Assembly of Fuel Cells and Stacks with Robots

Peter Konold, Avdo Muminovic, and Manfred Wehrheim

Abstract. PEM-fuel cell stacks (PEM = **P**olymer-**E**lectrolyte-**M**embrane) are still produced manually to a large extent. Therefore identical components have to be positioned precisely. Besides higher total costs, logistical and weight problems is also a result in a higher statistical sensitivity for failures due to assembly errors and the total of assembly tolerances. The aim of the project is to optimize the economic assembly of fuel cells in a significant way. Therefore the development of an automatic assembly process to join a membrane-electrode-arrangement with bipolar plates to a single cell stack in a leak-proof way is of essential importance. The single cells which have been produced and checked by a robot can be stored on work piece holders. These single cells are joined process-sure to bigger stacks also by an assembly robot. The benefits of this effective assembly by robots will be explained here.

1 Introduction

The production of PEM-fuel cell stacks (PEM = **P**olymer-**E**lectrolyte-**M**embrane) is still carried out manually to a large extent. Therefore identical components have to be positioned precisely. Besides higher total costs, logistical and weight problems, the large number of components also results in a higher statistical sensitivity for failures due to assembly or material errors and the total of assembly tolerances. The aim of the project is to optimize the economic assembly of fuel cells in a significant way. Therefore the development of an automatic assembly process to join a membrane-electrode-arrangement with bipolar plates to a single cell stack in a leak-proof way is of essential importance. The single cells which have been so produced and checked can be stored or held in readiness on work piece holders (part one of the research project).

In another automated assembly-step these single cells are joined process-sure to bigger stacks. Here the scaling-up to many-cell-stacks will be examined for logistic and assembly benefits (part two).

2 Automatic Joining of the Fuel Cell

Within the production of fuel cells at the ZSW (Centre for hydrogen and solar technology in Ulm) a robot assembling cell has already been built up. This cell is restricted to the mounting or combining of single components of the fuel cell.

A. Gottscheber et al. (Eds.): EUROBOT 2008, CCIS 33, pp. 168–179, 2009.

In this project of the University of Applied Sciences in Ulm in close collaboration with the ZSW the function of this robot-system will be expanded and then transferred into fully automated operation. The leak-proof function of the fuel cell has been archived by using a metal frame gaskets or the application of gaskets directly onto the main components. In this case the weight and cost saving technique of direct application of a glue gasket is used. For this a dispenser-system for applying the glue-gasket has been integrated into the robot cell. To control the glue gaskets a vision processing system with camera and PC has been installed. For part hardening, final control of the parts and following assembly to finished stacks a transfer system (TS 2plus from Rexroth) with carriers and identification systems (ID40) which transfers the fuel cells in and out of the robot cell has been introduced.

These measures required large changes and extensive works on the gripper, the integrated SPC (stored program control), the sensors and the valve-technology.

The system has the following components:

- Robot system (6 axis jointed-arm robot, with a lifting capacity of 12 kg and an operation distance of 1385 mm) with a SPC to control the periphery
- Batcher with a dispenser system containing
  - Dosing unit for gaskets, squirt dosing unit: a fully integrated system able to dispense products of a liquid to pasty consistency from 10ml plastic injection devices
  - Gasket-glue in 10ml plastic injection devices
  - Profiles and angles for fixed installation
  - Injection-holder with simple positioning system
- NeuroCheck Software for industrial vision processing with 16mm lens camera and PC, Fire wire connection and Digital I/O-card
- Transfer system TS 2plus with double belting and carriers, identification-system (ID 40), Supply and transport system to lift and position the parts.

In three cycles glue is applied to the bipolar plate1, a membrane and the bipolar plate2, controlled via the picture processing system and placed on the correct carrier. A single fuel cell is manufactured.

Plates or membranes with damaged glue gasket are removed from the assembly-process immediately and the process is repeated with a new plate or membrane.

Thanks to the space saving placement and the optimal exploitation of the carrier, three fuel cells can be placed on each carrier and transported out of the assembly-cell to harden.

If the leak control system is included in the assembly cell, the fuel cells will be kept in the assembly cell for hardening. Then they will be checked by the leak control system and then transported out of the assembly cell on carriers as assembled single fuel cells. This is where the identification system (ID40) which is installed on the carriers will come into operation. This system allows documentation of a single cell, the assembly time, the batch number, the leak check results before the assembling of the stack as well as statistics for a general analysis like number of manufactured cells, number of good parts, place and time of production. The data can be transferred contact free at any step in the system with a RW (Read Write) head and sent to data processing.

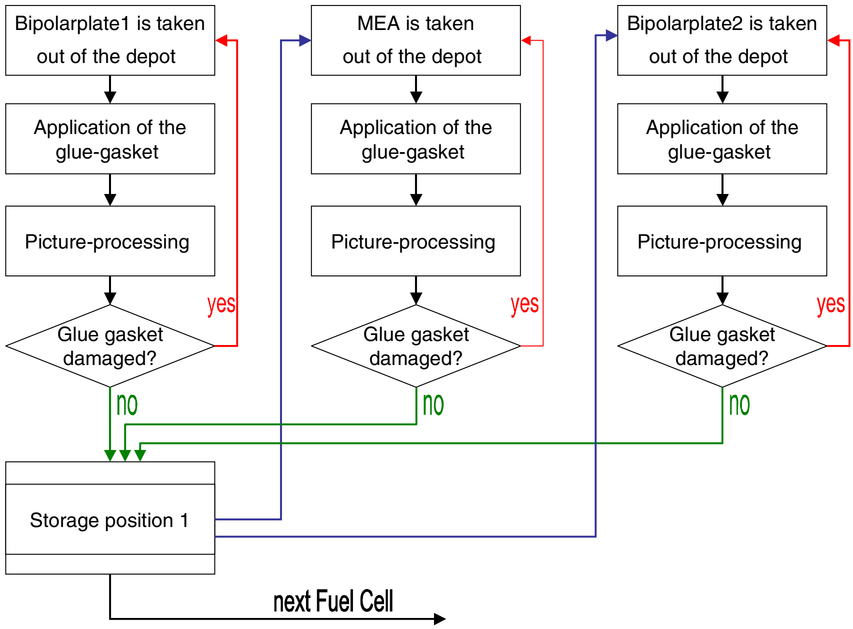


Fig. 1. New Assembly Structure

Glue application bipolar plates/MEA

The glue application, which is the application of a squirted gasket, is a sensitive process. Before the process can begin, the viscosity of the glue has to be checked with the help of the dosing unit. Also the injection needle must be free of glue.

The glue applications for the BP1 (figure 2) and the MEA are identical (large glue gasket), because of its different shape the glue gasket for the BP2 is smaller. The height of the glue gasket must not exceed 0.7mm and the gasket must be applied evenly. In case of an unevenly applied gasket problems may occur regarding the join and leak proof seal.

The glue-gasket is checked by a visual processing testing program created with NeuroCheck. The hardware used here consists of a FireWire camera with over 1 mega-pixel, a lens with a light intensity of 1.4, a PC and an I/O-card.

During the check there must be no change in light conditions which could affect the recording quality (e.g. extraneous light coming from the sun). The dim out of the checking area prevents reflections from the robot, gripper and other surrounding parts.

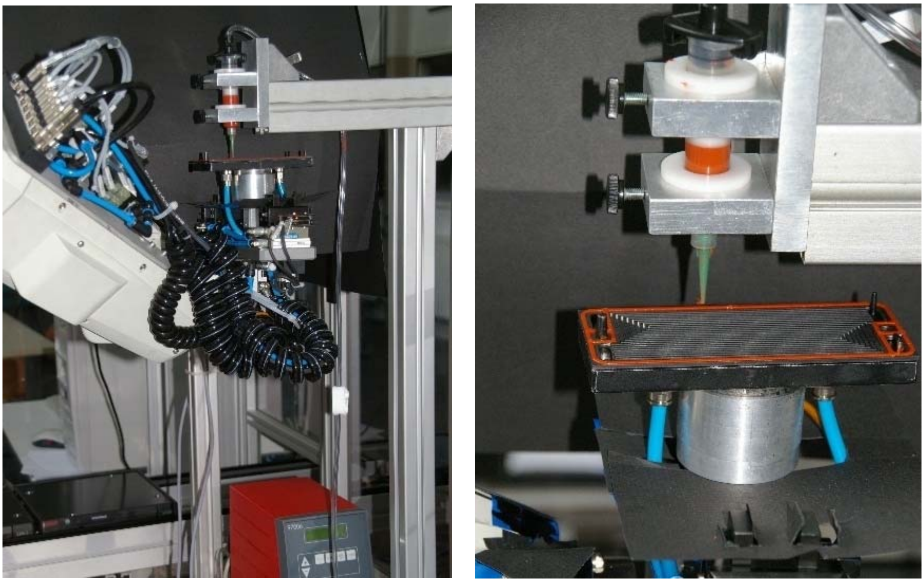


Fig. 2. Glue-Application with robot

Checking the glue-gasket

Through optimized adjustment and illumination the unbroken continuity of the gasket is checked. The program execution of the single checking-steps and the binary image used by the computer while processing the data is shown in figure 3.

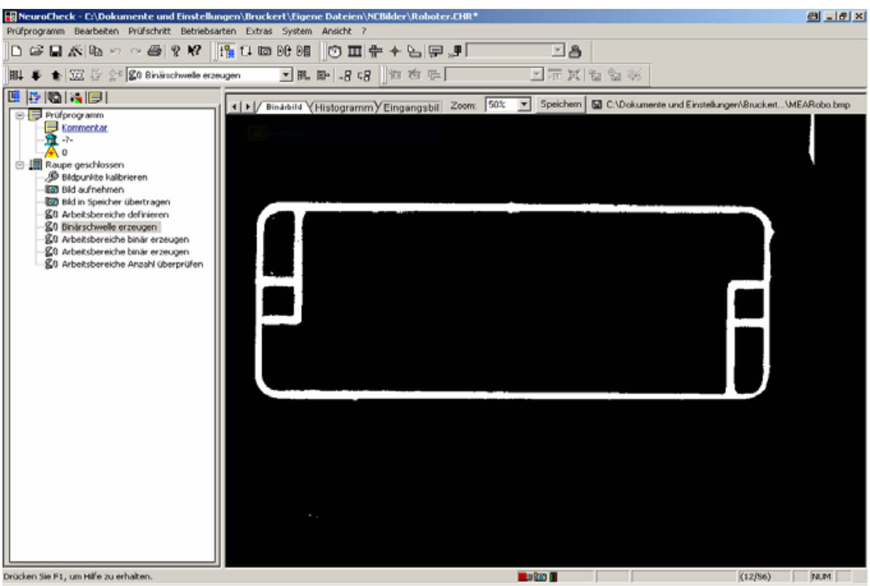


Fig. 3. Checking the glue gasket

The glue gasket on a MEA is also visible in figure 3. The adjustment of the optical exposure of a gasket on the MEA is much more difficult than on a bipolar plate, because the reflection of the foil has to be considered. Conclusion

Within this first part of the research project the automatic assembly of a single fuel cell has been developed and realized. To check the glue application the picture processing system NeuroCheck was used. The linking to other assembly and process stations is managed by a transfer system with carriers.

This research work "automated assembly of single fuel cells for the use in fuel cell stacks" is supported by the project "Innovative Projekte" of the Universities of Applied Sciences in Baden-Württemberg as well as in cooperation with the ZSW /4/.

With this robot cell (figure 4) it is now possible to automatically assemble single fuel cells beginning with lot size 1. The following tests will show how many cells can be produced, at what quantity a different assembly cell setup is required and what momentary advantages there are as well as the saving of an extra gasket due to the robot assembly.

Fig. 4. Carrier in the assembly station with 3 storage places

3 Construction of PEM Fuel Cell Stacks

In another process the hardened single cells are checked for leak proofness, and sorted into performance and quality categories.

The constructed fuel cell stack is a functioning power supply. Depending on the required Voltage it is necessary to assemble the number of needed single cells and the other elements for the operational discharge. In figure 5 these parts are shown before and after assembly.

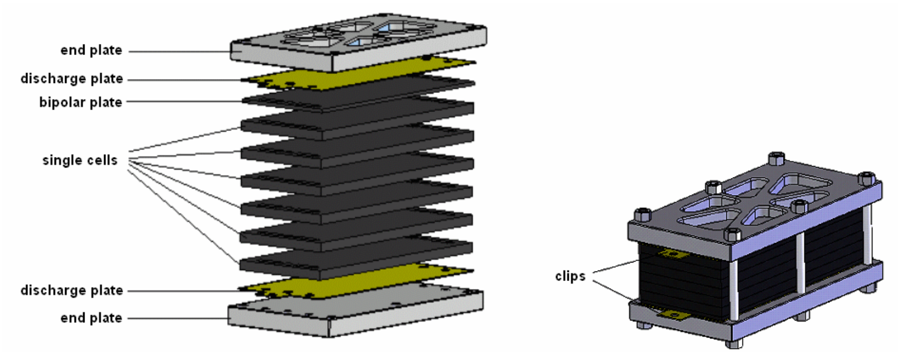


Fig. 5. Elements of a fuel cell stack – not assembled/assembled

Because parts such as the end plate, the flux voltage plate or the thread rods are needed only in small quantities for each fuel cell stack, these parts are considered as enclosed components by the material flow and are provided on staging carrier.

Automated assembly of stacks

The compact final assembly is done from staging carriers by a robot. The layout of this robot-station in figure 6 shows the transfer-circle with the material flow and the transport way of assembled fuel cell stacks. The screwing station attached to the

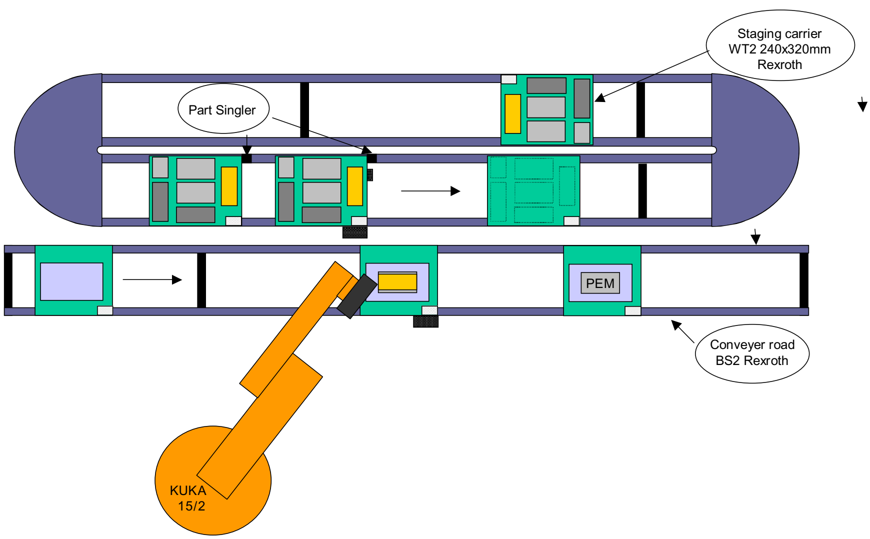


Fig. 6. Layout of stack-assembly with robot

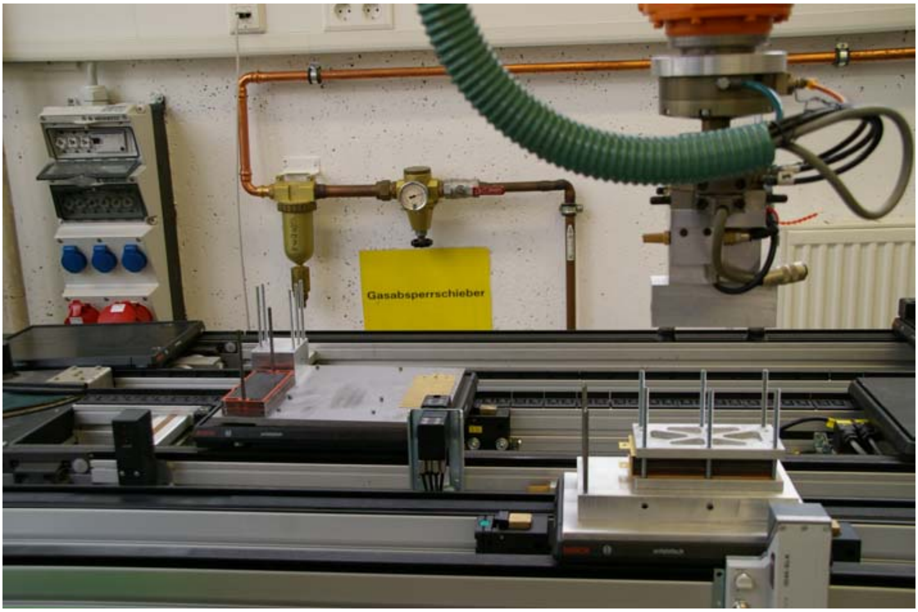


Fig. 7. Robot with gripper-change-system an vacuum-gripper

transport way is not taken into consideration here. For a universal application (e.g. further assembly methods) a robot with a 15kg lifting capacity is used during the experimental stage.

When the part supply is carried out this way, the assembly can also be managed by a cheaper SCARA-robot, because only xyz movements and rotations are necessary. The plates and flat parts are picked up by a vacuum gripper and the pins or rods are joined by a parallel gripper, therefore a gripper change system is recommended.

Transfer system

While designing the system a special focus was laid on a high flexibility and economic effectiveness. In our design the different sized staging carriers are transported via two double-belt transport systems. Each system is equipped with a lifting and positioning system for exact fixation of the staging carriers for part removal or final assembly. It also is equipped with a part singler. The electrical identification-system (ID40) attached to the staging carriers allows part tracing and the production of different voltage stacks.

Programming

The Kuka robot was coded at the Hochschule Ulm. A basis program allowed the assembly of different voltage fuel-cell stacks. Currently the system is set up for low voltage fuel-cell stacks (3V-12V). The assembly time of a 3V fuel cell stack is approximately 1.5 min including the gripper changes.

Fig. 8. Programming (teaching) of a Kuka robot

4 Economic Effects on Production

Analyses and tests of the automated assembly of fuel cell stacks show that fuel cells and fuel-cell stacks can be manufactured by robots. Here the production of a smaller lot size with a more complex robot cell or a higher quantity with more robot cells is the goal. If costs can be cut on the part itself (extra metal frame gasket), the production becomes even more economical. The costs with and without the extra metal frame gasket are shown in figure 9.

Depending on the size of the cell the costs of the metal frame gasket can be up to 25% of the other parts of a fuel cell. The costs for the extra supply carrier integrated in the production process and the extra production time also have to be added.

The momentary costs should not be the only thing taken into consideration. In a cost-benefit analysis the non-financial criteria such as the early selection of rejects due to defects shown in figure 10. It shows the considerable advantages of the glue-gasket robot assembly.

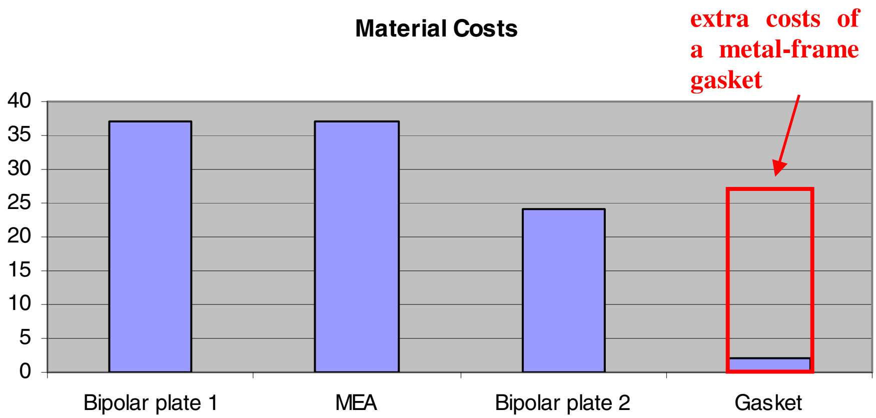


Fig. 9. Cost influence of the metal frame gasket on a fuell cell

		Conventional		Glue application	
Factor	**Weighting**	**Fulfilment**	**Value of benefit**	**Fulfilment**	**Value of benefit**
Higher durability and reliabiliy	30	4	120	8	240
Improvement in process-sureness	23	4	92	8	184
Relif of labor conditions	14	2	28	4	56
Early selection of defective goods	23	3	69	8	184
Design	10	3	30	7	70
Points total	**100**		**339**		**734**

Fig. 10. Non-financial criteria evaluation

In a cost benefit comparison of different experts of both production types it becomes even clearer. Unfortunately up until now we have not been able to document this with exact numbers. We have had to make do with projections for higher piece numbers.

If our calculations were transformed into a layout for a production system, a linear or parallel production line could be realized.

Because of the big difference in the way single cells and cell stacks are assembled a special eye has to be kept on the capacity utilisation. At the present stage of knowledge an assembly of nine single cells to a cell stack (figure 13) is the most efficient production type. The above shown parallel production relates to a production of a 12V PEM fuel cell with a base scale of 50x120 mm². Every modification in size, voltage etc. changes the layout, the number of production steps and robots in the production process. A yet-to-be-done optimisation of the robot movements and positioning of the staging carriers could result in a much higher productivity.

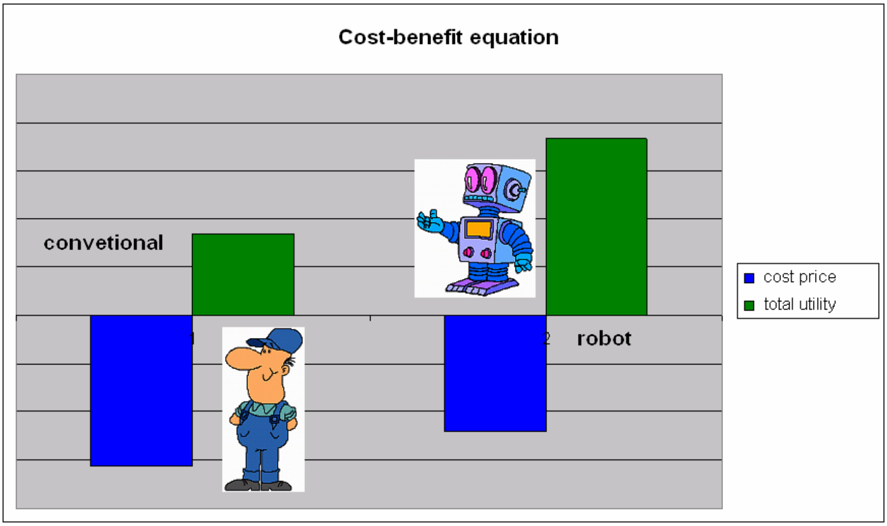
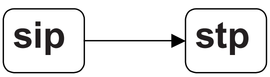


Fig. 11. Cost benefit comparison of conventional and robotic assembly

Line production



	single-cell production	cell-stack production
Available assembly time	1.870 h	1.870 h
Time per piece	75 sec	95 sec
Max. number of pieces	89.760 pcs	70.863 stacks
Number per stack		12
Max. Stack number		7.480 stacks
Utilisation	**100.00 %**	**10.56 %**

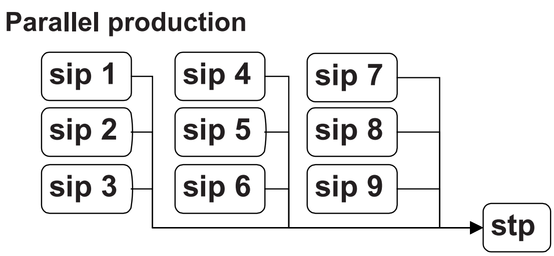
Legend

sip single-cell production

stp stack production

Fig. 12. System layout for a linear production

It is our goal to optimize the basic operation sequence and to make the production even more process sure to gain a high product quality which leads to high capacity cell stacks.



	single-cell production	cell-stack production
Machines	9 machines	1 machine
Available Asseblmy time p	1.870 h	1.870 h
Overall assembly time	16.830 h	1.870 h
Time per piece	75 sec	95 sec
Max. piece number	807.840 single-cells	70.863 stacks
Single-cells per stack		12 single-cells
Max. stack number		67.320 stacks
Utilisation	**100.00 %**	**95.00 %**

Legend
sip single-cell production
stp stack production

Fig. 13. System layout for a parallel production

5 Future Perspective

Analyses and tests of the automated assembly of fuel cell stacks show that fuel cells and fuel cell stacks can be manufactured by robots. With these robot cells the production of fuel cells with a very small lot size is possible. The goal is that big piece numbers of single cells will be produced by many robot cells and the cell stacks with one high performance robot. Further research will be conducted to support this.

Through the automation realized here and cost saving on the part itself the production will become even more economical.

The advancement of this technology which is environmentally friendly, smaller and weighs less than the conventional lead battery could be driven forward in terms of the price performance ratio through the automated production.

The procedure shown here indicates that if only one production step is optimised the costs can be reduced by up to 25 %.If further optimisation is done e.g. during the production of the MEA or the bipolar plates it can be estimated that in a few years the production costs could be so low that a mass production of energy through this technology is within reach.

If a good hydrogen distribution grid, a cheap and low in co2 emission production of hydrogen through for example wind energy or electrolysis could be established, a competitive system for multiple applications could be reached.

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