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Guiding practical pathways for photo-electrochemical solar-hydrogen generation

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Context

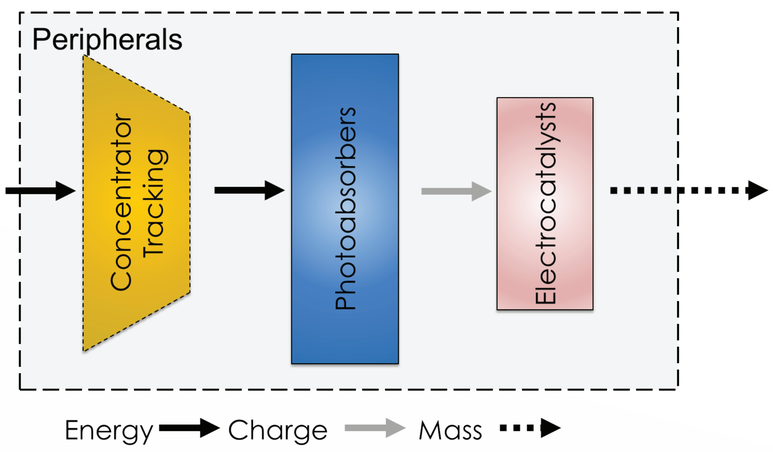
Photo-electrochemical water-splitting provides a pathway for direct solar fuel processing and has the potential to significantly contribute to a future, sustainable energy economy, if their technological implementation *simultaneously* meets four requirements:

1) High efficiency
2) Low cost
3) Stable long-term performance
4) Low environmental footprint

Objectives

- Provide holistic design guidance for integrated photo-electrochemical (integrated photovoltaics plus electrolyzers) devices showing best trade-off between efficiency, cost, lifetime and manufacturing energy input.
- Define material selection and design of best photo-electrochemical water-electrolysis devices.
- Evaluate the impact of component degradation and lifetime on the overall device performance.

System definition



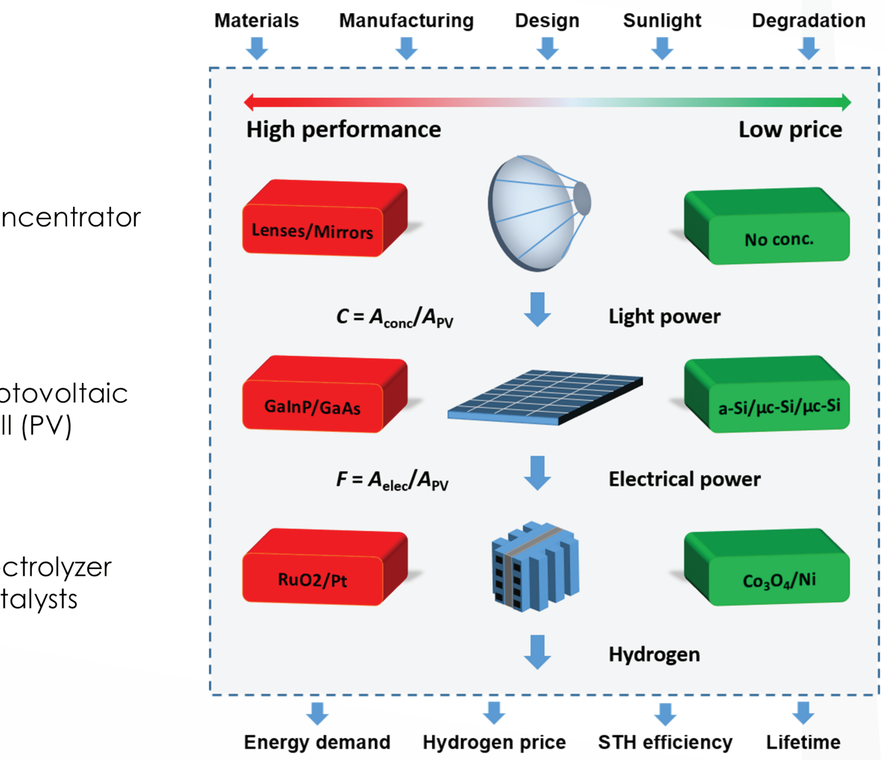
Irradiation concentration, *C*:
Ration between concentrator area and photoabsorber area

Current concentration, *F*:
Ration between electrocatalyst area and photoabsorber area

$F = A_{EC} / A_{PV}$

Devices studied (number code used):

		Varying *F*		*F* = 1	
Concentrator	**PV cell**	**RuO_2/Pt**	**Co_3O_4/Ni**	**RuO_2/Pt**	**Co_3O_4/Ni**
Yes (varying C)	**III-V**	**1**	**2**	**9**	**10**
	Silicon	**3**	**4**	**11**	**12**
No (C = 1)	**III-V**	**5**	**6**	**13**	**14**
	Silicon	**7**	**8**	**15**	**15**



Results

Optimum design (*C* and *F*)

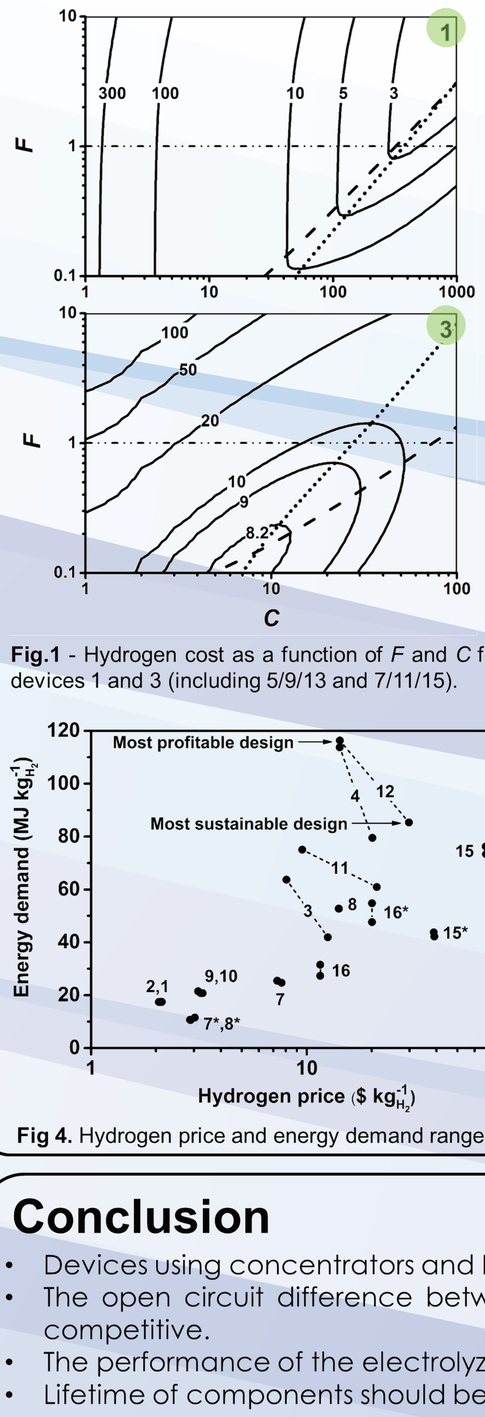


Fig.1 - Hydrogen cost as a function of *F* and *C* for devices 1 and 3 (including 5/9/13 and 7/11/15).

Effect of operating time on the outputs

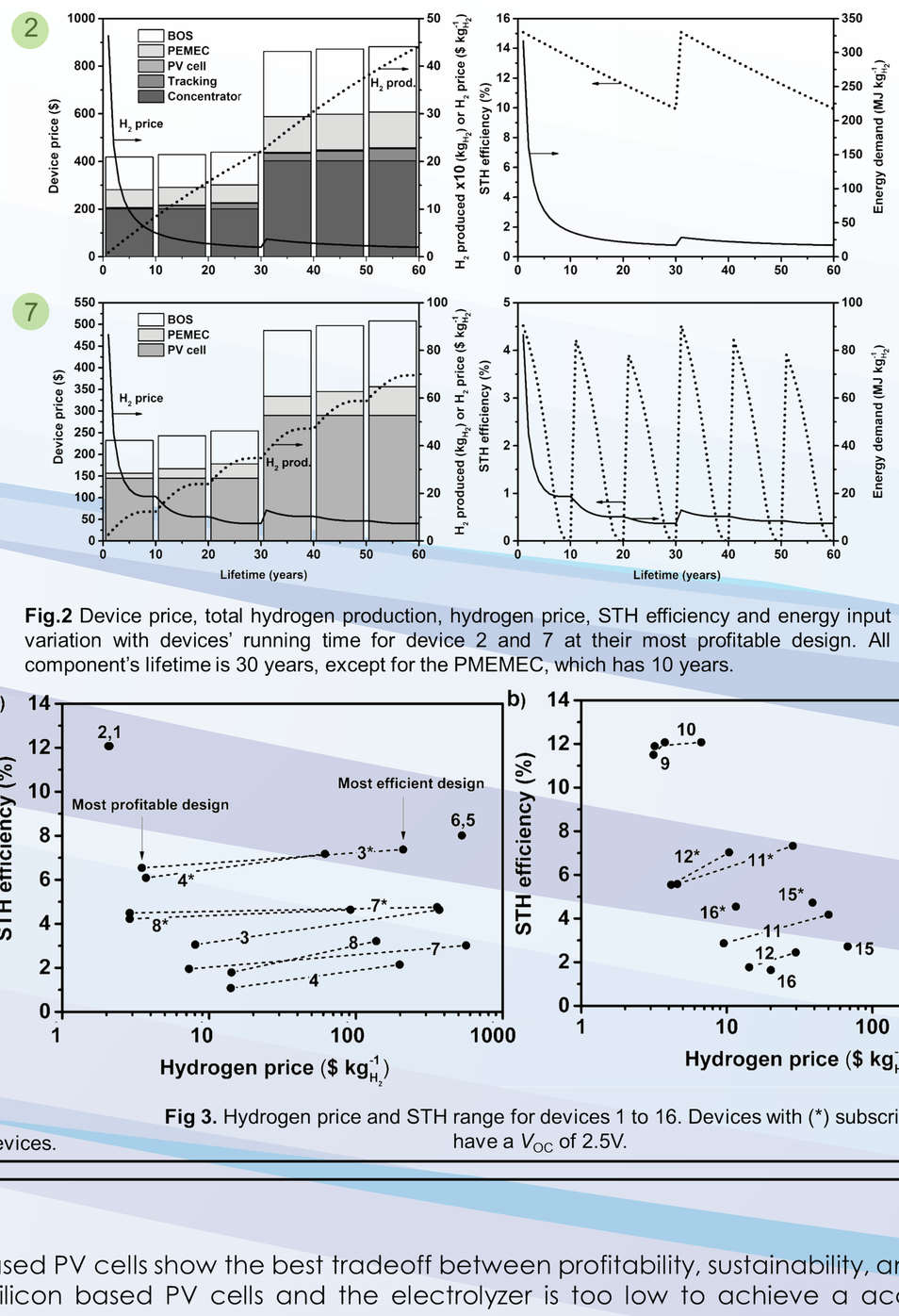


Fig.2 Device price, total hydrogen production, hydrogen price, STH efficiency and energy input variation with devices' running time for device 2 and 7 at their most profitable design. All component's lifetime is 30 years, except for the PMEMEC, which has 10 years.

Fig 3. Hydrogen price and STH range for devices 1 to 16. Devices with (*) subscript have a V_{OC} of 2.5V.

Fig 4. Hydrogen price and energy demand range for all devices.

Lifetime and degradation rates

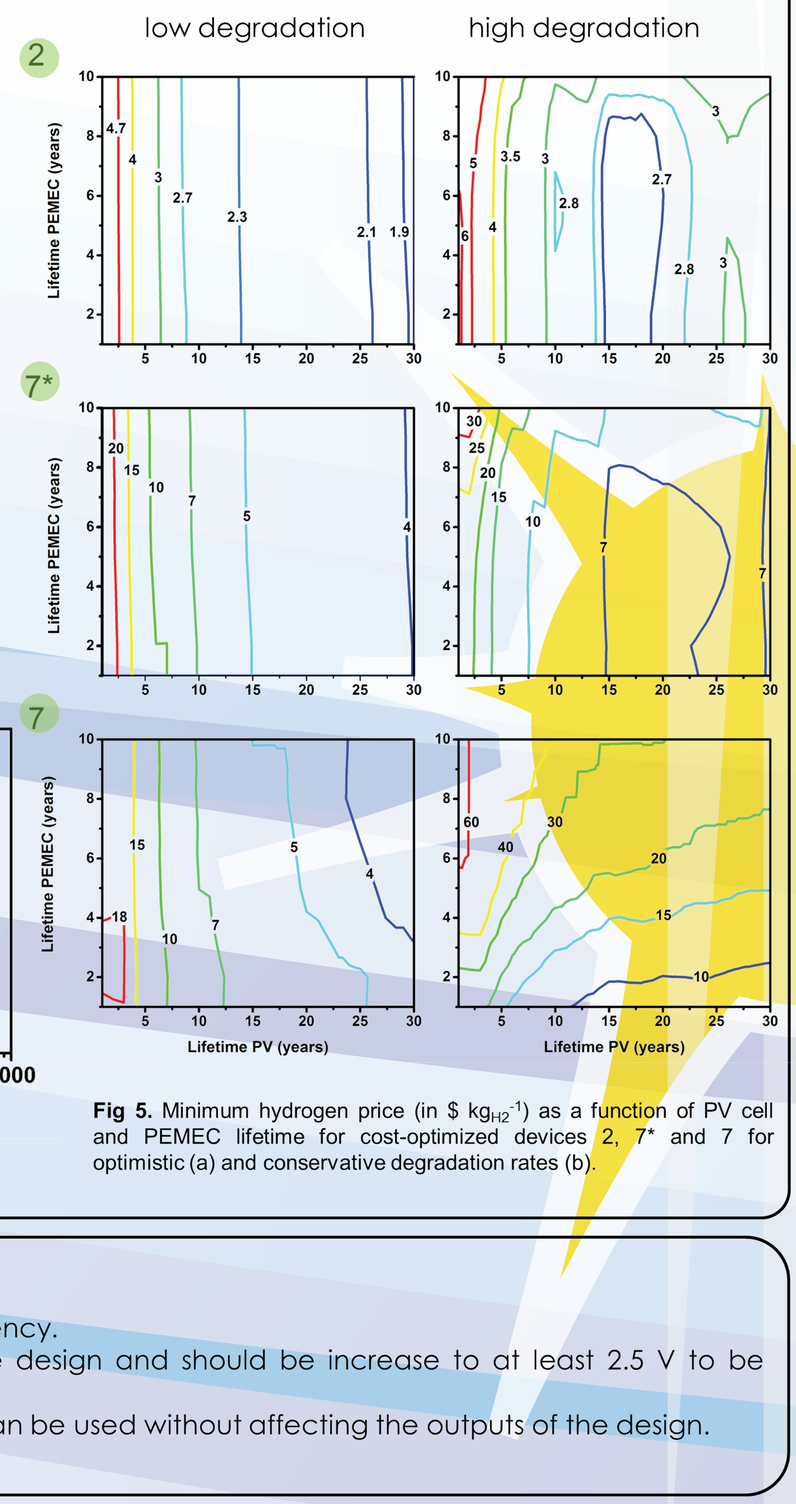


Fig 5. Minimum hydrogen price (in $ kg_{H2}^{-1}) as a function of PV cell and PEMEC lifetime for cost-optimized devices 2, 7* and 7 for optimistic (a) and conservative degradation rates (b).

Conclusion

- Devices using concentrators and III-V based PV cells show the best tradeoff between profitability, sustainability, and efficiency.
- The open circuit difference between silicon based PV cells and the electrolyzer is too low to achieve a acceptable design and should be increase to at least 2.5 V to be competitive.
- The performance of the electrolyzer prevails over its price and its energy requirements. Expensive and efficient catalysts can be used without affecting the outputs of the design.
- Lifetime of components should be calculated once the design and degradation rates are determined.

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