Information how to read the document

- RC: Referee Comment
    - Pages and lines in the author comments refer to the manuscript submitted before the revision process, as we did not want to change author comments here.
- AR: Authors Response
    - To avoid confusion, we have removed the line references in our responses that we mentioned in our author comments, as these referred to the unmarked revised manuscript, and we now include them in the author changes.
- AC: Authors Changes
    - Parts indicated in blue were added, parts indicated red and which are crossed out were deleted – all lines and page numbers refer to the lines in the marked-up manuscript for easy trackability.

RC2

RC	**1) The treatment of downstream hydrogen demand is insufficiently specified. In particular, it is unclear whether hydrogen demand is assumed to be fixed over time (e.g., annually, monthly, or daily). One would typically expect the hydrogen to be supplied to specific industrial clusters with relatively fixed consumption profiles. While the hydrogen storage tank and pipeline network may act as buffers enabling operational flexibility, the paper does not clarify whether total hydrogen demand must be fully met. Alternatively, it remains unclear whether hydrogen demand is assumed to be flexible or whether unmet demand can be supplied by other hydrogen production facilities.**
AR	In this case study, we assume that the produced hydrogen is injected into a public hydrogen grid. Consequently, the hydrogen network is modeled as an infinite sink, meaning that the system does not face a predefined time-varying or constant demand constraint that would require explicit fulfillment or lead to unmet demand. While the underlying model framework proposed by Reichartz et al. (2024b) is capable of incorporating specific industrial consumption profiles or transport logistics such as trailers, these features were deliberately excluded to focus on the model of the systems components, degradation, and operation. We have clarified this modeling assumption in the revised manuscript to avoid any ambiguity regarding the demand-side constraints.
AC	Page 21, line 523
	Consequently, we assume that produced hydrogen will be compressed and delivered to the hydrogen grid via pipeline, where the hydrogen grid is modeled as an infinite sink.

RC	**2) Section 2.1: How fast do HRES (or WHP) require electrolyzers to operate? What ramp-rate or other characteristics would you expect from an electrolysis plant to follow the daily wind profile? Is PEM the only technology that fits these requirements?**
AR	PEM electrolyzers are characterized by a high load range and highly dynamic response times, with ramp rates typically ranging within seconds. This allows them to follow the variable output of wind farms almost instantaneously. In our model, we apply an hourly resolution, which is appropriate for evaluating the seasonal and daily economic dispatch of the hybrid system. Given the high load and ramp-rate flexibility of PEM technology compared to the hourly time step, we assume that the electrolyzer can track the average hourly power output of the wind farm without significant latency. While alkaline electrolysis (AEL) technology is a viable alternative for hydrogen production, it exhibits slower response characteristics and higher minimum load requirements. Consequently, PEM technology is selected due to its superior dynamic flexibility.
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RC	**3) Section 2.1.3: Eq. 10-14 are not clear. It would help the reader first to introduce the voltage and Faraday efficiencies (eq. 11 and 12), and then derive eq. 10 using the variables from 11 and 12.**

	Equations 13 and 14 also use different variables, not connected to eq. 10-12, making it hard to link equations to each other.
AR	We have fundamentally restructured Sect. 2.1.3 to improve the mathematical readability. Following the reviewers suggestion, we first define the Faraday and voltage efficiencies as fundamental components, then derive the cell efficiency as their product, and finally integrate the auxiliary efficiency to define the overall system efficiency. All variables are now consistently defined across the sequence of equations.
AC	Page 8, Section 2.1.3
	The efficiency of the electrolysis cell is modeled by considering the voltage efficiency and the Faraday efficiency. First, the Faraday efficiency η_F reflects losses due to gas diffusion and is defined as the ratio between the real hydrogen flow $\dot{n}_{\mathrm{H}_2}$ and the ideal hydrogen flow $\dot{n}_{\mathrm{H}_2,\mathrm{ideal}}$, following Eq. (10): $\eta_F = \frac{\dot{n}_{\mathrm{H}_2}}{\dot{n}_{\mathrm{H}_2,\mathrm{ideal}}}.$ (10) With the ideal hydrogen flow determined by Faraday's law based on the cell current density i_{cell}, the active cell area A_{cell}, the Faraday constant F, and the number of electrons transerred per hydrogen molecule formed z, calculated according to Eq. (11) (Yodwong et al. 2020): $\dot{n}_{\mathrm{H}_2,\mathrm{ideal}} = \frac{i_{\mathrm{cell}}\cdot A_{\mathrm{cell}}}{z\cdot F}.$ (11) Second, the voltage efficiency η_V describes the ratio between the thermoneutral potential U_{th} and the actual cell voltage U_{cell} (Hernández-Gómez et al. 2020): $\eta_V = \frac{U_{\mathrm{th}}}{U_{\mathrm{cell}}}$ (12) The product of both efficiencies yields the cell efficiency η_{cell}, which relates the energy content of the produced hydrogen, based on the lower heating value ΔH_{H_2} to the electrical input power, following Eq. (13): $\eta_{\mathrm{cell}} = \eta_V \cdot \eta_F = \frac{\Delta H_{\mathrm{H}_2}\cdot \dot{n}_{\mathrm{H}_2}}{U_{\mathrm{cell}}\cdot i_{\mathrm{cell}}\cdot A_{\mathrm{cell}}}.$ (13) ~~The efficiency of an electrolysis cell η_{cell} is described by multiplying the voltage efficiency η_V and the Faraday efficiency η_F by the ratio of the produced hydrogen to the input power following Eq. (10).~~ ~~$\eta_{\mathrm{cell}} = \eta_V \cdot \eta_F = \frac{\Delta H_{\mathrm{H}_2}\cdot \dot{n}_{\mathrm{H}_2}}{U_{\mathrm{cell}}\cdot i_{\mathrm{cell}}\cdot A_{\mathrm{cell}}},$ (10)~~ ~~where ΔH_{H_2} is the lower heating value and $\dot{n}_{\mathrm{H}_2}$ the real mass flow of hydrogen. η_V is defined as the ratio between the thermally neutral potential U_{th} and U_{cell}, given in Eq. (11) (Hernández-Gómez et al. 2020).~~ ~~$\eta_V = \frac{U_{\mathrm{th}}}{U_{\mathrm{cell}}}$ (11)~~ ~~η_F reflects losses due to gas diffusion and is correlated to $\dot{n}_{\mathrm{H}_2}$and the ideal mass flow of hydrogen $\dot{n}_{\mathrm{H}_2,\mathrm{ideal}}$, following Eq. (12):~~ ~~$\eta_F = \frac{\dot{n}_{\mathrm{H}_2}}{\dot{n}_{\mathrm{H}_2,\mathrm{ideal}}},$ (12)~~ ~~with the ideal mass flow calculated by Eq. (13) (Yodwong et al. 2020):~~ ~~$\dot{n}_{\mathrm{H}_2} = \frac{i_{\mathrm{cell}}\cdot A_{\mathrm{cell}}}{z\cdot F}\cdot \eta_F.$ (13)~~ Finally, ~~E~~equation (14) shows the overall efficiency of an electrolyzer η_{El} with multiple cells and stacks and can be calculated by η_{cell} and an additional efficiency for auxiliary structures η_{Aux} such as water and heat management systems (Cheng et al. 2025; Lu et al. 2023; Tofighi-Milani et al. 2025): $\eta_{\mathrm{El}} = \eta_{\mathrm{cell}} \cdot \eta_{\mathrm{Aux}} = \frac{\Delta H_{\mathrm{H}_2}\cdot \eta_F}{U_{\mathrm{cell}}\cdot z\cdot F}\cdot \eta_{\mathrm{Aux}},$ (14) where η_{cell} is substituted to a combination of Eq. (10) and (13).

RC	**4) Some of the abbreviations (like RV and MIL) are used before they are defined.**
AR	"RV" is now introduced, when its first mentioned on page 6, line 143. Besides the abstract, "MIL" is first mentioned in Section 1on page 4, line 102, where it is introduced. It was introduced twice (again on page 15, line 395). The latter introduction was deleted.
AC	
	Page 6, line 143: …and a reference value (RV) describing the average expected electricity price achieved over the lifetime of the WF. *Page 15, line 395:* This subsection introduces the ~~mixed-integer linear (~~MIL~~)~~ operation optimization…

RC	**5). Section 2.2.3: You mentioned the voltage level of 2.5 V at which the stack should be replaced. What is the nominal voltage of one cell at nominal current, nominal temperature, and at the beginning of life? The comparison of the start point and the end point would be helpful to understand this value. Also, the choice of this voltage level is not clear: "the maximum cell voltage of PEM electrolyzers ranges between 1.65 and 2.5 V at a nominal current density of 2 A cm^{-2}." - It ranges depending on what and how it justifies the choice of the replacement level of 2.5 V?**
AR	We agree that providing the initial cell voltage at the beginning of life (BOL) and clarifying the rationale behind the 2.5 V end-of-life (EOL) threshold significantly enhances the transparency of our model assumptions. Under nominal operating conditions, which include a current density of 2 A cm^{-2}, a cell temperature of 80 °C, an anode pressure of 1.013 bar, and a cathode pressure of 13.78 bar, the empirical polarization curve model yields an initial cell voltage of 1.93 V. This value corresponds to an initial stack efficiency of 64 %. The voltage range of 1.65 V to 2.5 V reported by Buttler and Spliethoff (2018) reflects the wide technological diversity of commercial stacks spanning an efficiency range between 50% and 76%. In our methodology, the 2.5 V level is implemented as a techno-economic upper limit for stack replacement because degradation-induced overvoltages, cause the cell voltage to rise. Reaching the threshold of 2.5 V corresponds to the minimum efficiency bound of 50% defined in the literature. To reflect these details, the text in Section 2.2.3 has been revised to clarify the comparison between the beginning-of-life and end-of-life states.
AC	Page 14, line 352
	According to Buttler und Spliethoff (2018) the ~~maximum~~ cell voltage of PEM electrolyzers typically ranges between 1.65 V and 2.5 V at a nominal current density of 2 A cm^{-2}, which directly maps to lower heating value efficiencies between 76 % and 50 %, respectively. In this study, the initial cell voltage at the beginning of life (BOL) is calculated via the polarization curve model (Sect. **Fehler! Verweisquelle konnte nicht gefunden werden.**) as $U_{cell}^{\mathrm{BOL}} = 1.93$ V, corresponding to $\eta_{\mathrm{cell}}^{\mathrm{BOL}} = 0.64$. Due to degradation-induced overvoltages, the required cell voltage to maintain nominal current increases over time. The stack replacement threshold is set to a maximum limit of 2.5 V, representing an end-of-life criterion where cell efficiency drops to the literature-reported minimum of 50%. ~~On this basis, a stack is required to be replaced before the maximum cell voltage of $U_{cell}^{max} = 2.5$ V is exceeded because of degradation-induced overvoltage.~~

RC	**7) Formatting errors: reference gives message "Fehler!" and reference to figure as "Fig. Figure 7".**
AR	The reference is now given correctly.
AC	Page 6, lines 162
	…, which ~~that~~ is further described in Sect. **Fehler! Verweisquelle konnte nicht gefunden werden.**.

RC	**8) Typos: "Eighter", "Bevor", "pocc", etc**
AR	The Typos "eighter" and "bevore" have been corrected now. "pocc" is an abbreviation for point of common coupling, that is introduced on page 6, line 141. We have changed the abbreviation to "POCC" so that it aligned with the rest of the text.
AC	
	Page 5, line 128: ~~Bevor~~ Before starting the design optimization *Page 2, line 63:* ... Schnuelle et al. (2020) and Fabianek and Madlener (2024) ~~eighter~~ evaluated given… *Page 6, line 141:* …which the electrolyzer can be placed, POCC ~~pocc~~ the point of common coupling… *Table 1:* Shapefiles and points determining sh_{El}, POCC~~pocc~~, p_{H2O},p_{POD}