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Research Article

Exploring commercial water electrolyser systems: a data-based analysis of product characteristics

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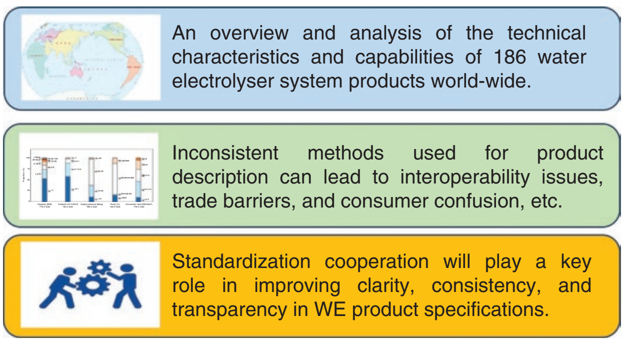
Abstract

The urgency for energy transition is evident through the increasing demand for new technologies such as water electrolysers (WEs), which have the potential to generate green hydrogen using renewable electricity. This paper aims to provide a comprehensive overview of the technical capabilities of commercially available WE system products. The analysis is based on publicly accessible data gathered from 28 WE manufacturers worldwide with a total of 186 products, focusing on technology types and various technical characteristics of each WE system, including capacity, footprint, hydrogen output pressure, hydrogen purity and conversion rate. The analysis reveals that the current WE system solutions in the market exhibit diverse and varied characteristics. Further, there is a lack of standardized product specifications adopted by manufacturers. This underscores the urgent need for the development of frameworks and standards. Implementing such standards is crucial for enhancing clarity and understanding, facilitating efficient comparisons and selection processes, and supporting the future advancement of WE technologies and WE-enabled Power-to-X applications on a global scale.

Graphical Abstract



Keywords: data analysis; hydrogen; Power-to-X; standards; water electrolyser system

Introduction

Green hydrogen and Power-to-X (PtX) technologies are crucial to achieving a sustainable energy future by mitigating greenhouse gas emissions, decarbonizing challenging sectors, providing energy storage solutions and diversifying the energy mix [1, 2]. Among the different pathways to producing green hydrogen, the utilization of renewable electricity in water electrolysers (WEs) has gained significant global attention, leading to a competitive race [3]. This is because the WE-based hydrogen production pathway offers several simultaneous advantages beyond conversion [4]. These benefits include energy storage capabilities [5] and power balancing [6], facilitating versatile integration of WEs with intermittent renewable energy sources in both onshore and offshore applications [7, 8].

The rapid development of WEs is further propelled by the strong promotion and support from governments worldwide [9]. According to the global review of hydrogen published by the International Energy Agency (IEA), by 2022, 25 countries, together with the European Commission, had already incorporated national hydrogen strategies into their clean energy transition plans [10]. This collective effort has resulted in a projected installation of ~350 GW of WE capacity by 2030, signifying an extreme growth trajectory compared with the global installed capacity of <500 MW in 2020. Consequently, the global manufacturing capacity for

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WEs has expanded substantially, reaching nearly 8 GW per year in 2021, more than doubling the installed capacity that existed at the end of 2020 [11].

To support the rapid progress of WE development and application, it is crucial to have timely updates and analysis of the technical characteristics of WEs. Several global institutions have published reports on state-of-the-art (SOA) performance and target key performance indicators (KPIs) for WEs. Notable examples include the performance analyses conducted by the International Renewable Energy Agency (IRENA) [12] and IEA [13], as well as the KPIs outlined in the EU Strategic Research and Innovation Agenda (SRIA) for 2021–27 [14]. Table 1 provides a concise overview of the performance of the four commercially available WE technologies: alkaline electrolysis, proton exchange membrane (PEM) electrolysis, anion exchange membrane (AEM) electrolysis and solid-oxide electrolysis (SOE), as reported by these studies. However, it is important to acknowledge that, despite these valuable studies offering comprehensive insights into WEs, challenges such as data inconsistency, lack of transparency in data sources and absence of explanation and verification exist. These challenges hinder potential WE owners from making informed and efficient choices, which may impede the progress of the WE and PtX industry. Addressing these issues is crucial to facilitating the growth and development of the WE sector and to supporting the advancement of PtX applications.

This article provides an overview and analysis of various technical characteristics of commercially available WE systems based on data released by global WE manufacturers in their product specifications from August 2022 to February 2023. To ensure clarity, Fig. 1 is included to illustrate the distinctions between a WE system, a WE stack and a WE cell. In simple words, a WE stack is an assembly of more than one cell that is part of a WE system. The objective of this study is to enhance understanding of existing WE system products and shed light on issues concerning WE product specification and description. By conducting this analysis, the study aims to emphasize the significance of standardization and benchmarking in relation to WE products. This, in turn, enables effective development and selection of WEs for diverse applications such as onshore versus offshore, small-scale versus large-scale, grid-connected versus off-grid and renewable-driven versus non-renewable-driven systems.

1 Data description

The study included an investigation of >50 worldwide manufacturers that supply WE system products. Due to variations in the level of product details provided by the manufacturers, the analysis focused on 28 WE manufacturers (as shown in Tables 2 and 3) and included a total of 186 products. Some WE products, such as the HONDA 70 MPa differential-pressure WE solution, were excluded from the analysis as they are still in the research-and-development phase and not commercially available.

All data sources used in the study are publicly accessible and correspond to product specifications released between August 2022 and February 2023. The data were thoroughly analysed and summarized, considering multiple aspects including the manufacturers' locations and various technical characteristics of each WE product. These technical characteristics include WE system capacity, efficiency, footprint, hydrogen output pressure, hydrogen purity and other relevant parameters.

Table 1: 2020 SOA and 2030 targets for selected technology indicators for water electrolysers (adapted from [12])

	Alkaline		PEM		AEM		SOE	
	2020	2030	2020	2030	2020	2030	2020	2030
Nominal current density (A/cm^2)	0.2–0.8 (0.6)	(1.0)	1–2	(3.0)	0.2–2 (0.5)	(1.5)	0.3–1 (0.6)	(1.5)
Voltage range (V)	1.4–3	–	1.4–2.5	–	1.4–2	–	1.0–1.5	–
Operating temperature (°C)	70–90 {60–80}	–	50–80 {50–80}	–	40–60	–	700–850 {650–1000}	–
Cell pressure (bar)	<30 {1–30}	–	<70 {30–80}	–	<35	–	1 {1}	–
Load range (% relative to nominal load)	15–100 {10–110}	–	5–120 {0–160}	–	5–100	–	30–125% {20–100}	–
H_2 purity (%)	99.9–99.9998	–	99.9–99.9999	–	99.9–99.999	–	99.9	–
Electrical efficiency_stack (kWh/kg H_2)	47–66	–	47–66	–	51.5–66	–	35–50	–
Electrical efficiency_system (kWh/kg H_2)	50–78 {48–53} (50)	{47–51} (48)	50–83 {56–60} (55)	{49–53} (48)	57–69 (55)	(48)	40–50[a] {41–45}[a] (40)[a]	{40–43}[a] (37)[a]
Stack lifetime (1000 hours)	60 {60–90} (83)	{90–00} (91)	50–80 {30–90} (53)	{60–90} (67)	>5 (10)	(11)[b]	<20 {10–30}	{40–60}
Cold start_to P_{norm} (seconds)	<3000 (900)	(300)	<1200 (30)	(10)	<1200 (1800)	(150)	>36 000 (432 000)	(14 400)

Values inside () are KPIs defined by EU SRIA 2021–2027 [14]. Values inside {} are performance data reported by IEA [13]. Values without parentheses are SOA reported by IRENA [12]. [a]To meet the electrical efficiency target of 2020 and 2030 for an SOE system, an additional amount of heat, i.e. 9.9 and 8 kWh/kg H_2, needs to be consumed, respectively, to keep the high operating temperature. [b]One commercial AEM supplier, i.e. Enapter, reported an expected lifetime of their stacks of >35 000 hours, which is much higher than the 2030 target [15].

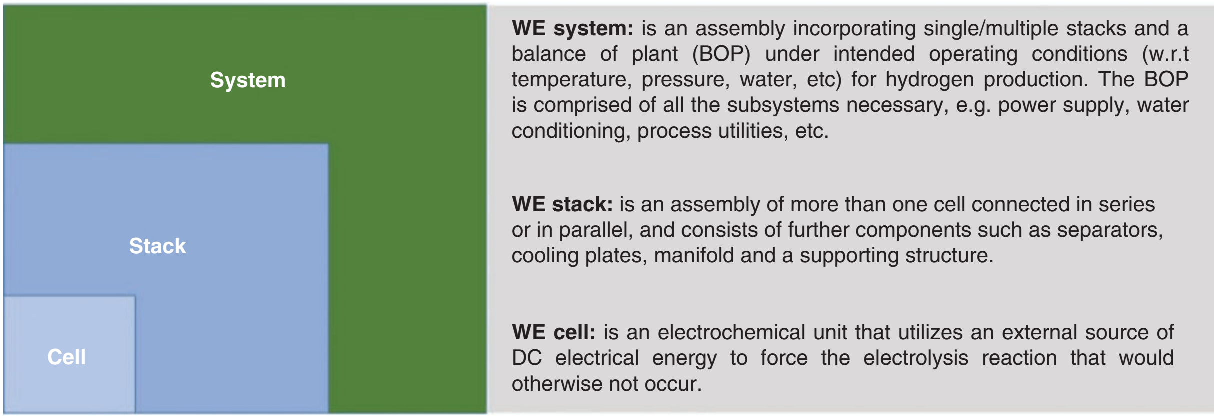

Fig. 1: A schematic description of the WE system, stack and cell. The power supply used in a WE system can include AC–DC rectifier(s) for stack operation and/or incoming power distribution for grid connection and changing incoming AC voltage levels to the operational AC voltage level.

Table 2: An overview of the surveyed WE product data

Region	Country	No. of manufacturers per technology (alkaline/PEM/AEM/SOE)	No. of products per technology (alkaline/PEM/AEM/SOE)
America	United States (US)	1/4/0/1	6/17/0/9
	Canada (CA)	1/0/0/0	3/0/0/0
Europe	United Kingdom (UK)	0/1/0/0	0/4/0/0
	Germany (DE)	2/1/1/1	2/2/2/1
	France (FR)	2/2/0/0	10/7/0/0
	Belgium (BE)	1/0/0/0	2/0/0/0
	Norway (NO)	1/1/0/0	5/15/0/0
	Denmark (DK)	1/0/0/1	2/0/0/1
Asia	Japan (JA)	1/0/0/0	2/0/0/0
	China (CN)	8/5/0/0	72/24/0/0
Total		18/15/1/3	104/69/2/11

2 Data analysis and visualization

2.1 Manufacturer location and products diversity

According to Table 2, the analysis reveals that the capacity for WE manufacture is predominantly concentrated on the continents of America, Europe and Asia. In America, the USA emerges as the leading market for WE, followed by Canada. In both countries, alkaline products are commercially available. Among the US manufacturers, there is a single alkaline manufacturer offering six products with varying hydrogen production capacities. In comparison, the availability of PEM products in the US market is nearly three times higher than that of alkaline products, with 17 products. Additionally, the US market also features SOE products, with one manufacturer providing nine different products ranging from megawatt (MW) to gigawatt (GW) capacities. In Canada, there is one alkaline manufacturer offering three distinct products.

In Europe, Germany is recognized as a leading country for green hydrogen production, which offers a comprehensive range of WE products that encompass all WE technologies. The market in Germany is served by two alkaline manufacturers, one PEM manufacturer, one AEM manufacturer and one SOE developer, ensuring a diverse selection of options for customers. In Denmark, two manufacturers specialize in the production of alkaline and SOE products, respectively, contributing to the country's WE market. France relies predominantly on alkaline and PEM technologies, with these two types dominating the main WE market. Norway has one manufacturer that stands out by offering a wide variety of alkaline and PEM products. In UK, the manufacturer focus primarily on PEM technology, to meet the demand for such products in their respective markets. Lastly, Belgium has two alkaline products offered by manufacturers operating in the country.

In Asia, the leading countries in WE development are China and Japan. The survey identified a total of nine Chinese WE manufacturers, collectively offering 96 alkaline and PEM system products. China's market demonstrates a robust presence of both alkaline and PEM technologies. In the case of Japan, the focus appears to be primarily on alkaline technology in the WE sector.

2.2 A comparative overview of the technical characteristics of the WE products

2.2.1 *Analysis of all WE products*

Fig. 2 presents a statistical overview of the WE products surveyed, focusing on various performance indicators reported by the manufacturers. The number of WE products providing information on these indicators is indicated at the bottom of each bar plot.

'Capacity', a key technological parameter, refers to the nominal electrical power capacity rating of the WE system and is measured in megawatts (MW). Among the WE products surveyed, as shown in the first column of Fig. 2, 93 products have a capacity of <1 MW,

Table 3: WE manufacturers and their technology included in the analysis

Manufacturer	Country	Technology			
		Alkaline	PEM	AEM	SOE
Plug power	US		√		
Cummins	US	√	√		
Bloom Energy	US				√
Ohmium	US		√		
Proton On-site	US		√		
Next Hydrogen	CA	√			
ITM power	UK		√		
Sunfire	DE	√			√
Enapter	DE			√	
Thyssenkrupp	DE	√			
Siemens	DE		√		
Elogen	FR		√		
McPhy energy	FR	√			
Air liquide[a]	FR	√	√		
John Cockerill	BE	√			
Nel hydrogen	NO	√	√		
Green hydrogen	DK	√			
Topsoe	DK				√
Asahi-Kasei	JA	√			
SinoHy energy	CN	√	√		
Longi	CN	√			
Peric Hydrogen	CN	√	√		
Sungrow	CN	√	√		
Shanghai Zhizhen[a]	CN		√		
Auyan	CN	√			
Guofuhee	CN	√	√		
Kohodo hydrogen energy	CN	√			
Suzhou John Cockerill	CN	√			

aManufacturer provided a general technical description of their WE technology instead of a one-by-one specification for each product.

accounting for 53% of the total. Furthermore, there are 35 commercially available WE products with a capacity ranging from 1 to 3 MW, 17 products in the range of 3–5 MW and 15 products in the range of 5–10 MW. For capacities of between 10 and 100 MW, the survey identified eight products in the range of 10–20 MW, three products in the range of 20–50 MW and three products in the range of 50–100 MW. It is worth noting that while two SOE products have capacities of >100 MW according to manufacturer information, many manufacturers emphasize the modularity and scalability of their WE products.

The 'footprint' of a WE product represents the physical space required to deliver a standard cubic foot of hydrogen per hour, measured in $m^2{\cdot}h/Nm^3$. Some manufacturers also provide this information in m^2/MW. Of the surveyed products, 82 products report the footprint parameter. As shown in the second column in Fig. 2, among these products, 48 WE systems (58.5% of the total) have a footprint of <0.1 $m^2{\cdot}h/Nm^3$. This represents the largest proportion of all products. The second-largest group consists of 24 products (29.3%) with a footprint range of 0.1–0.5 $m^2{\cdot}h/Nm^3$. For WE systems that require 0.5–1 m^2 or more space to deliver 1 Nm^3 of hydrogen per hour, there are eight products available on the market. Furthermore, only two products have a footprint of >1 m^2 when producing 1 Nm^3 of hydrogen per hour.

WE products capable of delivering hydrogen at high 'pressure' offer the advantage of requiring less energy for further compression and storage, making them suitable for intermediate and downstream applications. As shown in the third column of Fig. 2, of the 168 values collected, 63 WE products (~37.5% of the total) are designed to deliver hydrogen at a pressure of <20 bar gauge (barg). Furthermore, 100 WE products have the capability to deliver hydrogen at a pressure range of between 20 and 50 barg. However, the number of WE products that can deliver hydrogen at pressures of >50 barg is limited, with only five products falling into this category.

The fourth column in Fig. 2 represents the 'purity of the hydrogen gas' delivered by different WE products, which can have a significant impact on the performance and proper functioning of equipment involved in hydrogen storage, distribution and utilization. The acceptable purity levels may vary depending

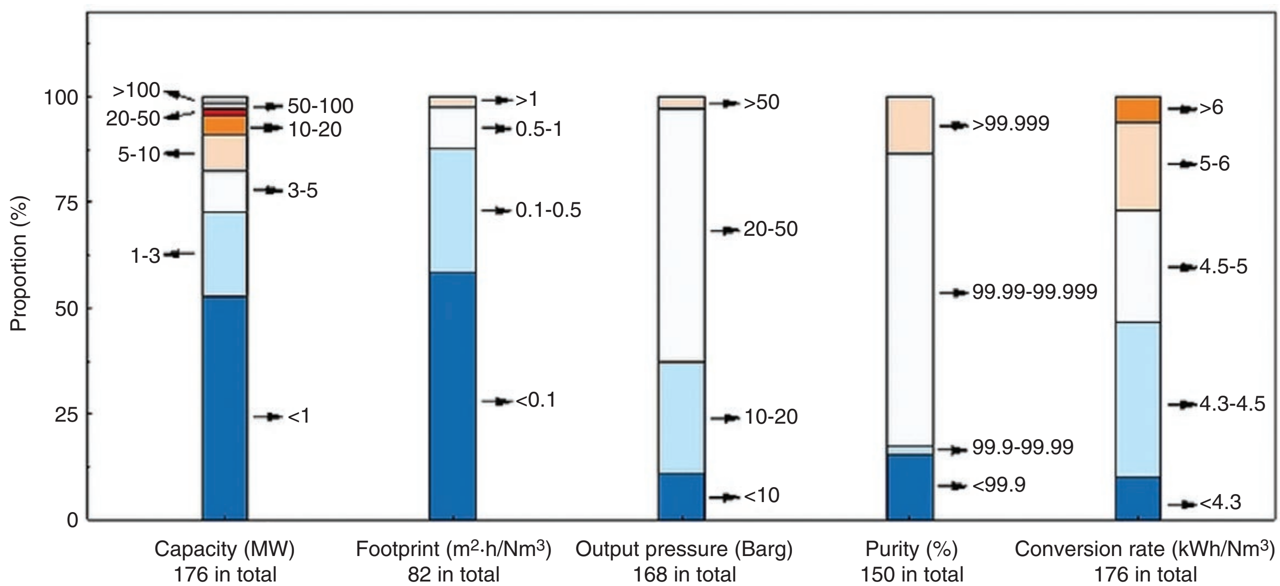

Fig. 2: Technical parameter distribution of the surveyed WE products

on the specific application. For example, while hydrogen combustion boilers can tolerate a higher percentage of impurities, fuel cell vehicles require higher purity levels. Based on the analysis conducted, it was found that only 23 WE products (17.3% of the total) deliver hydrogen with a purity level of <99.99%. Most of the surveyed WE products produce hydrogen gas with a purity level ranging from 99.99% to 99.999%. Additionally, 20 WE products (~13.3% of the total) have the capability to deliver hydrogen gas with a purity level of >99.999%.

The 'conversion rate', also known as the 'electrical system efficiency', represents the amount of electricity consumed to produce 1 Nm^3 of hydrogen when the WE system operates at its nominal power, which is normally calculated on a lower heating value basis. Although some manufacturers measure this rate in kWh/kg, many in the surveyed data prefer using kWh/Nm^3. The choice of Nm^3 as the unit provides a standard reference condition of temperature and pressure, allowing consistent comparisons. When examining the fifth column of Fig. 2, it can be observed that only 11 WE products require >6 kWh to produce 1 Nm^3 of hydrogen. A significant majority of the WE products surveyed, accounting for >73.3%, consume <5 kWh. The most common range for the conversion rate among WE products falls between 4.3 and 4.5 kWh/Nm^3. Following this, there is a slight decrease in the number of WE products, with proportions of 39.8% and 26.7% for the groups of 4.5–5 and 5–6 kWh/Nm^3, respectively. A minority of the WE products surveyed demonstrate a conversion rate of <4.3 kWh/Nm^3, indicating a higher electrical system efficiency in these cases.

2.2.2 *Analysis of alkaline products*

To provide a comprehensive overview of the performance of alkaline products, Fig. 3 showcases the surveyed data. Most alkaline products, representing 55.4%, have a capacity ranging from 0 to 1 MW, as seen in the first column. In contrast, the number of products decreases significantly in each subsequent capacity range. There is a clear downward trend in the distribution of larger-capacity alkaline products. The number of alkaline products with a capacity of between 1 and 3 MW decreases to 19. This figure further decreases to 12.9% and 10.9% for the capacity ranges of 3–5 and 5–10 MW, respectively. Only a small minority, represented by two products, have a capacity of between 10 and 20 MW.

Regarding the geometric dimensions, the available data were limited to 41 products, as shown in the second column. Of these, 25 alkaline products were found to have a footprint range of <0.1 $m^2 \cdot h/Nm^3$. The number of alkaline products that fall within the footprint range of 0.5–1.0 $m^2 \cdot h/Nm^3$ decreases to 13. The remaining products require >1 m^2 of space to deliver 1 Nm^3/h.

The third column in Fig. 3 provides a comparison of the hydrogen output pressure among 98 alkaline products that reported the output pressure. It is worth noting that 14 of these products have an output pressure of <10 barg and the rest can deliver at a higher pressure, indicating a significant interest in the development of high-pressure alkaline products. Thirty-eight alkaline products operate within the pressure range of 10–20 barg, while 41 products deliver hydrogen gas at a pressure level of between 20 and 50 barg. Additionally, five alkaline manufacturers report that their products can deliver hydrogen at pressures of >50 barg.

In terms of hydrogen gas purity, as shown in the fourth column, ~25% of the surveyed products have a purity level of <99.9%. However, >70% of the surveyed alkaline products can deliver hydrogen at a high purity level, specifically ranging between 99.99% and 99.999%.

Regarding the conversation rate, the collected data, as plotted in the fifth column of Fig. 3, show that over half of the alkaline products have a conversion rate ranging from 4.3 to 4.5 kWh/m^3. In particular, there are four products that have already achieved a conversion rate of <4.3 kWh/m^3, which aligns with the target value set for 2030 (i.e. 48 kWh/kg) as defined by the EU SRIA 2021–2027.

2.2.3 *Analysis of PEM products*

Fig. 4 provides an overview of the PEM products analysed, in which the collected information regarding capacity, footprint,

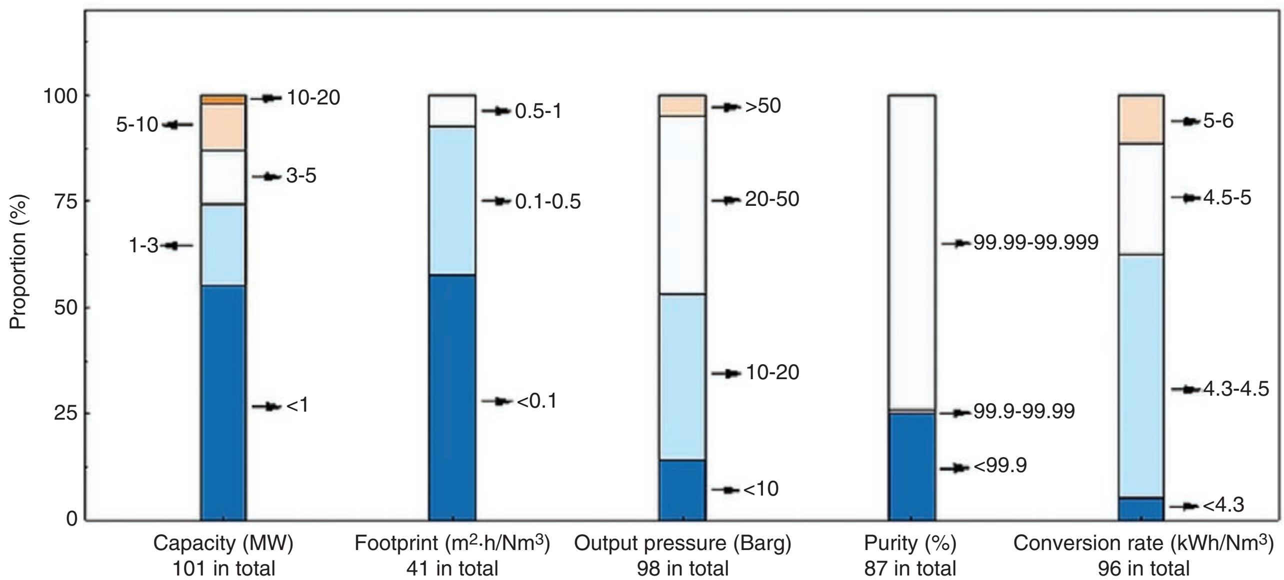

Fig. 3: Technical parameter distribution of the surveyed alkaline products

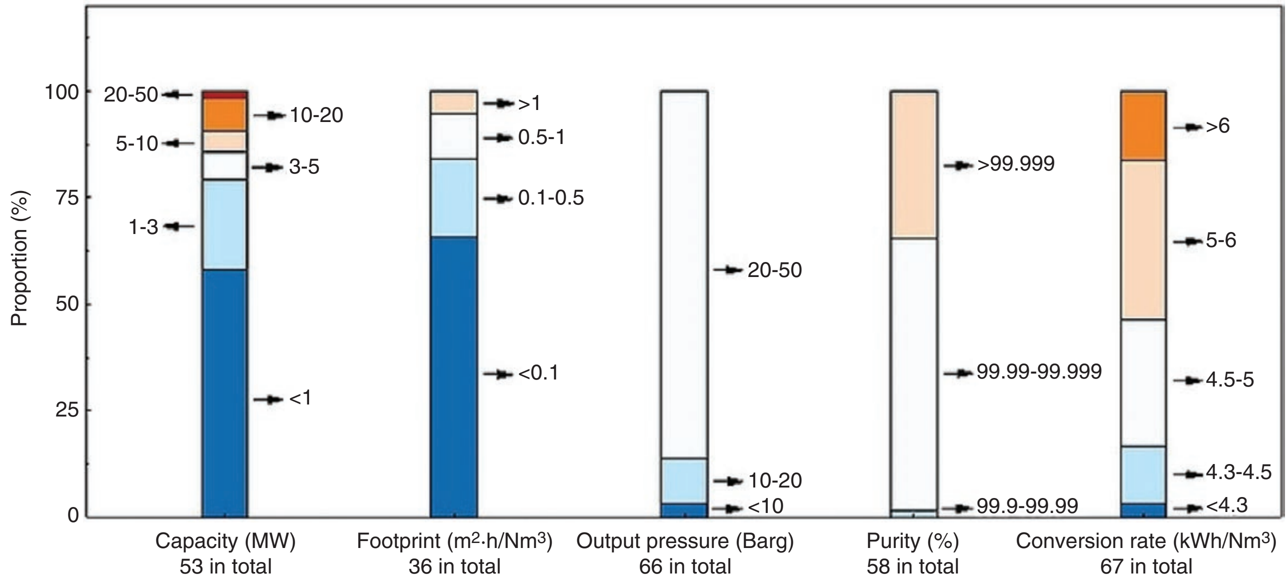

Fig. 4: Technical parameter distribution of the surveyed PEM products

output pressure, purity and conversation rate are visualized in five columns.

Of the 53 PEM products, the largest portion (27 products) falls within the capacity range of <1 MW. As the capacity increases, the number of products decreases, with 11 products in the range of 1–3 MW, three products in the range of 3–5 MW and two products in the range of 5–10 MW. Furthermore, there are nine products with a capacity ranging from 10 to 50 MW. In particular, only one product exceeds a capacity of 50 MW, representing a small proportion of just 1.6% of the total products surveyed.

The second column in Fig. 4 reveals that approximately half of the PEM products analysed have a relatively compact footprint, requiring <0.1 $m^2{\cdot}h/Nm^3$. Interestingly, two PEM products were identified with a larger footprint of >1 $m^2{\cdot}h/Nm^3$, which surpasses the maximum footprint value observed among alkaline products.

In terms of output pressure, it was found that only two PEM products are designed to deliver hydrogen at pressures of <10 barg. Most PEM products, accounting for 86.4%, operate within the pressure range of 20–50 barg.

When it comes to hydrogen purity, most PEM products deliver high purity levels, ranging from 99.99% to 99.999%. Interestingly, 17 PEM products claim to achieve even higher levels of purity, surpassing the maximum achievable purity of alkaline products, which is 99.999%.

Regarding the conversion rate, a relatively small proportion of PEM products, ~16.4%, have a higher value of >6.0 kWh/Nm^3. The largest portion of PEM products in the current market, representing 37.3% of the total, have a conversion rate ranging from 5 to 6 kWh/Nm^3. On the other hand, two PEM products consume <4.3 kWh to produce 1 $Nm^3$of hydrogen, which is the performance target value defined by the EU SRIA for the year 2030.

3 Discussion and future applications

In the global WE market, there is a proliferation of products based on different technologies. As a result of the higher technological maturity, WE products using alkaline and PEM represent the mainstream in the global market. AEM and SOE are also starting to gain prominence in the market. From the perspective of product diversity and comprehensiveness, WE manufacturers in Europe offer a wide range of products because the change in the paradigm towards a hydrogen economy is being prioritized in Europe. In North America, there are a few WE manufacturers but they offer a comprehensive range of alkaline, PEM and SOE products. In Asia, due to a sizable local market, there are quite a few newly established technology developers who mainly focus on providing products in the alkaline and PEM categories.

From the perspective of product performance, data reported by the suppliers show that there are WE products already achieving or even exceeding the 2030 efficiency targets—that is, 48 kWh/kg for both alkaline and PEM. It is also evident that there are products that still have a slight gap before reaching this benchmark. This can be attributed to variations in the level of technological accumulation and product design strategies among manufacturers. In terms of other technical parameters, PEM and alkaline are nearly comparable.

We have also observed significant variations in the methods and units used by manufacturers to describe product performance, even among manufacturers from the same region. For instance, there are differences in the preferred units for describing WE efficiency, with some using 'kWh/kg' and others using 'kWh/Nm^3'. Similarly, when it comes to describing the WE production capacity, different units such as MW_{el} (megawatt electrical power) and maximum kg or Nm^3 delivered per day have been used.

Another issue that arises is the lack of detailed explanation provided by manufacturers. Specifically, when it comes to performance indicators such as hydrogen purity and hydrogen output pressure, additional purification or compression processes can often be employed to enhance these parameters. However, many manufacturers do not clarify whether the impact of these additional auxiliary devices on the relevant parameters is considered when specifying their product specifications. Likewise, some manufacturers explicitly indicate whether the efficiency measurement pertains to the WE stack or the entire WE system, while others do not provide clear clarification.

The WEs that are commercially available today are designed and developed for applications that aim to tap or support the tapping of various hydrogen business opportunities. In addition to fulfilling the basic capability, i.e. hydrogen production, the WE products are expected to have additional capabilities, such as flexible production, intermittent power following, electricity-grid support, robustness in special environments with extremely high/low temperatures, ease of transport and upscaling, etc. A notable observation from the study is that information on additional capabilities of WEs is only provided by a few manufacturers. For example, crucial information related to operating flexibility, such as start/stop time, load range and ramp rates, is rarely included in product specifications, which greatly influences the effective utilization of fluctuating power sources such as wind and solar for hydrogen production. Furthermore, a significant number of product specifications lack details on water consumption and electrical connection requirements. Furthermore, the lack of reported information on footprints is another prevalent issue. In particular, for applications where space is a limiting factor, such as offshore platforms, the footprint of a WE product can have a significant impact on customers' choice.

The absence of consistent reporting standards across manufacturers indicates that the WE industry is still in its early stages and lacks maturity. This lack of uniformity in the approaches to product specifications can lead to various challenges, including interoperability issues, trade barriers, market fragmentation and consumer confusion. These factors collectively act as bottlenecks that hinder the overall development and widespread adoption of WE and renewable hydrogen technologies.

To tackle these challenges, it is crucial that stakeholders in the renewable-energy sector, including the WE and PtX industries, collaborate and enhance the description of WE products. This can be achieved through several specific actions, as follows, aimed at improving clarity, consistency and transparency in product specifications:

- further developing and promoting existing standards such as ISO22734:2019 and UL2264A, which will provide a valuable reference for defining WE products and describing their technical specifications;
- designing and developing detailed and harmonized templates, frameworks and benchmarks specifically tailored for WE product description, which will help to ensure uniformity in reporting and enable easy comparison among different products;
- encouraging manufacturers to embrace transparency and disclose comprehensive information about their WE products;
- facilitating third-party validation and certification processes to verify the accuracy and reliability of the reported performance data, which will enhance the credibility and trustworthiness of the information provided by manufacturers.

By implementing these actions, the industry can overcome the challenges posed by the lack of uniformity in the descriptions of WE products, fostering a more robust and integrated renewable-energy sector. This collaborative effort could help to drive market growth, improve interoperability and enhance consumer confidence in WE and PtX technologies, ultimately advancing the transition towards a sustainable and decarbonized energy future.

4 Conclusion

The WE market is poised to undergo substantial growth in the coming years, driven by the global demand for carbon emission reduction and the shift towards green fuels. This study provides an overview and data-driven analysis of the technical characteristics of existing WE products. The findings reveal that alkaline and PEM technologies dominate the current market. In particular, certain alkaline and PEM products have already exceeded expectations for the year 2030, including system efficiency, due to substantial investments and attention. However, there is a lack of standardization in the approaches taken by different manufacturers in terms of the technical specifications of WE products. This requires greater proactive and effective collaboration among relevant stakeholders in order to accelerate the development and adoption of renewable-based WE and PtX solutions.

The data used for the analysis in this article are derived from open-access information provided by manufacturers, which may introduce certain limitations in terms of timeliness and inherent uncertainty. Nevertheless, it is important to note that these factors have minimal impact on many of the conclusions drawn in this article. The analysis and findings presented are based on the available information and provide valuable insights into the current state of the industry.

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Author contributions

X.J.: data collection and analysis, writing – original draft. S.Y.: conceptualization, funding acquisition, editing. M.P., J.R.: review & editing. S.T.: visualization. C.T.: supervision. Z.F.: data collection.

Conflict of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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