Supporting Information (SI):
Anion Exchange Membrane Water Electrolysers

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1 TABLES FOR HER ACTIVITY MEASUREMENTS

Table S1. HER data for Pt/C catalysts measured in 1 M KOH

This Table contains HER data used for Figures 10 and 12 in the paper. The majority of the data were extracted from non-steady state measurements.

| Catalyst | Supplier | Loading (mgPt/cm²) | η¹ (mV) | Jmass¹ (A/mgPt) | “T.S.”² (mV/dec) | η region² (mV) | Ref. |
|----------|----------|-------------------|---------|-----------------|-----------------|---------------|------|
| 20 wt.% Pt/C | Alfa-Aesar | 0.0051 | 110 | 1.961 | 134 | 75-125 | ¹ |
|     | Fuel Cell Store        | 20 wt.% Pt/C |   |   |   |   |
|-----|-----------------------|--------------|---|---|---|---|
|     | Alfa-Aesar            | 0.0204       | 77| 0.49|46| 20-40|
| Pt/C|                       | 0.255        | 49| 0.039|39| 20-40|
|     |                       | 0.2          | 49| 0.05|39| 0-50 |
| Pt/C|                       | 0.283        | 40| 0.035|39| 0-20 |
|     |                       | 0.204        | 53| 0.049|30| -    |
| Pt/C| Alfa-Aesar            | -            | 70| 1.122|117| 0-90 |
|     | Alfa-Aesar            | 0.59         | 16| 0.085|43| 12-25|
| Pt/C|                       | 0.285        | 372| 0.035| -| 0-50 |
|     |                       | 0.0216       | -| 0.463| -| -    |
| Pt/C| Johnson-Matthew       | 0.0153       | -| 0.653| -| -    |
|     |                       | 0.14         | -| 0.071|46| 30-50|
| Pt/C|                       | -            | -| -    | -| 0-20 |
| Pt/C|                       |              | -| -    | -|      |
|     | PtNW                  |              | 0.0175| -| 0.571| -|      |
Table S2. HER data for Pt-Co and Pt-Ni based catalysts measured in 1 M KOH

This Table contains HER data used for Figure 12 in the paper. The majority of the data were extracted from non-steady state measurements.

| Catalyst                  | Loading (mg_Pt/cm²) | η¹ (mV) | j_mass¹ (A/mg_Pt) | j_mass¹,² (A/mg_cat) | “T.S.”³ (mV/dec) | η region⁴ (mV) | Ref. |
|---------------------------|---------------------|---------|-------------------|----------------------|-----------------|----------------|------|
| PtCo-Co/TiM               | 0.043               | 28      | 0.233             | -                    | 35              | 10-50          | 13   |
| PtCo(OH)₂/CC             | 0.39                | 32      | 0.026             | -                    | 70              | -              | 15   |
| Pt NW/SL-Ni(OH)₂         | 0.016               | 59      | 0.625             | -                    | -               | -              | 11   |
| Pt NP/SL-Ni(OH)₂         | 0.0218              | 78      | 0.459             | -                    | -               | -              | 11   |
| 5Pt/Ni-SP                | 0.204               | 32      | 0.049             | -                    | 30              | -              | 7    |

¹: measured at 10 mA/cm²_geom.

²: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the reported “Tafel-slopes” were measured at a η region, i.e., below η < RT/F as indicated in column 7 in the Table.

³: η region used by the authors to extract the “Tafel-slope”.

⁴: "region"
| Catalyst                        | Current Density | Overpotential | Current Efficiency | 0.512 | 0.667 | 1.961 | 70 mV |
|--------------------------------|-----------------|---------------|--------------------|--------|-------|-------|-------|
| Pt₃Ni₃ NWs/C-air                | 0.015           | 40            | 0.667              | 0.512  | -     | -     | -     |
| Pt₃Ni₃ NWs/C-air⁵              | 0.015           | 45            | 0.667              | 0.512  | -     | -     | -     |
| Pt₃Ni₂⁻ NWs-S/C                | 0.015           | 42            | 0.667              | 0.512  | -     | -     | -     |
| Pt₃Ni₂⁻ NWs-S/C⁵               | 0.015           | 42            | 0.667              | 0.512  | -     | -     | -     |
| hcp-Pt-Ni alloys               | 0.00764         | 65            | 1.309              | -      | 78    | 0-70  | 8     |
| PtNi-O                         | 0.0051          | 40            | 1.961              | -      | 79    | 60-100| 1     |
| PtNi                           | 0.0051          | 42            | 1.961              | -      | 85    | 50-80 | 1     |

¹: measured at 10 mA/cm²₉geom.

²: \( j_{\text{mass}} \) per total catalyst mass, i.e., A/mg\(_{\text{cat}}\)

³: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the reported “Tafel-slopes” were measured at a \( \eta \) region, i.e., below \( \eta < \) RT/F as indicated in column 7 in the Table.

⁴: \( \eta \) region used by the authors to extract the “Tafel-slope”.

⁵: 0.1 M instead of 1 M KOH was used.

**Table S3.** HER data for Pt/C and Pt-Ni catalysts measured in 1 M KOH and at \( \eta \) of 70 mV
This Table contains HER data used for Figure 12b in the paper. The majority of the data were extracted from non-steady state measurements.

| Catalyst                  | Supplier       | \( j_{\text{mass}} \) (A/m\(_{\text{Pt}}\)) | \( j_{\text{int}} \) (A/cm\(^2\)\(_{\text{Pt}}\)) | ECSA (m\(^2\)/g\(_{\text{Pt}}\)) | Ref. |
|---------------------------|----------------|------------------------------------------|------------------------------------------|---------------------------------|------|
| 20 wt.% Pt/C              | Alfa-Aesar     | 52.5                                     | 0.28                                     | 70.9                            |      |
| Pt/NW                     | home-made      | 40.7                                     | 0.46                                     | 40.7                            |      |
| Pt\(_3\)Ni\(_3\) NWs/C-air| home-made      | 27.6                                     | 3                                        | 22.8                            |      |
| Pt\(_3\)Ni\(_2\)-NWs-S/C | home-made      | 22.8                                     | 1.1                                      | 27.6                            |      |
| hcp-Pt-Ni alloys          | home-made      | 27.3                                     | 11.1                                     | 27.3                            |      |
| PtNi-O                    | home-made      | 49.4                                     | 14.8                                     | 48.8                            |      |
| PtNi                      | home-made      | 48.8                                     | 10.8                                     | 49.4                            |      |

Table S4. HER data for Ru-based catalysts measured in 1 M KOH

This Table contains HER data used for Figure 13 in the paper. The majority of the data were extracted from non-steady state measurements.

| Catalyst | Loading (mg\(_{\text{PGM}}\)/cm\(^2\)\(_{\text{geom}}\)) | Loading (mg\(_{\text{cat}}\)/cm\(^2\)\(_{\text{ge}}\)) | \( \eta' \) (mV) | \( j_{\text{mass}} \) (A/cm\(^2\)\(_{\text{ge}}\)) | “T.S.” (mV/dec) | \( \eta \) region (mV) | Ref. |
|-----------|----------------------------------------------------------|----------------------------------------------------------|-----------------|---------------------------------|-----------------|------------------------|------|
| Pt\(_1\)Ru\(_{1.54}\) NP/BP | 0.0148                                                   | -                                                        | 22              | 0.676                           | 19              | 10-20                  |      |
|                  | 20 wt.% |    |    |    |    |    |
|------------------|---------|----|----|----|----|----|
|                  | 0.01    |    | 40 | 0.2|    |    |
| PtRu (Fuel Cell Store) |         |    |    |    |    |    |
| Ru@CN            | -       | 0.273 | 32 | 0.037 | 53 |    |
| Ru2P             | -       | 0.233 | 52 | 0.043 | 69 |    |
| Ru@C2N           | -       | 0.285 | 17 | 0.035 | 38 | 0-50 |
| Ru/C-300         | -       | 0.59  | 14 | 0.017 | 33 |    |
| Ru-NC-700        | -       | 0.2   | 12 | 0.05  | 14 | 0-20 |
| Co-substituted Ru nanosheet | -       | 0.153 | 13 | 0.065 | 29 | 10-40 |
| RuCo@NC          | -       | 0.275 | 28 | 0.036 | 31 |    |
| RuCoP            | -       | 0.3   | 23 | 0.033 | 37 | 6-20 |
| RuCo@NC-600      | -       | 0.255 | 34 | 0.039 | 36 | 20-40 |
| Ru1Ni1-NCNFs     | -       | 0.612 | 35 | 0.016 | 30 |    |
| NiRu@N–C         | -       | 0.273 | 32 | 0.037 | 64 |    |
| NiRu@MW CNTs     | -       | 0.283 | 14 | 0.035 | 32 | 0-20 |
| R-NiRu           | -       | -     | 16 | 40   |    | 0-50 |
| Ru/C3N4/C        | -       | 0.2   | 80 | 0.05  |    |    |
Table S5. HER data for other, mainly non-PGM catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements.

| Catalyst          | Loading (mg_{cat}/cm^{2}_{geom}) | η^{1} (mV) | j_{mass}^{1} (A/cm^{2}_{geom}) | “T.S.”^{2} (mV/dec) | Ref. |
|-------------------|----------------------------------|------------|--------------------------------|---------------------|-----|
| RuNi nano-sheets  | 0.027                            | -          | 15                             | 0.372               | 28  | 0-20 | 24 |

1: measured at 10 mA/cm^{2}_{geom}.

2: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the reported “Tafel-slopes” were measured at a η region, i.e., below η < RT/F as indicated in column 7 in the Table.

3: η region used by the authors to extract the “Tafel-slope”.

Table S5. HER data for other, mainly non-PGM catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements.
| Catalyst          | Supplier          | Loading \( \text{mg}_{\text{cat}}/\text{cm}^2_{\text{geom}} \) | \( \eta^1 \) (V) | \( j_{\text{mass}}^1 \) (A/cm\(^2\)_{\text{geom}}) | “T.S.” \(^2\) (mV/dec) | Ref. |
|------------------|-------------------|-------------------------------------------------|-----------------|---------------------------------|-----------------------|-----|
| Mo\(_2\)C        |                   | 1.4                                             | 190             | 0.00714                         | 54                    | 32  |
| Ni\(_3\)S\(_2\)/Ni foam |          | 1.6                                             | 223             | 0.00625                         | -                     | 33  |
| Ni\(_2\)P\(_4\) pellet |         | 177                                             | 49              | 0.0000566                       | 98                    | 34  |
| Ni\(_2\)P pellet |                   | 177                                             | 69              | 0.0000564                       | 118                   | 34  |
| NiO@Ni          |                   | 2                                               | 105             | 0.005                           | -                     | 35  |
| np-Ni\(_3\)N     |                   | 0.16                                            | 68              | 0.0625                          | 32                    | 3   |

\(^1\): measured at 10 mA/cm\(^2\)_{\text{geom}}.

\(^2\): “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the reported “Tafel-slopes” were measured at a \( \eta \) region, i.e., below \( \eta < \eta_{RT/F} \) as indicated in column 7 in the Table.

## 2 TABLES FOR OER ACTIVITY MEASUREMENTS

**Table S6. OER data for Ir-oxide catalysts measured in 1 M KOH**

This Table contains HER data used for Figure 19 in the paper. The majority of the data were extracted from non-steady state measurements.

| Catalyst \( \text{IrO}_x \) | Supplier          | Loading \( \text{mg}_{\text{cat}}/\text{cm}^2_{\text{geom}} \) | \( \eta^1 \) (V) | \( j_{\text{mass}}^1 \) (A/cm\(^2\)_{\text{geom}}) | “T.S.” \(^2\) (mV/dec) | Ref. |
|------------------|-------------------|-------------------------------------------------|-----------------|---------------------------------|-----------------------|-----|
| (SA-100)         | Tanaka Kikinzoku Kogyo | 0.2                                             | 0.281           | 0.05                           | 51                    | 36  |
| \( \text{IrO}_x \) | Proton Onsite     | 0.01                                            | 0.393           | 1.01                           | 47                    | 37  |
| \( \text{IrO}_2 \) | -                 | 0.07                                            | 0.338           | 0.143                          | 47                    | 38  |
| Sample Type       | Substrate | Tafel Slope | Current Efficiency | Tafel Efficiency | Source          | Comment       |
|-------------------|-----------|-------------|--------------------|------------------|-----------------|---------------|
| IrO$_2^{1}$       |           | 0.427       | -                  | 49               | 39              |
| IrO$_2$           |           | 0.32        | -                  | -                | 40              |
| IrO$_2$ Sigma-Aldrich | 0.51      | 0.378       | 0.02               | 98               | 41              |
| IrO$_2$           |           | 0.32        | 0.297              | 0.031            | 63              |
| IrO$_2$ Commercial | 0.142     | 0.338       | 0.07               | 49               | 43              |
| IrO$_2$           |           | 0.2         | -                  | 0.05             | 54              |
| IrO$_2$ Sigma-Aldrich | 0.7       | 0.32        | 0.014              | 76               | 45              |
| IrO$_2$           |           | 0.15        | 0.256              | 0.067            | 70              |
| IrO$_2^{1}$       |           | 0.204       | 0.467              | 0.049            | 80              |
| IrO$_2$ Commercial | 0.14      | 0.39        | 0.071              | 79               | 48              |
| IrO$_2$ Alfa Aesar | 0.2       | 0.339       | 0.05               | 59               | 49              |
| IrO$_2$ Commercial | 0.15      | 0.34        | 0.067              | 78               | 50              |
| IrO$_2$ Sigma-Aldrich | 1         | 0.338       | 0.01               | 50               | 51              |
| IrO$_2$ Alfa Aesar | 2.2       | 0.219       | 0.005              | 89               | 52              |
| IrO$_2$           |           | 0.14        | 0.47               | 0.071            | 61              |
| IrO$_2$           |           | 0.28        | 0.39               | 0.036            | 78              |

1: measured at 10 mA/cm$^2_{geom}$.

2: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the measurements used non-steady state methods for the evaluation.

3: 1 M NaOH was used as electrolyte.
0.1 M KOH was used as electrolyte.

Table S7. OER data for NiFe-based catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements.

| Catalyst | Loading (mg\textsubscript{cat}/cm\textsuperscript{2}_{\text{geom}}) | $\eta^i$ (V) | j\textsubscript{mass}\textsuperscript{1,2} (A/cm\textsuperscript{2}_{\text{geom}}) | “T.S.\textsuperscript{3}” (mV/dec) | Ref. |
|----------|-------------------------------------------------|--------------|---------------------------------|-----------------|-----|
| NiFe/C   | 0.36                                            | 0.22         | 0.0278                          | 30              | 55  |
| FeNi/NiFe\textsubscript{2}O\textsubscript{4} @NC-800 | 0.131                                           | 0.316        | 0.0763                          | 91              | 56  |
| FeNi@N-CNT | 2                                               | 0.3          | 0.005                           | 48              | 57  |
| Ni\textsubscript{0.9}Fe\textsubscript{0.1}/NC | 2                                               | 0.27         | 0.005                           | 45              | 58  |
| Fe-Ni nano-particles | 0.029                                           | 0.311        | 0.3448                          | 65              | 59  |
| NiFe\textsubscript{2}O\textsubscript{4} QDs | 0.21                                            | 0.262        | 0.0476                          | 37              | 60  |
| Ni\textsubscript{2/3}Fe\textsubscript{1/3}-rGO | 0.25                                            | 0.21         | 0.04                            | 40              | 61  |
| Ni\textsubscript{2/3}Fe\textsubscript{1/3}-GO | 0.25                                            | 0.23         | 0.04                            | 42              | 61  |
| Ni\textsubscript{2/3}Fe\textsubscript{1/3}-NS | 0.25                                            | 0.31         | 0.04                            | -               | 61  |
| Ni\textsubscript{3}FeN-NPs | 0.35                                            | 0.28         | 0.0286                          | 46              | 62  |
| Ni\textsubscript{2}Fe\textsubscript{1}-O | 0.15                                            | 0.244        | 0.0667                          | 39              | 50  |
| Ni-Fe-Se cages | 0.1                                             | 0.24         | 0.1                             | 24              | 63  |
| Glassy Ni\textsubscript{40}Fe\textsubscript{40}P\textsubscript{20} | 1                                              | 0.27         | 0.01                            | 35              | 51  |
| Material                        | C  | O   | Pt  | W  |
|--------------------------------|----|-----|-----|----|
| Crystallized Ni_{40}Fe_{40}P_{20} | 1  | 0.288 | 0.01 | 41 |
| FeNiP-NP                       | 4.12 | 0.18 | 0.0024 | 76 |
| n-NiFe LDH/NGF                 | 0.25 | 0.337 | 0.04 | 45 |
| FeNi-rGO LDH                   | 0.25 | 0.206 | 0.04 | 39 |
| FeNi LDH                       | 0.25 | 0.232 | 0.04 | 48 |
| Fe_{6}Ni_{10}O_{x}             | 0.1 | 0.286 | 0.01 | 48 |
| NiFeMn-LDH                     | 0.2 | 0.262 | 0.05 | 47 |
| Ni_{1}Fe_{2}-250               | 0.17 | 0.31 | 0.059 | 42 |
| NiFe LDH/C                     | 0.1 | 0.36 | 0.1 | 51 |
| Fe-Ni hydroxide/GM C           | 0.147 | 0.32 | 0.068 | 57 |
| Na_{0.08}Ni_{0.9}Fe_{0.1}O_{2} | 0.13 | 0.26 | 0.077 | 44 |
| NaNi_{0.9}Fe_{0.1}O_{2}        | 0.13 | 0.29 | 0.077 | 44 |
| NiFe LDH@Cu foam               | 2.2 | 0.199 | 0.005 | 28 |
| NiFe-B                         | 0.07 | 0.347 | 0.143 | 67 |
| NiFe-NS                        | 0.07 | 0.302 | 0.143 | 40 |
| NiFe_{2}O_{4}                  | 0.8 | 0.51 | 0.0125 | - |
| Material               | Capacity | Initial Efficiency | Steady Efficiency | Operating Temperature | Reference |
|------------------------|----------|--------------------|-------------------|-----------------------|-----------|
| NiFe-MoO$_x$ NS        | 0.2      | 0.276              | 0.05              | 55                    | 74        |
| NiFeO$_x$ /CoN$_y$ -C  | 0.196    | 0.31               | 0.051             | 60                    | 75        |
| S-NiFe-700@C           | 0.286    | 0.281              | 0.035             | 53                    | 76        |
| 3D NiFe LDH/Ni foam$^d$| 1        | 0.249              | 0.01              | 50                    | 77        |
| Ni-Fe/Au               | 0.14     | 0.331              | 0.071             | 58                    | 53        |
| Ni-Fe/2D-ErGO          | 0.14     | 0.278              | 0.071             | 42                    | 53        |
| Ni-Fe film$^d$         | 0.027    | 0.28               | 0.374             | 40                    | 78        |
| NiFe-LDH/CNT           | 0.25     | 0.247              | 0.04              | 31                    | 79        |
| NiFe-LDH/CNT$^d$       | 0.25     | 0.308              | 0.04              | 35                    | 79        |
| NiFe-LDH/oGSH$^d$      | 0.25     | 0.35               | 0.04              | 54                    | 80        |
| (Ni–Fe)-LDH/3D-ErGO (8:2) | 0.14   | 0.259              | 0.071             | 39                    | 53        |
| Ni$_{0.9}$Fe$_{0.1}$O$_x$ | 0.0012  | 0.336              | 8.55              | 30                    | 39        |
| Material                        | X | Y1  | Y2  | Z1  | Reference |
|--------------------------------|---|-----|-----|-----|-----------|
| RGO-Ni-Fe LDH                  | 0.2 | 0.25 | 0.05 | 33  | 81        |
| NiFeMo                         | 0.28 | 0.28 | 0.036 | 40  | 82        |
| NiFe                           | 0.28 | 0.315 | 0.036 | 40  | 82        |
| NiFe/NF                        | 0.032 | 0.24  | 0.312 | 33  | 83        |
| NiFe/NF                        | 0.032 | 0.215  | 0.312 | 28  | 83        |
| NiFeOₓ/CFP                     | 1.6 | 0.23  | 0.006 | 32  | 84        |
| NiFeOₓ/CFP                     | 1.6 | 0.25  | 0.006 | -   | 84        |
| NiFe LDH                       | 0.05 | 0.26  | 0.2  | 21  | 85        |
| 24:0-RT NiFe-LDH               | 0.1 | 0.27  | 0.1  | 34  | 86        |
| Ni₀.₇₅Fe₀.₂₅OOH – GCE          | 0.21 | 0.286 | 0.048 | -   | 87        |
| Ni₀.₇₁Fe₀.₂₉(OH)ₓ              | 0.317 | 0.296 | 0.032 | 58  | 88        |
| Ni₀.₈₉Fe₀.₁₁(OH)ₓ              | 0.402 | 0.348 | 0.025 | 78  | 88        |
| HPGC@NiFe LDHs                 | 0.285 | 0.265 | 0.035 | 56  | 89        |
| Ni₀.₇₅Fe₀.₂₅Ho-np              | 0.135 | 0.23  | 0.074 | 24  | 90        |
| NiFe-LDH                      | 0.2  | 0.247 | 0.05  | 37  | 36        |
| Catalyst                        | Loading (mg cat/cm²geom) | η₁ (V) | jmass,1,2 (A/cm²geom) | “T.S.”,3 (mV/dec) | Ref. |
|--------------------------------|--------------------------|--------|-----------------------|------------------|-----|
| FeNi-rGO hybrids              | 0.25                     | 0.195  | 0.04                  | 39               | 66  |

1: measured at 10 mA/cm²geom.  
2: jmass is per total catalyst mass  
3: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the measurements used non-steady state methods for the evaluation.  
4: 0.1 M KOH.  
5: 1 M NaOH.  

Table S8. OER data for NiCo-based catalysts measured in 1 M KOH  
The majority of the data were extracted from non-steady state measurements. The majority of papers do not specify if Fe-free chemicals and electrolytes were used for the synthesis and extraction of OER data.  

| Catalyst                        | Loading (mg cat/cm²geom) | η₁ (V) | jmass,1,2 (A/cm²geom) | “T.S.”,3 (mV/dec) | Ref. |
|--------------------------------|--------------------------|--------|-----------------------|------------------|-----|
| NiCo₂.₇(OH)ₓ                   | 0.2                      | 0.35   | 0.05                  | 65               | 91  |
| Ni₂Co₁@Ni₂Co₁Oₓ                 | 0.4                      | 0.32   | 0.025                 | -                | 92  |
| NiCoP/rGO                      | 0.15                     | 0.27   | 0.06667               | 45               | 93  |
| NiCo                        | 2.8                      | 0.258  | 0.00357               | 42               | 94  |
| NiCo diselenide/CC             | 0.07                     | 0.385  | 0.143                 | 65               | 38  |
| NiCo-B                         | 0.07                     | 0.337  | 0.143                 | 64               | 95  |
| NiCo₂S₄                        | 0.07                     | 0.337  | 0.143                 | 64               | 95  |
| Material                  | Ni  | Co  | P  | O  |
|---------------------------|-----|-----|----|----|
| NiCo₂O₄                   | 0.07| 0.377| 0.143| 91 |
| NiCo₂O₄@C                 | 1   | 0.267| 0.01 | 63 |
| NiCo LDH nano-sheets      | 0.17| 0.367| 0.059| 53 |
| Ni-Co-OH                  | 0.82| 0.337| 0.0122| 40 |
| NiCoP/NF                  | 1.6 | 0.28 | 0.0062| 75 |
| Ni₀.₇Co₀.₃/NC              | 0.1 | 0.337| 0.1 | 37 |
| Ni₀.₅Co₀.₅/NC              | 0.1 | 0.3 | 0.1 | >120 |
| Ni₀.₄Co₀.₆/NC              | 0.1 | 0.328| 0.1 | >120 |
| Ni₀.₃Co₀.₇/NC              | 0.1 | 0.342| 0.1 | >120 |
| Ni₀.₂Co₀.₈/NC              | 0.1 | 0.349| 0.1 | >120 |
| CoNi hydroxide            | 0.2 | 0.324| 0.05 | - |
| CoNi LDH/CoO nano-sheets  | 0.265| 0.3 | 0.038| - |
| CoNi LDH/CoO/GO nano-sheet| 0.265| 0.315| 0.038| - |
| NiCo₂O₄                   | 0.4 | 0.36 | 0.025| 55 |
| Ni₀.₆₉Co₀.₃₁-P             | 3.5 | 0.266| 0.00286| 47 |
| NiCoO₂⁺                   | 0.8 | 0.39 | 0.0125| 42 |
| Co₃O₄@Ni                  | 0.83| 0.265| 0.012| 65 |
Table S9. OER data for NiCoFe-based catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements. The majority of papers do not specify if Fe-free chemicals and electrolytes were used for the synthesis and extraction of OER data.

| Catalyst                  | Loading (mg_{cat}/cm^{2}_{geom}) | η (V)  | j_{mass}^{1,2} (A/cm^{2}_{geom}) | “T.S.”^{3} (mV/dec) | Ref. |
|---------------------------|----------------------------------|--------|---------------------------------|---------------------|------|
| FeCoNi-2 CP               | 1                                | 0.288  | 0.01                            | -                   | 107  |
| FeCoNi-2                  | 0.32                             | 0.325  | 0.031                           | 60                  | 107  |
| NiCoFe LTHs/CFC           | 0.4                              | 0.239  | 0.025                           | 32                  | 108  |
| O–NiCoFe–LDH^{4}          | 0.12                             | 0.34   | 0.083                           | 93                  | 109  |
| FeNi_{5}Co_{2} LDH        | 0.25                             | 0.224  | 0.04                            | 42                  | 110  |
| Co-Ni-Fe511               | 0.12                             | 0.288  | 0.083                           | 55                  | 30   |

1: measured at 10 mA/cm^{2}_{geom}.

2: j_{mass} is per total catalyst mass.

3: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the measurements used non-steady state methods for the evaluation.

4: 1 M NaOH.
Table S10. OER data for Ni-based catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements. The majority of papers do not specify if Fe-free chemicals and electrolytes were used for the synthesis and extraction of OER data.

| Catalyst                     | Loading $(\text{mg}_{\text{cat}}/\text{cm}^2_{\text{geom}})$ | $\eta^1$ (V) | $j^1_{\text{mass}}$ (A/cm$^2_{\text{geom}}$) | “T.S.”$^2$ (mV/dec) | Ref. |
|------------------------------|-------------------------------------------------------------|--------------|---------------------------------------------|---------------------|------|
| Ni(OH)$_2$/NF                | 2.9                                                         | 0.17         | 0.0034                                      | >120                | 112  |
| Ni@NC-800                    | 0.31                                                        | 0.28         | 0.032                                       | 45                  | 113  |
| Ni$_{2.7}$Zn(OH)$_x$         | 0.05                                                        | 0.29         | 0.2                                          | 43                  | 114  |
| Ni(OH)$_2$                   | 0.14                                                        | 0.331        | 0.071                                       | -                   | 115  |
| NiO                          | 0.14                                                        | 0.364        | 0.071                                       | -                   | 115  |
| Ni                            | 0.14                                                        | 0.377        | 0.071                                       | -                   | 115  |
| NiO                           | 0.2                                                         | 0.43         | 0.05                                        | 81                  | 116  |
| Ni(OH)$_2$                   | 0.2                                                         | 0.36         | 0.05                                        | 111                 | 116  |
| NiO-(i)$^3$                  | 0.8                                                         | 0.43         | 0.012                                       | 62                  | 52   |
| Catalyst          | Loading (mg_cat/cm²_geom) | η₁ (V) | j_mass₁,₂ (A/cm²_geom) | “T.S.”³ (mV/dec) | Ref. |
|-------------------|---------------------------|--------|------------------------|------------------|------|
| NiO/Ni-350        | 0.5                       | 0.345  | 0.02                   | 53               | 117  |
| Ni/NC             | 0.1                       | 0.42   | 0.1                    | >120             | 100  |

¹: measured at 10 mA/cm²_geom.
²: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the measurements used non-steady state methods for the evaluation.
³: 1 M NaOH was used as electrolyte.

Table S11. OER data for Co-based catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements. The majority of papers do not specify if Fe-free chemicals and electrolytes were used for the synthesis and extraction of OER data.
| Sample                     | Ni    | Co    | P     | C   | Ref. |
|----------------------------|-------|-------|-------|-----|------|
| CoP NR/C                   | 0.71  | 0.32  | 0.014 | 86  | 121  |
| Sandwich-like CoP/C        | 0.36  | 0.33  | 0.028 | 53  | 122  |
| CoP-MNA                    | 6.2   | 0.29  | 0.002 | 65  | 123  |
| Co$_2$P@N, P-PCN/CNTs      | 0.36  | 0.28  | 0.028 | 72  | 124  |
| CoP$_2$/RGO                | 0.285 | 0.3   | 0.035 | 96  | 125  |
| CoPh/NG                    | 2.5   | 0.262 | 0.004 | 54  | 46   |
| CoPh/NG GC                 | 0.15  | 0.31  | 0.067 | 98  | 46   |
| CoPs/NG                    | 2.5   | 0.289 | 0.004 | 68  | 46   |
| CoPh/G                     | 2.5   | 0.292 | 0.004 | -   | 46   |
| CoP/TM                     | 2.1   | 0.31  | 0.005 | 87  | 126  |
| Co-P foam                  | 1.52  | 0.3   | 0.007 | 46  | 127  |
| Co$_3$P/CNT-900            | 1     | 0.292 | 0.01  | 68  | 128  |
| Co$_3$Mn–LDH/MWCNT         | 0.283 | 0.3   | 0.035 | 74  | 129  |
| Mn-Co oxyphosphide multi-shelled particles | 0.25 | 0.32 | 0.04 | 52  | 130  |
| Mn@CoMnO NPs               | 0.3   | 0.246 | 0.033 | 46  | 131  |
| Compound                        | C   | O   | H   | N   | Reference |
|--------------------------------|-----|-----|-----|-----|-----------|
| CoMn LDH                        | 0.142 | 0.324 | 0.07 | 43 | 43        |
| Co$_{0.5}$Mn$_{0.5}$WO$_4$      | 0.2  | 0.4  | 0.05 | 84 | 47        |
| gelled FeCoW                     | 0.21 | 0.191 | 0.048 | -  | 87        |
| Co$_6$Mo$_6$C$_2$/NC RGO         | 0.14 | 0.26 | 0.071 | 50 | 48        |
| CoMoS$_4$/β-Co(OH)$_2$           | 1    | 0.342 | 0.01 | 105| 132       |
| CoS-Co(OH)$_2$@MoS$_{2+x}$       | 0.2  | 0.38 | 0.05 | 68 | 133       |
| ZnCo$_2$O$_4$ spindle            | 0.24 | 0.389 | 0.042 | 60 | 134       |
| Zn$_x$Co$_{3-x}$O$_4$-3:1 RP arrays | 1   | 0.32 | 0.01 | 51 | 135       |
| ZnO-CoO$_x$/CPEC                 | 0.45 | 0.276 | 0.022 | 59 | 136       |
| NG-CoSe$_2^4$                    | 0.2  | 0.366 | 0.05 | 40 | 137       |
| CoSe$_2$/CF                      | 2.9  | 0.297 | 0.003 | 41 | 138       |
| a-CoSe/Ti                        | 3.8  | 0.292 | 0.003 | -  | 139       |
| peapod-like Co(S$_{0.71}$Se$_{0.29}$)$_2$ | 1   | 0.283 | 0.01 | 68 | 140       |
| Co$_2$B/CoSe$_2$                 | 0.4  | 0.32 | 0.025 | 56 | 141       |
### Table S12. OER data for FeCo-based catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements.

| Catalyst                  | Loading $(\text{mg cat/cm}^2_{\text{geom}})$ | $\eta^1$ (V) | $j_{\text{mass}}^1$ $(\text{A/cm}^2_{\text{geom}})$ | “T.S.”$^2$ (mV/dec) | Ref. |
|---------------------------|-------------------------------------------|--------------|-------------------------------------------------|---------------------|------|
| CoFe LDH-F                | 0.2                                       | 0.3          | 0.05                                            | 40                  | 145  |
| Co-Fe-P-1.7               | 0.424                                     | 0.26         | 0.024                                           | 58                  | 111  |
| CoFePO                    | 2.2                                       | 0.274        | 0.005                                           | 52                  | 146  |
| Fe-Co-2.3Ni-B             | 0.3                                       | 0.274        | 0.033                                           | 38                  | 147  |
| Fe$_3$O$_4$Co$_9$S$_8$/rGO-2 | 0.25                                     | 0.32         | 0.04                                            | 55                  | 148  |

$^1$: measured at 10 mA/cm$^2_{\text{geom}}$.

$^2$: $j_{\text{mass}}$ is per total catalyst mass.

$^3$: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the measurements used non-steady state methods for the evaluation.

$^4$: 0.1 M KOH.
| Composite Material                        | Co | Fe | O   | Ts  | C  | Ref. |
|------------------------------------------|----|----|-----|-----|----|------|
| Co$_{0.7}$Fe$_{0.3}$/P/CN Ts             | 0.5|     | 0.243| 0.02| 36 |       |
| CoFe$_2$O$_4$/C NRAs                     | 1.03|    | 0.24 | 0.01| 45 |       |
| CoFe-LDH$^2$                            | 0.204|   | 0.34 | 0.049| -  |       |
| Co–Fe LDH/rGO$^2$                        | 0.204|   | 0.325| 0.049| -  |       |
| NiFeMn-LDH                              | 0.2|     | 0.262| 0.05| 47 | 68    |
| Fe-Co$_3$O$_4$ (32/1)$^3$                | 0.12|     | 0.486| 0.083| -  |       |
| CoFe35 LDH$^3$                           | 0.25|     | 0.35 | 0.04| 47 | 153   |
| V-Co-Fe-343                              | 0.28|     | 0.307| 0.036| 36 | 154   |
| Fe$_{0.4}$Co$_{0.6}$                     | 1.2 |     | 0.283| 0.008| 34 | 155   |
| CoFe$_2$O$_4$-np/PANIMWC NTs             | 0.285|   | 0.314| 0.035| 31 | 156   |
| Co$_3$Fe$_7$O$_{15}$/NPC-450             | 0.36|     | 0.328| 0.028| 31 | 157   |
| α-Co$_4$Fe(OH)$_x$                       | 0.28|     | 0.295| 0.036| 52 | 54    |
| Fe$_{0.5}$Co$_{0.5}$@NC/NCNS-800         | 0.306|   | 0.27 | 0.033| 50 | 158   |
| Fe$_3$O$_4$/Co(OH)$_2$ NSs(Co/Fe 15)     | 0.111|   | 0.39 | 0.09 | -  | 159   |
| Material                          | Current | Overpotential | i (mA/cm$^2$) | resistance (ohm) |
|----------------------------------|---------|---------------|---------------|------------------|
| Fe$_3$O$_4$/Co(OH$_2$) NSs(Co/Fe 15)$^3$ | 0.111   | 0.37          | 0.09          | 61               |
| Fe$_3$O$_4$-Co$_3$S$_4$ NS       | 0.672   | 0.27          | 0.015         | 56               |
| G-FeCoW - Au foam                | 0.21    | 0.191         | 0.048         | -                |
| LDH FeCo - Au foam               | 0.21    | 0.279         | 0.048         | -                |
| G-FeCo - Au foam                 | 0.21    | 0.215         | 0.048         | -                |
| A-FeCoW - Au foam                | 0.21    | 0.232         | 0.048         | -                |
| LDH FeCo – GCE                   | 0.21    | 0.331         | 0.048         | -                |
| G-FeCo – GCE                     | 0.21    | 0.277         | 0.048         | -                |
| G-FeCoW – GCE                    | 0.21    | 0.223         | 0.048         | -                |
| A-FeCoW – GCE                    | 0.21    | 0.301         | 0.048         | -                |
| Co$_{0.54}$Fe$_{0.46}$OO H$^+$   | 0.2     | 0.39          | 0.05          | 47               |

$^1$: measured at 10 mA/cm$^2$$_{geom}$. 
2: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the measurements used non-steady state methods for the evaluation.

3: 0.1 M KOH was used as electrolyte.

Table S13. OER data for Fe-based catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements.

| Catalyst          | Loading (mg_{cat}/cm^{2}_{geom}) | \(\eta^1\) (V) | \(j_{mass}^1\) (A/cm^{2}_{geom}) | “T.S.”\(^2\) (mV/dec) | Ref. |
|-------------------|----------------------------------|-----------------|----------------------------------|------------------------|------|
| Fe\(_3\)C/Fe@NC NTs-NCNFs | 0.56                            | 0.284           | 0.018                            | 56                     | 162  |
| Fe\(_{0.5}\)V\(_{0.5}\) | 0.143                           | 0.39            | 0.07                             | 38                     | 163  |
| Fe(TCNQ)\(_2\)/Fe | 0.49                            | 0.36            | 0.02                             | 110                    | 164  |
| Fe\(_2\)O\(_3\)\(^3\) | 0.8                             | 1.24            | 0.01                             | -                      | 73   |

1: measured at 10 mA/cm^{2}_{geom}.

2: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the measurements used non-steady state methods for the evaluation.

3: 1 M NaOH was used as electrolyte.

Table S14. OER data for NiP-based catalysts measured in 1 M KOH

The majority of the data were extracted from non-steady state measurements. The majority of papers do not specify if Fe-free chemicals and electrolytes were used for the synthesis and extraction of OER data.
| Catalyst                  | Loading (mg<sub>cat/cm<sup>2</sup>geom) | η<sup>1</sup> (V) | \( j_{mass}^{1} \) (A/cm<sup>2</sup>geom) | “T.S.”<sup>2</sup> (mV/dec) | Ref. |
|--------------------------|--------------------------------------|-------------------|---------------------------------|--------------------------|------|
| Ni-P/NF                  | 3.2                                  | 0.309             | 0.003                           | 58                       | 165  |
| Ni<sub>2</sub>P          | 0.14                                 | 0.29              | 0.071                           | 47                       | 115  |
| Ni-P                     | 0.2                                  | 0.3               | 0.05                            | 77                       | 116  |
| C@Ni<sub>8</sub>P<sub>3</sub> | 1.9                                  | 0.267             | 0.005                           | 51                       | 166  |
| Ni<sub>x</sub>P<sub>y</sub>-325 | 0.15                                 | 0.32              | 0.067                           | 107                      | 167  |
| Ni<sub>12</sub>P<sub>5</sub>/NF | 3                                    | 0.24              | 0.003                           | 106                      | 168  |
| Ni<sub>2</sub>P/NF       | 3                                    | 0.26              | 0.003                           | 112                      | 168  |
| Ni<sub>12</sub>P<sub>5</sub>/NF | 1                                    | 0.295             | 0.01                            | -                        | 168  |
| Ni<sub>2</sub>P/NF       | 1                                    | 0.33              | 0.01                            | -                        | 168  |
| CP@Ni-P                  | 25.8                                 | 0.19              | 0.0004                          | 73                       | 169  |
| MoS<sub>2</sub>/Ni<sub>3</sub>S<sub>2</sub> Heterostructures | 9.7                                  | 0.218             | 0.001                           | 83                       | 170  |
| Ni<sub>2</sub>P@NF-6     | 5.6                                  | 0.142             | 0.002                           | 109                      | 171  |
| NiCuP                    | 6.7                                  | 0.292             | 0.001                           | 49                       | 172  |

<sup>1</sup>: measured at 10 mA/cm<sup>2</sup>geom.

<sup>2</sup>: “T.S.” stands for “Tafel-slope”. The values are as reported. Quotation marks are used as the majority of the measurements used non-steady state methods for the evaluation.

Tables 2, 3, 5, 7-14 contain some information provided by Kibgsaard et al.

Additional metrics and various catalysts are added in this publication.
3 PROTOCOLS TO EVALUATE HER AND OER CATALYSTS

As discussed throughout the review paper, consistent catalytic activity and stability measurements for HER and OER electro-catalysts at conditions mimicking AEMWE operation are needed. Therefore, in the following sections recommendations for measurement procedures are made.

The need for accurate HER and OER catalysts measurements has already been discussed throughout the catalyst section in the review paper. As discussed, steady-state measurements need to be carried out to measure mass activities, intrinsic activities and Tafel-slopes in valid $\eta$ regions. The measurement of the HER characteristics is more challenging than for the OER as the HER and its corresponding back reaction, namely the oxidation of adsorbed hydrogen (the HOR) are fast electrochemical reactions and the reaction can be kinetically controlled. The end goal of the measurements should be a plot showing the steady-state data as a Tafel plot, i.e., $\eta$ vs. the logarithm of the current density and a Table showing metrics relevant to the HER and OER as suggested in the following Table S15.

Table S15. Template suggesting a format to report HER and OER catalyst metrics

| Catalyst | Catalyst loading $^2$ (µg/cm$^2$) | $\eta$ at 10 mA/cm$^2_{\text{geom}}$ (mV) | $j_{\text{mass}}$ at $\eta$ = 70 mV | $j_{\text{lim}}$ at $\eta$ = 70 mV | Tafel slope $^3$ (mV/dec) | ECSA $^4$ /m$^2$ g$^{-1}$ |
|----------|----------------------------------|-------------------------------------|----------------------------------|----------------------------------|------------------|----------------------|

---

$^2$ Catalyst loading

$^3$ Tafel slope

$^4$ ECSA
| “Catalyst of interest” | ⋯ | ⋯ | ⋯ | ⋯ | ⋯ | ⋯ |
|------------------------|---|---|---|---|---|---|
| “Commercial baseline catalyst” | ⋯ | ⋯ | ⋯ | ⋯ | ⋯ | ⋯ |

1: The electrolyte solution needs to be given as well as the temperature used for the measurements.

2: The catalyst loading needs to be listed. Ideally, the wt.% of the active component of the catalyst, which typically is a metal is measured.

3: The Tafel plots need to be extracted in a \( \eta \) region exceeding \( RT/F \), i.e., > 50 mV. Some catalysts show more than one Tafel slope. In this case, both slopes and the corresponding \( \eta \) regions need to be published.

4: ESCA is the electrochemical surface area. It is not possible to determine the ECSA accurately for every catalysts but trends can be established. The method used to determine or approximate the ECSA value needs to be stated.

5: The same data (as for the catalyst of interest) need to be measured and reported for at least one baseline catalyst from a commercial supplier. The supplier of the baseline catalyst needs to be stated. In case of the HER, a commercial Pt/C catalysts (20 or 40 wt.% Pt/C, C being Vulcan XC-72 or Ketjenblack) is recommended. In case of the OER, a commercial unsupported IrO\(_x\) powder catalyst is recommended.

In addition to reporting the electrochemical characteristics, a full physical characterisation of in-house developed as well as commercial baseline catalysts is needed.
using methods as XRD, SEM, TEM and XPS. The study by Mahmood et al., is a good example demonstrating an appropriate variety of physical and analytical characterisation techniques.\(^\text{10}\)

3.1 Electrode Preparation

In case of catalyst powders, a catalyst ink, from which an aliquot is pipetted onto a flat and inert electrode surface, is typically formed and left to dry on air and room temperature. Afterwards, a thin layer of a (in water or in lower alcohols soluble) ionomer is deposited onto the catalyst layer. Again, this is done by pipetting a small volume of a very dilute ionomer solution across the entire catalyst layer surface. This ionomer layer serves the purpose of holding the catalyst on the electrode surface, i.e., acting as a glue during the electrochemical measurements. Often, a solution of approx. 0.025 wt.% Nafion in H\(_2\)O is used and typically 5-10 µLs are pipetted onto e.g., a 0.196 cm\(^2\)\text{geom} (0.25 mm diameter) circular electrode surface area of a rotating disc electrode (RDE). Reports exist (specifically in the case of the HER) of ionomers altering the catalyst activity (see section 6 in the review paper) hence, the ionomer is not added to the ink and very dilute ionomer solution are used to minimise any possible interactions. In case of doubt, catalytic activity results can be compared to results obtained from electrodes made using different ionomers, e.g., without sulfonic acid or phenolic groups or using different amounts of ionomers. It is of high importance that a thin ionomer (glue) layer is applied on top of the thin catalyst layer to ensure rapid product and reactant flow from and to the catalyst sites. This has been extensively discussed for the evaluation of the O\(_2\) reduction reaction (ORR), which is mass
transport controlled. Mass-transport limitations are of lower concern for the OER in thin layer electrodes, however, the guidelines established for the ORR should be followed.

The catalyst needs to be uniformly distributed on an inert electrode surface of known area. RDEs are well suited as electrodes for thin layer measurements as they have smooth and defined surface areas. In case, of the HER measurements, rotating the electrodes is also needed to rule out mass transport limitations. For the HER, glassy carbon electrodes and for the OER, gold or even glassy carbon and smooth nickel electrodes can be used. It needs to be kept in mind that these electrodes can exhibit HER and OER activities. Therefore, establishing the background catalytic activities (i.e., HER or OER currents) of the electrode substrates is essential prior to any activity measurement. The catalyst loading (measured in mg/cm$^2_{\text{geom}}$) influences the activity, although not in a uniform manner. Therefore, measurements of the activity at different catalyst loadings are needed to ensure that a catalyst loading range, which yields a constant mass activity as explained by Anantharaj et al. is used. For example, catalyst loadings in the range of 5 to 15 µg/cm$^2_{\text{geom}}$ are typical for very active OER catalysts. The amount of the active component in the catalyst, specifically for supported catalysts, needs to be identified.

For accurate measurements, a real ink needs to be formed, which can be challenging. A known amount of catalyst, which depends on the activity of the catalyst, is weight into water or a lower alcohol-based solution of known volume and sonicated for 30 to 60 min. Catalysts can also be directly formed on the electrode. Again, in order to determine the catalyst activity, the catalyst loading and the ECSA need to be known for the determination of the mass and the intrinsic activities, respectively.
3.2 Electrolyte

Most commonly 1 M KOH is used as electrolyte for thin layer catalyst activity measurements. Some reports exist for NaOH or 0.1 M KOH electrolytes, however for consistency, it is recommended to carry out the measurements in 1 M KOH. If another electrolyte is of interest as feed for single cell AEMWE measurements, it is recommended to carry out activity measurements in 1 M KOH as well as in the other electrolyte for the catalysts of interest as well as the baseline catalyst. The alkali electrolyte cannot be stored in glass. In case, of Fe-free measurements, high purity KOH needs to be used. Fe can be removed from KOH using either a chemical or an electrochemical method.\textsuperscript{176,177}

3.3 Counter and Reference Electrodes

High surface area counter electrodes need to be used in order to avoid dissolution of the counter electrode and avoid erroneous capacitive contribution. In case of the HER, a high surface area electrode such as a carbon rod is recommended. Pt cannot be used for the HER, as it has a high HER activity and dissolves upon potential cycling into the Pt-oxide formation region. This can lead to deposition of Pt onto the working electrode, i.e., onto the catalyst of interest, thus resulting in erroneous HER activity measurements.

A Hg/HgO or reversible hydrogen electrode (RHE) needs to be used for the measurements in alkaline electrolytes. The reference electrode needs to be calibrated before and after each experiment. Reference electrodes such as Ag/AgCl combinations are not suitable as the AgCl is transformed into silver-hydroxide in alkaline solutions. The reference electrode will need to be placed close to the working electrode surface to reduce the IR-drop, however a distance of two times the diameter of the reference electrode needs
to be maintained to ensure uniform potential and current distribution. Ideally, a Luggin capillary is used and can be made out of e.g., Teflon tubing. The IR drop should be less than a few mV, otherwise an IR drop correction need to be applied.

3.4 Activity Measurements

The electrochemical steps recommended for the performance assessment are as follows: Carbonates are removed by N\(_2\) or Argon bubbling through the alkaline electrolyte in order to prevent a drop in the pH. The HER, is carried out in saturated H\(_2\) electrolyte, while the OER is carried out in a saturated O\(_2\) electrolyte at a constant temperature such as 20 °C. Carrying out CVs at least before and after the Tafel slope measurements is strongly recommended to allow comparison between different electrodes and understand if the catalyst is altered and/or physically detached during the measurements. Removal of H\(_2\) or O\(_2\) gas bubbles from the electrode surface is needed to ensure that the electrode surface is not blocked. Some research group rotate the RDE with the purpose to remove gas bubbles. However, rotating a horizontal surface has the opposite effect and gas bubbles will be pulled to the center of the electrode.

Steady-state Tafel plots can be obtained by gradually stepping the working electrode potential in 10 or 25 mV steps and measuring the current after a 5 min. period. Repeats of the current measurements on the same electrode need to be included to ensure that the catalyst is not altered during the experiment. At least three electrodes need to be measured. The procedures of measuring HER and OER activities in this manner are described in the literature by e.g., Lyons et al.\(^{178}\)
4  PROTOCOL TO EVALUATE HER AND OER CATALYST STABILITY

A few protocols to measure HER and OER catalysts stability have been suggested with the goal to increase the accuracy of the measurements. Many stability measurements are solely based on electrochemical experiments.\textsuperscript{179} Electrochemical stability measurements should last at least a few (10-24) h, but run for several hundreds of hours for catalysts of high interest. Measurements over longer periods allow to probe the catalyst stability when the catalyst has reached a thermodynamically stable state under relevant conditions. Care needs to be taken in selecting the substrate on which the catalyst is deposited and studied. A substrate needs to be stable under the conditions of interest and not display significant catalytic activity for the reaction of interest. A common substrate for HER studies outside of an AEMWE cell (e.g., using an H-cell) is glassy carbon, while gold, fluorine-doped tin-oxides and sometimes also glassy carbon is used as substrate for the OER. Nickel metal could be a substrate for OER catalyst stability studies. It needs to be remembered that nickel on its own has some OER activity, which could be enhanced during the stability study by Fe incorporation and/or possible surface alterations.

4.1 Stability Measurements

CVs should be performed before and after the stability tests. OER and HER stability measurements can be performed at 1.6 V and at -0.1 V vs. RHE, respectively. However, measurements at additional potentials and the addition of cycling the potential within a narrow region also provide meaningful information (see Tables S16 and S17) and\textsuperscript{73,180}. Measurements at a constant potential (chrono-amperometric) provide thermodynamic control, while potential cycling experiments reflect changing conditions and fluctuations,
which can occur in a CL during AEMWE operation. In addition, experiments from a specific $\eta$ value to open-circuit conditions (transient experiments) are also recommended to mimic start-up and shut-down operation (Table S18). The bare electrode substrate should also be tested using the same experimental conditions to establish the baseline. The stability measurements need to be carried out at constant temperature conditions. Higher temperatures such as 60-80 °C can be a benefit as it could reflect accelerated tests and also real operating conditions but the stability of other components such as the ionomer needs to be considered.

Table S16. Suggested testing conditions and template for reporting catalyst stability measurements by chrono-amperometry

| $E$ at $\eta$ / V | Activity initial ($A/\text{mg}_{\text{cat}}$) | Activity final ($A/\text{mg}_{\text{cat}}$) | Activity changes (%) | ECSA initial ($\text{m}^2/\text{g}_{\text{cat}}$) | ECSA final ($\text{m}^2/\text{g}_{\text{cat}}$) | ECSA changes (%) |
|-------------------|---------------------------------|---------------------------------|-----------------|---------------------------------|---------------------------------|-----------------|
| 0.1               | ....                            | ....                            | ....            | ....                            | ....                            | ....            |
| 0.2               | ....                            | ....                            | ....            | ....                            | ....                            | ....            |
| 0.3               | ....                            | ....                            | ....            | ....                            | ....                            | ....            |
| 0.5               | ....                            | ....                            | ....            | ....                            | ....                            | ....            |
| 0.7               | ....                            | ....                            | ....            | ....                            | ....                            | ....            |

Table S17. Suggested testing conditions and template for reporting catalyst stability measurements by potential cycling within a small voltage range
| Potential cycle (V) | Activity initial (A/mg<sub>cat</sub>) | Activity final (A/mg<sub>cat</sub>) | Activity changes (%) | ECSA initial (m<sup>2</sup>/g<sub>cat</sub>) | ECSA final (m<sup>2</sup>/g<sub>cat</sub>) | ECSA changes (%) |
|---------------------|--------------------------------------|-------------------------------------|----------------------|------------------------------------------|------------------------------------------|------------------|
| 0.1-0.2             | .....                                | .....                                | .....                | .....                                     | .....                                     | .....             |
| 0.1-0.3             | .....                                | .....                                | .....                | .....                                     | .....                                     | .....             |
| 0.1-0.4             | .....                                | .....                                | .....                | .....                                     | .....                                     | .....             |
| 0.1-0.5             | .....                                | .....                                | .....                | .....                                     | .....                                     | .....             |
| 0.1-0.7             | .....                                | .....                                | .....                | .....                                     | .....                                     | .....             |

1: The values in column 1 are given as $\eta$.

Table S18. Suggested testing conditions and template for reporting catalyst stability measurements mimicking start-up an shut-down conditions: Transient cycling

| Transient cycle<sup>1</sup> | Activity initial (A/mg<sub>cat</sub>) | Activity final (A/mg<sub>cat</sub>) | Activity changes (%) | ECSA initial (m<sup>2</sup>/g<sub>cat</sub>) | ECSA final (m<sup>2</sup>/g<sub>cat</sub>) | ECSA changes (%) |
|-----------------------------|--------------------------------------|-------------------------------------|----------------------|------------------------------------------|------------------------------------------|------------------|
| 1                           | .....                                | .....                                | .....                | .....                                     | .....                                     | .....             |
| 2                           | .....                                | .....                                | .....                | .....                                     | .....                                     | .....             |
| N<sub>th</sub><sup>2</sup>  | .....                                | .....                                | .....                | .....                                     | .....                                     | .....             |

<sup>1</sup>: A transient cycle consist of a potential step and holding at a defined $\eta$ value of e.g., 0.1, 0.2 or 0.3 V followed by exposure for a defined period of time to open-circuit conditions. Between 10 to a 100 transient cycles are recommended.

<sup>2</sup>: $N_{th}$ equals the transient cycle number.
The electrochemical stability measurements need to be coupled with an analytical technique such as ICP-MS/OES to quantify metal ion dissolution during the course and/or at end of the stability test. Calibration for the ICP-MS/OES is needed. KOH electrolyte samples require acidification using HNO$_3$ prior to the ICP-MS/OES measurement to ensure that metal ions in the electrolyte are completely dissolved. The catalysts need be thoroughly characterized before and after the stability measurements, as also suggested in section 3 above. Details for the selection of counter and reference electrodes are also given in section 3 above.

5 ECSA MEASUREMENTS FOR HER/OER ACTIVITY REPORTING

As mentioned throughout the catalysts section of the review paper consistent measurements of HER and OER activities that allow comparison and validation among studies are needed. Intrinsic activities are important to understand a catalyst, thus the knowledge of the ECSA of a catalyst is crucial. Unfortunately, reliable ECSA methods for many of the catalysts discussed in the review paper are not available. Therefore, the ECSA methods and its challenges are briefly discussed below.

For Pt and Pt-based catalyst, the ECSA can be determined from the H$_{ads/des}$ charge as described in the literature.$^{181}$ For polycrystalline Pt, the H$_{ads/des}$ charge is converted to the Pt surface area using a conversion factor of 210 C/cm$^2$Pt.$^{181}$

In case of catalyst sites in the metallic state, CO$_{ads}$ stripping voltammetry can also be used. CO does not adsorb as a monolayer on catalyst sites present in the oxide form and similarly the under potential deposition (upd) method of metals like the Cu$_{upd}$ is specific to catalyst in the metallic state.$^{181}$
Other electrochemical methods have been used to estimate ECSA values such as $C_{dl}$ measurements and charges observed for the oxidation and/or reduction of the catalyst sites. These methods can be of value to establish trends but they often do not yield accurate ECSA values.\textsuperscript{182}

Some researchers have applied different methods to extract ECSA values and for some catalysts similar ECSA values extracted from different methods have been reported. An example is a study for Ru nano-particle catalysts embedded in a functionalised carbon matrix (as already mentioned in section 3.2 in the review paper), where the agreement between the $H_{\text{ads/des}}$, $CO_{\text{ads}}$ and $Cu_{\text{upd}}$ methods allowed the extraction of the number of metallic Ru sites in the catalyst.\textsuperscript{10} Anderson et al. also used such methods to obtain estimates of ECSA values for powder catalysts by extrapolating from ECSA values determined for the corresponding bulk metal electrodes.\textsuperscript{180}

In summary, accurate ECSA values and therefore, also accurate intrinsic catalytic activities can be extracted for some catalysts, while for a large number of catalysts only trends can be determined.
## 6 SUMMARY OF AEMS EVALUATED IN AEMWE SINGLE CELLS

Table S19. Summary of the various developed to date AEMs with their performances in AEMWE single cells

| Backbone | Ref. | Membrane Electrode Assembly | AEMWE Cell Performance |
|----------|------|-----------------------------|------------------------|
|          |      | Membrane | Anode Catalyst loading mg/cm² | Cathode Catalyst loading mg/cm² | Ionomer | Voltage (V) | Current density (mA/cm²) | T (°C) | Electrolyte | Time (h) |
|          |      | Membrane | Catalyst | Ionomer | Voltage | Current density | Temperature | Electrolyte | Time |
|          |      | ATM-PP | IrO₂,3 | Pt black, 3 | F-PAE | 2.2-2.5 | 200 | 50 | H₂O | 2000 |
| Polyphenylene based AEMs | 183 | Quaternized PP | IrO₂, 0.6 | Pt Ru/C, 0.3 | BPN | 1.8 | 150 | 80 | H₂O | - |
|          | 184 | HTMA-DAPP | Ni-Fe, 3 | Pt-Ru/C, 2 | TMA-70 or TMA-53 | 1.8 | 2700 | 85 | H₂O | - |
|          | 185 | HTMA-DAPP | Ni-Fe, 3 | Pt-Ru/C, 2 | TMA-70 | ~1.6-2.5 | 200 | 60 | H₂O | 14 |
|          | 186 | HTMA-DAPP | Ni-Fe, 3 | Pt-Ru/C, 2 | TMA-53 | ~1.75-2.1 | 200 | 60 | H₂O | 170 |
|          | 187 | HTMA-DAPP | IrO₂, 0.75 | Pt-Ru/C, 0.36 | HTMA-DAPP | 2.0 | 400 | 60 | H₂O | - |
|          | 188 | HTMA-DAPP | Co₃O₄, 3 | Pt/C, 3 | Aemion | 1.9-2.1 | 500 | 50 | 1 wt.% K₂CO₃ | 750 |
|          | 188 | PTP-90 | IrO₂, 2.5 | Pt/C, 0.5 | - | 2.2 | 1000 | 75 | 1 M NaOH | - |
|          | 189 | PTP-90 | IrO₂, 2.5 | Pt/C, 0.5 | - | 2.13-2.28 | 400 | 55 | 1 M NaOH | 120 |
|          | 189 | BPN1-100 | PGM, 2 | PGM, 2 | AS-4 | 2.0-2.13 | 200 | 50 | H₂O | 6 |
|          | 189 | TPN1-100 | PGM, 2 | PGM, 2 | AS-4 | 2.15-2.21 | 200 | 50 | H₂O | 6 |
|          | 190 | PAP-TP-85 | FeₙNiₙOOH-20F, 4.8 | Pt/C, 0.94 | PAP-TP-85 and PAP-TP-85 MQN | 1.74 | 1500 | 80 | 1 M KOH | - |
| Polymers          | Anode Material | Cathode Material | AEM          | Temperature | Current Density | Potential | Catalyst | Hydrogen | Water | KOH | Notes |
|-------------------|---------------|------------------|--------------|-------------|----------------|-----------|----------|----------|-------|-----|-------|
| PAP-TP-85         | Fe,Ni,OOH-20F, 4.8 | Pt/C, 0.94       | PAP-TP-85 and PAP-TP-85 MQN | 1.8 | 1020 | 90 | H₂O | - |
| PAP-TP-85         | Fe,Ni,OOH-20F, 4.8 | Pt/C, 0.94       | PAP-TP-85 and PAP-TP-85 MQN | 1.62-1.68 | 200 | 80 | H₂O | >160 |
| PAP-TP-85         | Fe,Ni,OOH-20F, 4.8 | Pt/C, 0.94       | PAP-TP-85 and PAP-TP-85 MQN | 1.71-1.81 | 500 | 80 | H₂O | 70 |
| PFTP-13           | IrO₂, 2        | Pt/C, 0.5        | PFTP-8/PFBP-14 | 2.0 | 7680 | 80 | 1 M KOH | - |
| PFTP-13           | IrO₂, 2        | Pt/C, 0.5        | PFTP-8/PFBP-14 | ~2.1 | 500 | 60 | 1 M KOH | ~1100 |
| PFTP-8            | IrO₂, 2        | Pt/C, 0.5        | PFTP-8/PFBP-14 | 2.0 | 4880 | 80 | 1 M KOH | - |
| x-PFTP            | IrO₂, 2        | Pt/C, 0.5        | PFTP-8/PFBP-14 | 2.0 | 3600 | 80 | 1 M KOH | - |
| PFTP-13           | Ni-Fe, 20      | Ni-Fe, 20        | -             | 2.0 | 1600 | 80 | 1 M KOH | - |
| PFTP-13           | Ni-Fe, 20      | Ni-Fe, 20        | -             | ~1.5 | 500 | 60 | 1 M KOH | ~1000 |
| Polyfluorene      | PFTP-13        | NiCo₂O₄, 8       | qPPO-TMA      | 2.0 | 1000 | 70 | 10 wt.% KOH | - |

| Polyaryl ether based AEMs |
|--------------------------|
| PPO-TMA<sup>+</sup>O⁻     | IrO₂, 2.5 | Pt black, 2.5 | PPO-TMA<sup>+</sup>O⁻ | 1.6-1.7 | 100 | 50 | H₂O | 5 |
| PPO-ABCO<sup>+</sup>O⁻     | IrO₂, 2.5 | Pt black, 2.5 | PPO-ABCO<sup>+</sup>O⁻ | 1.8-2.0 | 100 | 50 | H₂O | 5 |
| PPO24-BIM                 | IrO₂, 3   | Pt/C, 1.5     | PTFE           | 1.8 | 300 | 50 | 0.5 M KOH | 900 cycles |
| qPPO-TMA                  | NiCo₂O₄, 8 | Pt/C, 0.3 | qPPO           | 2.0 | 1000 | 70 | 10 wt.% KOH | - |
|                | qPPO-TMA       | NiCo₂O₄, 8 | Pt/C, 0.3 | qPPO      | 1.79-1.84 | 300 | 50 | 400 |
|----------------|----------------|------------|-----------|-----------|-----------|-----|----|-----|
| Poly arylene | LSCPi          | IrO₂, 8    | Pt/C, 0.4 | PTFE      | 1.8       | 300 | 50 | H₂O |
| ether ketone  | LSCPi          | IrO₂, 8    | Pt/C, 0.4 | PTFE      | 1.74-2.3  | 200 | 50 | H₂O |
|                | PAEK-APMP      | Ni foam, - | Ni foam, - | -         | 2.0       | ~25  | 60 | 10 wt.% KOH |
|                | xQAPs          | Ni-Fe, -   | Ni-Mo, 40 | xQAPS     | 1.8-1.85  | 400 | 70 | H₂O |
|                | PSf-DABCO      | NiCO₂O₄, 5 | NiFe₂O₄, 1.5 | PTFE   | 2.0       | 180 | 50 | 10 wt.% KOH |
|                | PSf-TMA’OH⁻     | Pb₂Ru₂O₆.₅, 2.5 | Pt black, 2.5 | PSF-TMA’OH⁻ | 1.8       | 400 | 50 | H₂O |
|                | PSf-TMA’OH⁻     | Pb₂Ru₂O₆.₅, 2.5 | Pt black, 2.5 | PSF-TMA’OH⁻ | 1.51-2.33 | 200 | 50 | H₂O |
| Polybenzimazole based AEMs |                |            |            |           |           |     |    |     |
|                | p-PBI          | Ti₃O₂ₓ₋₁-supported nano Pt, 0.2 | Ti₃O₂ₓ₋₁-supported nano Pt, 0.2 | - | 2.0 | 100 | 80 | H₂O |
|                | linear, crosslinked, and thermal cured PBI | Ni, - | Ni, - | - | 2.0 | 100 -210 | 80 | 30 wt.% KOH |
|                | linear, crosslinked, and thermal cured PBI | Ni, - | Ni, - | - | 1.8 | <100 | 80 | 30 wt.% KOH |
|                | C-ABPBI        | Ni Foam, - | Ni Foam, - | - | 2.0 | 335 | 70 | 3 M KOH |

**Poly arylene ether ketone:**
- LSCPi: NiCo₂O₄, 8
- PAEK-APMP: Ni foam, -

**Poly sulfone:**
- xQAPs: Ni-Fe, -
- PSf-DABCO: NiCO₂O₄, 5
- PSf-TMA’OH⁻: Pb₂Ru₂O₆.₅, 2.5

**Polybenzimazole based AEMs:**
- p-PBI: Ti₃O₂ₓ₋₁-supported nano Pt, 0.2
- linear, crosslinked, and thermal cured PBI: Ni, -
|   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|
| 203 | C-ABPBI | Ni Foam, - | Ni Foam, - | - | 2.0 | 180 | 50 | 1.9 M KOH | - |
|    | L-ABPBI | Ni Foam, - | Ni Foam, - | - | 2.0 | 280 | 70 | 3 M KOH | - |
|    | L-ABPBI | Ni Foam, - | Ni Foam, - | - | 2.0 | 155 | 50 | 1.9 M KOH | - |
| 204 | PBI based AEM | Ni-Fe-Ox, 5 | Ni-Fe-Co, 5 | Sustainion® XB-7 | 2.09-2.08 | 1000 | 60 | 1 M KOH | 100 |
|    | PBI based AEM | Ni-Fe-Ox, 5 | Ni-Fe-Co, 5 | Sustainion® XB-7 | 1.89-1.88 | 600 | 60 | 1 M KOH | 100 |
| 205 | m-PBI | NiAl, - | NiAlMo, - | - | 1.8 | 1700 | 80 | 24 wt.% KOH | - |
| 206 | HMT-PMBI | NiAlMo, 42.7 | NiAlMo, 42.7 | - | 2.086 | 2000 | 60 | 1 M KOH | - |
|    | HMT-PMBI | NiAl, 47.9 | NiAlMo, 42.7 | - | 2.1 | 1000 | 60 | 1 M KOH | 154 |
| 207 | HMT-PMBI | Pt, 0.5 | Pt, 0.5 | HMT-PMBI (Cl) | 2.2-2.5 | 25 | 60 | 1 M KOH | 195 (+50 h conditioning) |
| 208 | m-PBI | Ni Foam, - | Ni Foam, - | - | 2.4 | 1500 | 80 | 20 wt.% KOH | - |
| 209 | Mes-PBI | None noble metals, - | None noble metals, - | - | 2.0 | 200 | 80 | 25 wt.% KOH | ~80 |

**Polyolefin-based AEMs**

|   |   |   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|---|---|
| 210 | LDPE-g-VBC-DABCO | Proprietary non PGM, ACTA SpA catalyst | Proprietary non PGM, ACTA SpA catalyst | AS4 | 2.08-2.25 | 460 | 45 | 1 wt.% K2CO3 | 500 |
| 211 | Aminated poly (LDPE-co-VBC) | Cu,Mn0.9-Co2.1O4, 3 | Pt/C, I | Developmental ionomer | 1.82 | 100 | 40 | 1 M KOH | - |
| Page | Material 1                 | Material 2                        | Pt/C, | PSEBS-CM- | Conc. | Current | Voltage | Temperature | pH | Origin | Notes |
|------|---------------------------|----------------------------------|------|------------|-------|---------|---------|-------------|----|--------|-------|
| 212  | LDPE-g-VBC-TMA NiCo₂O₄, 10 | Pt/C, 0.4                        |      | PSEBS-CM- | 1.65  | 100     | 60      | 0.1 M KOH   | -  | -      |       |
|      | LDPE-g-VBC-TMA NiCo₂O₄, 10 | Pt/C, 0.4                        |      | PSEBS-CM- | 1.72  | 100     | 20      | 1 M NaOH   | -  | -      |       |
| 213  | PSEBS-CM-TMA/Pt/C 8      | Py/Co, 0.3                       |      | PSEBS-CM- | 1.76  | 300     | 50      | 10 wt.% KOH | 800| -      |       |
| 214  | SEBS-Pi IrO₂, 2          | Pt/C, 2                          |      | CMSEBS     | 2.08  | 400     | 50      | 5.6 wt.% KOH | 105| -      |       |
| 215  | PSEBS-CM-DABCO NiCo₂O₄, 10 | NiFe₂O₄, 10                      |      | PSEBS-CM- | 2.0   | 120     | 40      | 10 wt.% KOH | -  | -      |       |
|      | PSEBS-CM-DABCO NiCo₂O₄, 10 | NiFe₂O₄, 10                      |      | PSEBS-CM- | 2.26  | 300     | 50      | 10 wt.% KOH | 160| -      |       |
|      | PSEBS-CM-DABCO NiCo₂O₄, 10 | NiFe₂O₄, 10                      |      | PSEBS-CM- | 2.0   | 150     | 40      | 15 wt.% KOH | -  | -      |       |
| 216  | poly (ST-co-VBC) Ni, -   | Ni, -                            |      | -          | 2.5   | 100     | 25      | H₂O         | ~1.3| -      |       |
| 187  | SES-TMA, 53 µm NiCo₂O₄, 3 | Pt/C, 3                          |      | Aemeon     | 1.9-2.0 | 500     | 50      | 1 wt.% K₂CO₃ | ~500| -      |       |
| 217  | mm-qPVBz/Cl² NiCo₂O₄, 3   | Pt/C, 3                          |      | QPVB/Cl²  | 1.99  | 100     | 55      | H₂O         | -  | -      |       |
| 218  | Cranfield-membrane Cu₀.₇₅O₂.₃O₄, 3 | Nano Ni, 2 | QPDTB | 1.9 | 100 | 22 | H₂O | - |
|      | Cranfield-membrane Cu₀.₇₅O₂.₃O₄, 3 | Nano Ni, 2 | QPDTB | 1.8 | 50 | 20-30 | H₂O | ~5 |
| 219  | Cranfield-membrane Li₀.₂₁CO₂.₇₅O₄, 2.5 | Nano Ni, 2 | QPDTB-OH⁻ | 2.05 | 300 | 45 | H₂O | - |
|      | Cranfield-membrane Li₀.₂₁CO₂.₇₅O₄, 2.5 | Nano Ni, 2 | QPDTB-OH⁻ | 2.15 | 300 | 30 | H₂O | 10 |
| Polycarbazole | 220 | QPC-TMA | IrO$_2$, 2 | Pt/C, 0.4 | QPC-TMA | 1.9 | 3500 | 70 | 1 M KOH | - |
|--------------|-----|---------|------------|----------|---------|-----|------|----|---------|---|
| QPC-TMA      |     | IrO$_2$, 2 | Pt/C, 0.4 | QPC-TMA | 1.6 | 780 | 70 | 1 M KOH | <3 |

### Composite AEMs

| 221 | PBI /FAA-3 – 20% PF-41 | IrO$_2$ 3.5 | Pt/C, 1.5 | PTFE | 2.0 | 200 | 60 | 20 wt.% KOH | 100 |
|-----|------------------------|-------------|------------|------|-----|-----|----|----------------|----|

| 222 | C-PVA-ABPBI 4:1 | Ni foam, - | Ni foam, - | - | 2.0 | 450 | 50 | 15 wt.% KOH | - |
|-----|----------------|-------------|------------|----|-----|-----|----|----------------|----|
|     | Ni foam, - | Ni foam, - | - | ~2.10 | 200 | 50 | 15 wt.% KOH | 1 |
|     | Ni foam, - | Ni foam, - | - | 2.0 | 900 | 70 | 15 wt.% KOH | - |
|     | Ni foam, - | Ni foam, - | - | ~1.95 | 200 | 70 | 15 wt.% KOH | 1 |

| 222 | L-PVA-ABPBI 4:1 | Ni foam, - | Ni foam, - | - | 2.0 | 220 | 50 | 15 wt.% KOH | - |
|-----|----------------|-------------|------------|----|-----|-----|----|----------------|----|
|     | Ni foam, - | Ni foam, - | - | ~2.55 | 200 | 50 | 15 wt.% KOH | 1 |
|     | Ni foam, - | Ni foam, - | - | 2.0 | 290 | 70 | 15 wt.% KOH | - |
|     | Ni foam, - | Ni foam, - | - | ~2.25 | 200 | 70 | 15 wt.% KOH | 1 |

| 222 | L-PVA-PBI 4:1 | Ni foam, - | Ni foam, - | - | 2.0 | 180 | 50 | 15 wt.% KOH | - |
|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| Dowex Marathon A+ LDPE blend and press-molded between poly(ethylene terephthalate) films | NiCo₂O₄, 8 | Pt/C, 0.3 | qPPO | 1.70-1.75 | 300 | 70 | 1 M KOH | 100 |
| | NiCo₂O₄, 8 | Pt/C, 0.3 | qPPO | 1.97-2.0 | 300 | 70 | 0.5 M Na₂CO₃ | 100 |
| | NiCo₂O₄, 8 | Pt/C, 0.3 | qPPO | ~1.8 | 300 | 50 | 1.95 M KOH | 100h |
| PTFE/QPDTB | Cu₀.₆Mn₀.₃Co₂₁₀₄, 3 | Pt/C, 0.1 | qPDTB-OH⁻ | 1.61-1.75 | 100 | 22 | H₂O | 175 |
| PISPVA46 | IrO₂, 2.01 | Pt/C, 0.5 | Naftion EW1100 | 2.0 | 547.7 | 60 | 0.5 M KOH | - |
| PISPVA46 | IrO₂, 2.01 | Pt/C, 0.5 | Naftion EW1100 | 1.8 | 354.1-224 | 60 | 0.5 M KOH | 80 |
| 120 μm PSU/PVP(25:75) | Ni foam, - | Proprietary cathode, - | - | 2.0 | 500 | 80 | 20 wt.% KOH | 700 |
| PFSA/PVP | Ni, - | Ni, - | - | 2.0 | ~100 | 80 | 30 wt. % KOH | - |
| LDPE-PEG-PPG-ANEX | NiCo₂O₄, 10 | Ni, - | MEA-qPPO | 1.85 | 135 | 50 | 10 wt. % KOH | - |
| LDPE-PEG-PPG-ANEX | NiCo₂O₄, 10 | Ni, - | PTFE | 2.02-2.05 | 225 | 50 | 10 wt. % KOH | 135 |

**Commercial AEM**

|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| A-201 Tokuyama | IrO₂, 2.9 | Pt black, 3.2 | As-4 | 1.8 | 399 | 50 | 1 M KOH | - |
| | IrO₂, 2.6 | Pt black, 2.4 | A-Radel | 2.0-2.15 | 200 | 50 | H₂O | >535 |
|   | A-201 Tokuyama | CuCoOₓ (Acta 3030), 36 | Ni/(CeO₂-Lₐ₂O₃)/C (Acta 4030), 7.4 | PTFE | 1.75 | 470 | 43 | 1 M KOH | - |
|---|----------------|-------------------------|---------------------------------|------|------|-----|-----|--------|----|
|   | A-201 Tokuyama | CuCoOₓ (Acta 3030), 36 | Ni/(CeO₂-Lₐ₂O₃)/C (Acta 4030), 7.4 | PTFE | 1.93 | 470 | 43 | 1 wt.% K₂CO₃/KH CO₃ | 1000 |
|   | A-201 Tokuyama | CuCoOₓ (Acta 3030), 36 | Ni/(CeO₂-Lₐ₂O₃)/C (Acta 4030), 7.4 | PTFE | 1.85 | 470 | 43 | 1 wt.% K₂CO₃ | 1000 |
|   | A-201 Tokuyama | Ni/CP, 0.017 | Ni/CP, 0.017 | - | 1.9 | 150 | 50 | 1 M KOH | - |
|   | A-201 Tokuyama | IrO₂, - | Pt/C, - | PTFE | 1.8 | 299 | 50 | 0.5 M KOH | - |
|   | A-201 Tokuyama | IrO₂, - | Pt/C, - | PTFE | 2.2 | ~800 | 50 | 0.5 M KOH | 100 cycles |
|   | A-201 Tokuyama | IrO₂, - | Pt/C, - | PTFE | 1.8 | 1070 | 50 | 0.5 M KOH | - |
|   | A-201 Tokuyama | IrO₂, - | Pt/C, - | PTFE | 2.2 | ~1500 | 50 | 0.5 M KOH | 1600 cycles |
|   | A-201 Tokuyama | CuCoOₓ (Acta 3030), 30 | Ni/(CeO₂-Lₐ₂O₃)/C (Acta 4030), 7.4 | Ionomer I₂/ Teflon AF | 1.98-2.08 | 500 | 60 | 1 wt.% K₂CO₃ | 200 |
|   | FAA-3-PP-75 | CuCoOₓ (Acta 3030), 30 | Ni/(CeO₂-Lₐ₂O₃)/C (Acta 4030), 7.4 | Ionomer I₂/ Teflon AF | 2.05-2.43 | 500 | 60 | 1 wt.% K₂CO₃ | 200 |
|   | A-901 Tokuyama | Acta 3030® (CuCoOₓ), 30 | Acta 4030® (Ni/(CeO₂-Lₐ₂O₃)/C), 7.4 | Ionomer I₂/Teflon AF | 1.94 | 400 | 50 | 1 wt.% K₂CO₃ | - |
|   | A-901 Tokuyama | Acta 3030® (CuCoOₓ), 30 | Acta 4030® (Ni/(CeO₂-Lₐ₂O₃)/C), 7.4 | Ionomer I₂/Teflon AF | 2.13-2.17 V | 500 | 50 | 1 wt.% K₂CO₃ | 180 |
| 236 | FAA3-PK-130 | Ce$_{0.2}$MnFe$_{1.8}$O$_4$, 3.5 | La$_2$O$_3$(C), 7.4 | FAA3-PK-130 | 1.8 | 300 | 25 | H$_2$O | >100 |
| 237 | FAA3-PK-130 | NiFe-BTC-GNPs/NF, 2.5 | NiMo$_4$/MoO$_3$/NF, 2.5 | FAA3-PK-130 | 1.85 | 540 | 70 | H$_2$O | - |
|     | FAA3-PK-130 | NiFe-BTC-GNPs/NF, 2.5 | NiMo$_4$/MoO$_3$/NF, 2.5 | FAA3-PK-130 | 1.85 | ~450 | 50 | H$_2$O | 72 |
| 238 | FAA3-50 | NiMn$_2$O$_4$, 3 | Pt/C, 0.5 | FAA3-50 | 2.0 | 530 | 80 | 1 M KOH | - |
|     | FAA3-50 | NiMn$_2$O$_4$, 3 | Pt/C, 0.5 | FAA3-50 | 1-1.8 | ~300 | 50 | 1 M KOH | 1000 |
| 239 | FAA3-50 | g-CN-CNF-800, 6 | Pt/C, 0.4 | FAA3-50 | 1.9 | 734 | 60 | 1 M KOH | - |
|     | FAA 3-PE | Ir black, 3 | NiMo/X72, 5 | FAA 3-PE | 1.9 | 1000 | 50 | 1 M KOH | - |
|     | FAA 3-PE | Ir black, 3 | Pt/C, 1 | FAA 3-PE | 1.8 | 1000 | 50 | 1 M KOH | - |
| 241 | Fumasep FAA-3-PE-30 | Cu$_{0.81}$Co$_{2.19}$O$_4$, - | Pt/C, 1 | Fumasep FAA-3-PE-30 | 1.68 | 100 | 30 | 0.1 M KOH | 100 |
| 242 | FAA3-50 | NiCo$_2$O$_4$, 1.2 | Pt/C, 1 | FAA3-50 | 1.8 | 303 | 50 | 6 M KOH | - |
|     | FAA3-50 | NiMn$_2$O$_4$, 0.5 | Pt/C, 1 | FAA3-50 | 1.8 | 181 | 50 | 6 M KOH | - |
| 243 | FAA3-50 | IrO$_2$, 4 | Pt/C, 0.4 | FAA3-50 | 1.9 | 1500 | 70 | 1 M KOH | - |
| 244 | Selecion AMV | GO-NiO, - | Ni/Zn/S, - | Selecion AMV | 1.9 | 513 | 80 | 5.36 M KOH | 20 |
| 245 | Selecion AMV | NiO, - | Pt, - | Selecion AMV | 1.9 | 400 | 80 | 1 M KOH | - |
| 246, 247, 248 | Sustainion X37-50 | NiFe$_2$O$_4$, 2 | NiFeCo, 3 or 2 | Sustainion X37-50 or Nafion | 1.9 | 1000 | 60 | 1 M KOH | ~2000 |
| 249 | Sustainion® X37-50 | NiMo-NH$_3$H$_2$, 3 | Fe-NiMo-NH$_3$H$_2$, 3 | Nafion | 1.57 | 1000 | 80 | 1 M KOH | - |
|     | Sustainion® X37-50 | NiMo-NH$_3$H$_2$, 3 | Fe-NiMo-NH$_3$H$_2$, 3 | Nafion | 1.69 | 500 | 20 | 1 M KOH | 25 |
| Substance                        | Electrolyte | Pt/C | thời gian (giờ) | Medium | pH | M KOH |
|---------------------------------|-------------|------|-----------------|--------|----|-------|
| Sustainion® X37-50 NiMo-NH₃/H₂ | Fe-NiMo-NH₃/H₂ | Nafion | 1.52 | 50 | 20 | 1 M KOH |
| Sustainion® X37-50 NiMo-N₂/H₂ | Fe-NiMo-N₂/H₂ | Nafion | 1.68 | 1000 | 80 | 1 M KOH |
| Sustainion® X37-50 NiMo-NH₃ | Fe-NiMo-NH₃ | Nafion | 1.62 | 1000 | 80 | 1 M KOH |
| Sustainion® X37-50 NiFe-LDH | NiFe-LDH | Pt/C | 1.59 | 1000 | 80 | 1 M KOH |
| Sustainion® Grade T NiFe_2O_4 | Raney Ni | - | 1.8 | 837 | 60 | 1 M KOH |
| Sustainion® Grade T NiFe_2O_4 | Raney Ni | - | 1.83 | 1000 | 60 | 1 M KOH |
| Sustainion® X37-50 NiFe_2O_4 | Raney Ni | - | 1.85 | 1000 | 60 | 1 M KOH |
| Sustainion® X37-50 NiFe_2O_4 | Raney Ni | - | 1.85 | 1000 | 60 | 1 M KOH |
| Sustainion® X37-50 CE-CCO | Pt | - | 1.8 | 1390 | 45 | 1 M KOH |
| Sustainion® X37-50 CE-CCO | Pt | - | 1.66 | 500 | 45 | 1 M KOH |
| Sustainion® X37-50 CCO-11 | Pt | PTFE | 1.63 | 400 | 45 | 1 M KOH |
| Sustainion® X37-50 Cu₀.₅Co₂.₅O₄ | Pt | PTFE | 1.8 | 1300 | 45 | 1 M KOH |
| Sustainion® X37-50 Ni₀.₇₅Fe₂.₅O₄ | Pt | PVDF | 1.9 | 2000 | 45 | 1 M KOH |
| Sustainion® X37-50 Ni₀.₇₅Fe₂.₅O₄ | Pt | PVDF | 1.6 | 500 | 45 | 1 M KOH |
| Sustainion® X37-50 IrO₂ | Pt | Nafion | 1.8 | 870 | 45 | 1 M KOH |
| PTFE-Sustainion Ni-Fe | Ni-Fe | PFTP-8/PFBP | 2.0 | 620 | 60 | 1 M KOH |
| Material | Anode | Cathode | Membrane | Potential (V) | Current Density (mA cm⁻²) | KOH Concentration | Other AEMs |
|----------|-------|---------|-----------|--------------|--------------------------|------------------|-----------|
| PTFE-Sustainion | Ni-Fe, 20 | Ni-Fe, 20 | PFTP-8/PFBP | 1.9-2.1 | 500 | 60 | 1 M KOH | 240 |
| PFTP -13 | Pt/C,0.5 | IrO₂, 2 | PFTP-8/PFBP-14 | 2 | 7680 | 80 | 1 M KOH | - |
| PFTP -13 | Pt/C,0.5 | IrO₂, 2 | PFTP-8/PFBP-14 | 2.2 | 500 | 60 | 1 M KOH | 1100 |
| PFTP -8 | Pt/C,0.5 | IrO₂, 2 | PFTP-8/PFBP-14 | 2.0 | 4880 | 80 | 1 M KOH | - |
| x- PFTP | Pt/C,0.5 | IrO₂, 2 | PFTP-8/PFBP-14 | 2.0 | 3600 | 80 | 1 M KOH | - |
| PFTP -13 | Pt/C,0.5 | IrO₂, 2 | PFTP-8/PFBP-14 | 2.0 | 1800 | 80 | H₂O | - |
| PFTP -13 | Ni-Fe, 20 | Ni-Fe, 20 | - | 2.0 | 1600 | 80 | 1 M KOH | - |
| PFTP -13 | Ni-Fe, 20 | Ni-Fe, 20 | - | 1.5 | 500 | 60 | 1 M KOH | 1000 |

253 a Zirfon Perl 500 UTP (AGFA) | SS316L | Raney Ni | - | 1.75 | 300 | 75 | 6 M KOH | 720 |

254 Aemion™ AF1-HNN8-50 | Ir black, 3.5-3.8 | Pt/C, 1 | FAA-3 | 1.82 | 2000 | 60 | 1 M KOH | - |
| Ir black, 3.5-3.8 | Pt/C, 1 | Aemion™ , AP1-HNN8 | 1.73-1.76V | 500 | 50 | 0.1 M KOH | ~17 |
| Aemion™ AF1-HNN8-25 | Ir black, 3.5-3.8 | Pt/C, 1 | Aemion™ , AP1-HNN8 | 1.68-1.73V | 500 | 50 | 0.1 M KOH | ~17 |

121 YAB membrane, Foma Co. | CoP NS, 5 | CoP NS, 5 | PTFE | 1.74-1.78V | 300 | 50 | 1 M KOH | ~24 |

255 Commercial AEM | IrO₂, 3 | Pt black, 3 | - | 1.87 | 200 | 35 | 1 wt.% KHCO₃ | ~190 |
| Pb₂Ru₂O₆.5, 3 | Pt black, 3 | - | 1.75 | 200 | 35 | 1 wt.% KHCO₃ | ~190 |

Other AEMs
| No. | Material Details | Composition | Catalyst | Current | Temperature | Electrolyte | Fuel Efficiency |
|-----|------------------|-------------|----------|---------|-------------|-------------|-----------------|
| 256 | AEM with quaternary ammonium | Cu$_{0.7}$Co$_{2.3}$O$_4$, 3 | Pt/C, 1 | - | 1.8 | 1000 | 25 | 1 M KOH | - |
| 257 | Membrane from ITM power plc | NiFe(OH)$_2$, - | Pt, - | - | 2.10 V to 2.25 V | 1000 | 60 | 4 M NaOH | ~240 |
| 258 | in-house prepared APE | Ni$_{0.7}$Co$_{0.3}$O$_x$, 2 | Pt/C, 1 | AS-4 | 1.94 V to 2.05 V | 100 | 50 | 1 wt.% KHCO$_3$ | 550 |
7 ADDITIONAL DATA TO STATE OF THE ART AEMWE SINGLE CELL TESTS

Table S20 provides additional experimental and operational information for the AEMWE single cell tests discussed in section 6. Table S20 complements Table S6 in the review paper. The study numbers shown in the two tables are identical.

Table S20. Experimental and operational data for State of the Art AEMWE single cell tests

This table provides supporting information to Table 6 presented in the review paper.

| Study | Anode: PTL | Cathode: GDL | T [°C] | Feed mode | Ref. |
|-------|------------|--------------|--------|-----------|------|
| 1     | Ti         | Carbon paper | 50     | n/a       | 259  |
| 2     | Ni foam    | Carbon paper | 80     | Anode     | 190  |
| 3     | NiMPL-PTL (stainless steel) | NiMPL-PTL (stainless steel) | 60 | Both | 260 |
| 4     | Ti foam    | Carbon paper, untreated | 50 | cathode (first 2 h) then anode only | 229 |
| 5     | Platinized Ti | Carbon paper (SGL BC 29) | 60 | Anode | 185 |
| 6     | Platinized Ti | Carbon paper (SGL BC29) | 80 | Cathode | 184 |
| 7     | Ni foam    | Carbon paper (SGL 29AA) | 80 | Anode | 261 |
| 8     | Stainless steel (400 µm), on sintered Ti plate for back support | carbon paper (Toray 090) | 55 | anode and cathode | 262 |
| 9     | Ni foam    | Ni foam      | 60     | Anode     | 204  |
| 10a   | stainless steel | Ni fiber paper | 60 | anode and cathode | 250 |
| 10b   | stainless steel | Ni fiber paper | 60 | anode and cathode | 250 |
| 11    | Ni foam    | Ni foam      | 60     | Anode     | 191  |
| 12    | stainless steel | carbon paper | 70 | Anode and cathode | 263 |
|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 13 | Ni | Ni | 60 | anode and cathode | 246 |
| 14 | Ni foam | carbon paper (SGL 29AA) | 80 | Anode | 261 |
| 15 | Titanium felt | carbon paper (SGL 38 BC) | 60 | Anode | 191 |
| 16 | stainless steel | stainless steel | 60 | anode and cathode | 206 |
| 17 | Ni foam | Ni foam | 60 | Anode | 191 |
| 18 | Ni foam | Ni foam | 50 | n/a | 223 |
| 19 | Ni foam | Ni foam | 50 | n/a | 215 |
| 20 | Ni foam | Ni foam | 50 | n/a | 194 |
| 21 | Ni foam (pore size 580 mm) | Ni foam (pore size 580 mm) | 50 | anode and cathode | 213 |
| 22 | Porous Ni | C-cloth coated with hydrophobic MPL, on Ni | 43 | Anode | 230 |
| 23 | Porous Ti, Pt plated | PTFE treated carbon paper | 50 | Anode | 258 |
| 24a | Ni foam | carbon paper | 60 | Anode | 234 |
| 24b | Ni foam | carbon paper | 60 | Anode | 234 |

*: MPL: Microporous layer

8 PROTOCOL FOR SINGLE CELL AEMWE TESTING

In the absence of defined testing protocols it is difficult to reliably reproduce and compare single cell AEMWE performance data between studies. Furthermore, the lack of baseline materials for AEM systems contributes to the complexity of comparing results across studies. Therefore, in this section a testing protocol to evaluate the performance and durability measurements of single cell AEMWEs is proposed.

The conditioning of the membrane usually entails soaking the membrane in 1-3 M KOH for 24- 48 h according to the manufacturers guidelines. This allows for the exchange of the counter ion (typically I⁻ or Cl⁻) with OH⁻ before assembling the cell. Complete OH⁻ exchange may require the use of different hydroxide concentrations.
depending on how strongly the hydrated ions interact with the charged end-groups of the AEM. A similar behaviour is expected for the ionomers in the catalyst layer, but these ionomers are seldomly pre-doped before electrolyzer operation and a steady improvement in cell voltage, in the “conditioning” phase of electrolyzer operation, may well be attributed to the exchange of ionomer with KOH.

The MEA also needs to be preconditioned in the AEMWE cell prior to performance measurements. First a stable cell temperature is established, while circulating pure water or supporting electrolyte to the anode and/or cathode. Usually after one hour, conditioning is applied as follows: i) Either by current stepping (typically 100 mA/cm² to 1A/cm², in 100 mA steps, for holding time 2-5 min. at each step) or by ii) applying a constant voltage (typically in the range of 1.6-2 V) until the current is stabilized. A steady state is typically reached after 30-60 min. This step also allows to identify possible pinholes in the MEA, before starting with the performance assessment of the electrolyzer cell.

Lindquist et al. recently showed the impact of insufficient cell conditioning on the low-current-density performance of polarization curves (up to 200 mV) obtained before and after conditioning for commercial PiperION in water feed.

Some studies have been found to condition AEMWE cells in alkaline electrolyte, followed by purging with pure water and measuring performance thereafter. Lindquist et al. found that insufficient purging with water after conditioning in KOH could result in an enhanced performance attributed to residual KOH. They recorded linear sweep voltammograms (LSVs) accompanied with conductivity measurements of the effluent electrolyte to conduct the study.
Table S21. Conditioning and testing protocols for AEMWE single cells summarized from the literature

| Pre-cell conditioning of membrane | KOH doping, exchanging of I⁻/Br⁻/Cl⁻ groups | Activation of catalyst | Investigated studies on GDL scale\textsuperscript{190} | Pre-conditioning of cell | Compare polarization curves before and after cell conditioning step to confirm conditioning is complete. |
|----------------------------------|---------------------------------------------|------------------------|-------------------------------------------------|--------------------------|----------------------------------------------------------------------------------|
|                                  |                                              |                        |                                                 | i) Current steps, e.g. 100 mA/cm² to 1 A/cm², in 100 mA steps, for holding time 2-5 min at each step.\textsuperscript{262} | Once steady cell voltage is achieved for applied current steps, conditioning is considered effective. |
|                                  |                                              |                        |                                                 | ii) Constant current of 0.2 A/cm² applied for 30 min, while recording iV-curves before and after to compare steady state for recorded cell voltage.\textsuperscript{260} | If still unstable or the measured voltage difference between iV-curves is > 50 mV, the conditioning step could be repeated. Once the cell voltage keeps increasing it could be a sign the cell is unstable and either membrane or ionomer degradation has started. |
| Performance assessment | Polarization curves (voltage measured at current density increments) are recorded, supported with EIS | $J_{\text{max}}$ measured up to the cut-off cell voltage of 2.2-2.4 V. This is to limit the probability of oxidation/corrosion of cell components at higher cell potentials. (PEWME at 1.8 and 2.0 V).<sup>268</sup> |
|------------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| Short and long term stability | Galvanostatic, constant current applied for a minimum of 100 hours. H<sub>2</sub>O feed: 0.2-0.5 A/cm<sup>2</sup> KOH/K<sub>2</sub>CO<sub>3</sub>: 0.3, 0.5 or 1 A/cm<sup>2</sup> Alternatively, intermittent operation (e.g. voltage cycling) allows for cycling between a high and low cell voltages with varying rest times.<sup>269,238</sup> | The voltage degradation rate over time is calculated ($\mu$V/h) for comparison between studies |
| Post-characterization/ex-situ tests | Most commonly performed to assess the degradation of electrode materials. This includes SEM-EDX measurements, XRD or XPS to establish a change in structure or intensity of characteristic signals as compared to pristine samples.<sup>190,262</sup> |
ABBREVIATIONS AND SYMBOLS

List of abbreviations and symbols used throughout the manuscript and SI:

a: intercept in Tafel plot
A: surface area
ads: adsorbed
AEI: anion exchange ionomer
AEM: anion exchange membrane
AEMFC: anion exchange membrane fuel cell
AEMWE: anion exchange membrane water electrolyzer
AEP: anion exchange polymers
AFM: atomic force microscopy
ALD: atomic layer deposition
AMS: aqueous model system
ASU: 6-azonia-spiro [5.5] undecane
at.: atomic
b: Tafel-slope value [mV/dec]
BP: bipolar plates
BPM: bipolar membranes
BPN: quaternized biphenylene ionomer
BTMA: benzyltrimethylammonium
C_{dl}: double layer capacitance
CL: catalyst layer
cm$^2_{\text{geom}}$: geometrical electrode surface area in cm$^2$.

CO$_{\text{ads}}$: adsorbed CO

CV: cyclic voltammogram

CVD: chemical vapor deposition

Cu$_{\text{upd}}$: underpotential deposition of Copper

E$\text{act}$: activation energy

CAPEX: capital investment cost

CCM: catalyst coated membrane

CEM: cation exchange membrane

CCS: catalyst coated substrate

CNT: carbon nanotubes

DABCO: 1,4-diazabicyclo[2.2.2]octane

dec: decade

DFT: density functional theory

dl: double layer

DMP: N,N-dimethylpiperidinium

E$\text{act}$: activation energy

E$_{\text{an}}$: anode potential

E$_{\text{cat}}$: cathode potential

E$_{\text{Cell}}$: cell potential

E$^\circ$: reversible potential

E$^\circ_{\text{rev}}$: standard reversible potential

E$^\circ_{\text{th}}$: thermoneutral voltage
ECSA: electrochemical surface area
EIS: electrochemical impedance spectroscopy
EO: ethylene oxide
EQCM: electrochemical quartz crystal microbalance
ES: energy storage
F: Faraday’s constant [96485 C/mol]
FC: fuel cell
FE-SEM: field emission scanning electron microscope
GC: gas chromatography
GDE: gas diffusion electrode
GDL: gas diffusion layer
H$_{\text{ads/des}}$: adsorbed/desorbed molecular hydrogen
HBE: hydrogen binding energy
HER: hydrogen evolution reaction
HOR: hydrogen oxidation reaction
HFR: high frequency resistance
HHV: high heating value
IC: initial capital cost (initial cost of the water electrolysers)
ICP-MS: inductively coupled plasma mass spectrometry
ICP-OES: inductively coupled optical emission spectrometry
IEC: ion exchange capacity
IM: imidazolium
IPNs: interpenetrating polymer networks
IR: voltage drop (current multiplied by the resistance)
iV: current-potential curves
j: current density
\( j_{\text{crit}} \): critical current density
\( j_{\text{int}} \): intrinsic current density
\( j_{\text{mass}} \): mass current density
\( j_{\text{max}} \): maximum current density
\( j_0 \): exchange current density
\( j_{0-\text{int}} \): intrinsic exchange current density
\( j_{0-\text{mass}} \): mass exchange current density
LDH: layered double helix
LSVs: linear sweep voltammograms
LT: lifetime
MEA: membrane electrode assembly
\( M_{\text{H2}} \): molecular hydrogen weight
MMT: million metric tons
MPL: micro-porous layer
MS: mass-spectrometry
\( n \): number of catalyst atoms
NC: nano-carbons
\( n_e \): number of electrons
np: nano-particles
\( N_{\text{th}} \): transient cycle number
OER: oxygen evolution reaction
OPEX: operating investment cost
ORR: oxygen reduction reaction
P: Pressure
PBI: polybenzimidazole
pc: polycrystalline
PEMWE: proton exchange membrane water electrolyser
PES: polyethersulfone
PFOTFPh: poly(fluorene-alt-tetrafluorophenylene)
PGM: platinum group metal
PTFE: polytetrafluoroethylene
PTL: porous transfer layer
PNB: polynorbornene
PPO: polypropylene oxide
PSF: polysulfone
QA: quaternary amines
QP: quaternary phosphonium
R: gas constant \([8.314 \text{ kg} \cdot \text{m}^2 \cdot \text{s}^{-2} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}]\) or resistance
R_{Cell}: cell resistance
RDE: rotating ring disc electrode
RH: relative humidity
RHE: reversible hydrogen electrode
SHE: standard hydrogen electrode
S: geometrical electrode surface area
SEM: scanning electron microscopy
SFC: scanning flow cell
SI: supporting information
SMR: steam methane reforming
SoA: State of the Art
SS: stainless steel
T: Temperature
T_g: glass temperature
TEM: transmission electron microscopy
TM: transmission metal
TOF: turn over frequency
T.S.: Tafel-slope
upd: under-potential deposition
WE: water electrolyzer
wt.: weight
W_u: water uptake
XRD: x-ray diffraction
XPS: X-ray photon spectroscopy

Symbols:
*: surface adsorbed species
\( \lambda \): number of water molecules per OH\(^-\)
η: overpotential

Ω: resistance / ohm
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