | Alkaline |
| Nproxx | LI | South | | X | | | | Generic |
| NTS Norma | OV | East | X | | X | | | PEM |
| Oreel | FR | North | | X | | | | Generic |
| Port of Rotterdam | ZH | West | | | | | X | Generic |
| Prodrive-Technologies | NB | South | | X | | | | Generic |
| PTG | NB | South | X | | | | | Generic |
| Resato | DR | North | | X | | | | Generic |
| Stork | GRO | North | | | | X | | Generic |
| SuwoTec | GRO | North | X | | | | | Generic |
| Teljin Aramid | GLD | East | X | X | | | | Generic |
| Tieluk | FR | North | X | X | X | X | | Alkaline |
| VDL | NB | South | X | | X | X | | Generic |
| Veco Precision | GLD | East | X | | | | | PEM |
| Xintc Global | GLD | East | | | X | X | | Alkaline |
| Yokogawa | UT | West | | X | | | | Generic |
| ZEPP solutions | ZH | West | | | | X | | Generic |
| Zero Emission Fuels | ZH | West | | | X | | | Alkaline |
| Zeton | OV | East | | | | X | | Generic |

FME POWERED BY DUTCH TECHNOLOGY

TNO innovation for life