

Real-life tests to assess the device versatility and resilience

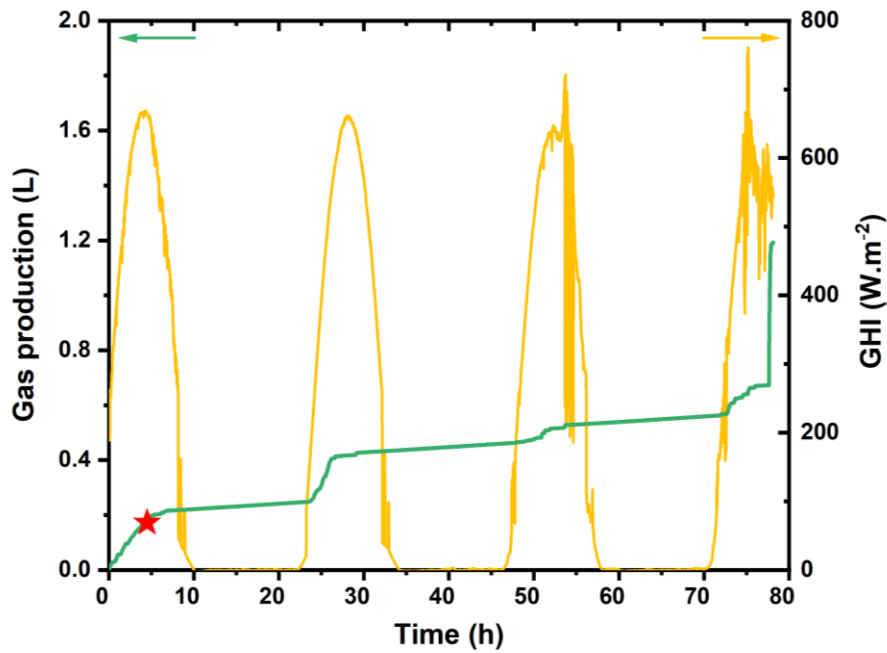


Figure S1. Outdoor test of EASI Fuel device in Grenoble (second campaign, in autumn), performance.

Cumulated volume of gas produced (in green), Global Horizontal Irradiance (GHI, in yellow). Red star : beginning of the solar production. The initial gas volume of 0.18 L, present within the reactor before this point, was omitted in the STF calculation.

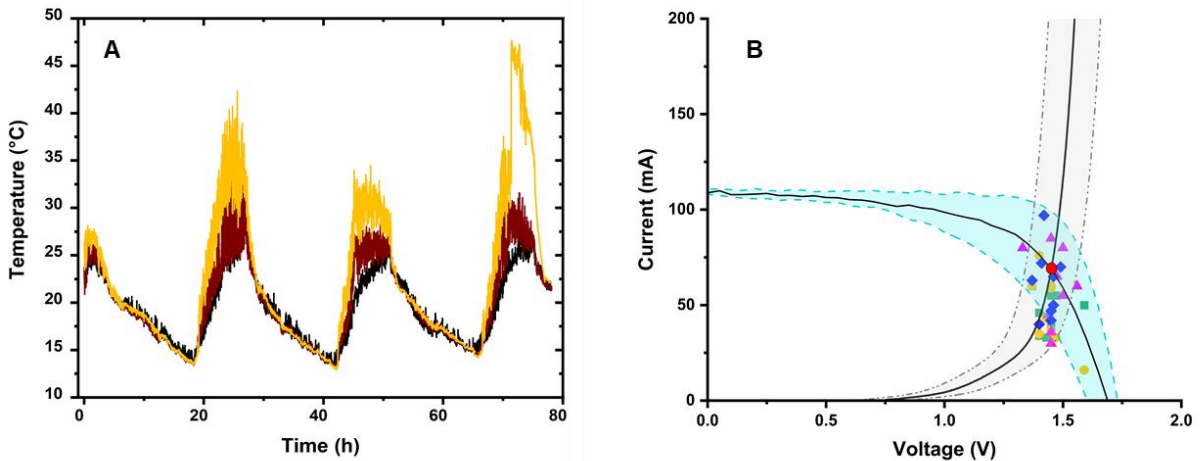


Figure S2. Outdoor test of EASI Fuel device in Grenoble (second campaign, in autumn), ageing.

(A) Temperature monitoring during the outdoor test of EASI Fuel device in Grenoble: measured ambient temperature close to the mixing plate (in black), measured ambient temperature close to the IPEC modules (in brown), measured temperature on the tandem solar cells (in yellow).

(B) Determination of operating point (red dot) of an IPEC cell at the intersection of the I-V curve of a tandem Si/PK solar cell, and the I-V curve of a PEM electrolyser (plain black trace). The cloud of filled colored symbols (■◆▼●) represents the experimental operating points of the 36 IPEC cells, measured before the 72 h outdoor test at CEA, in Grenoble, in October 2022. Each color corresponds to one of the 4 IPEC modules. The shaded blue and grey area represent the dispersion of I-V curves for solar and PEM cells, respectively.

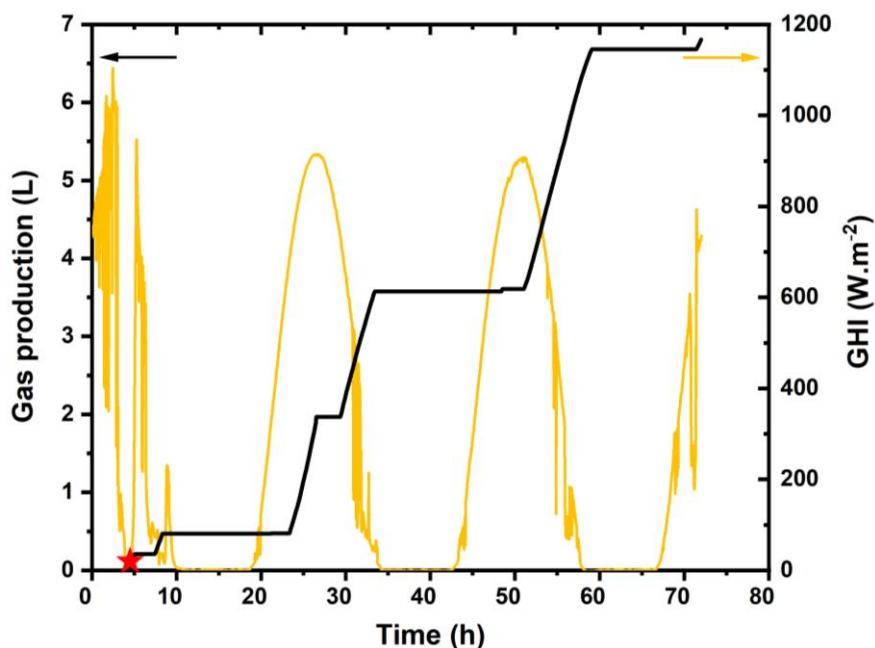


Figure S3. Outdoor test of EASI Fuel device in Ispra (first campaign, in summer), performance. Cumulated volume of solar H₂ produced (in black), Global Horizontal Irradiance (GHI, in yellow). Red star: beginning of the summer measurement campaign.

Solar cells degradation:

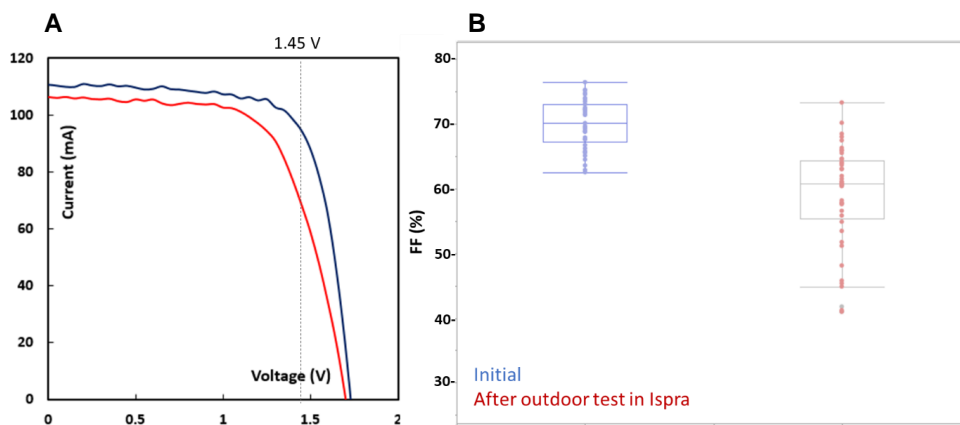


Figure S4. Loss of fill factor (FF) following the outdoor test of EASI Fuel device in Ispra (first campaign, in summer).

Typical evolution of I-V curves of a tandem Si/PK solar cell before / after outdoor test in Ispra, and statistics on fill factor for the whole dataset. To perform these measurements, the solar cells were decoupled from the electrolyzers.

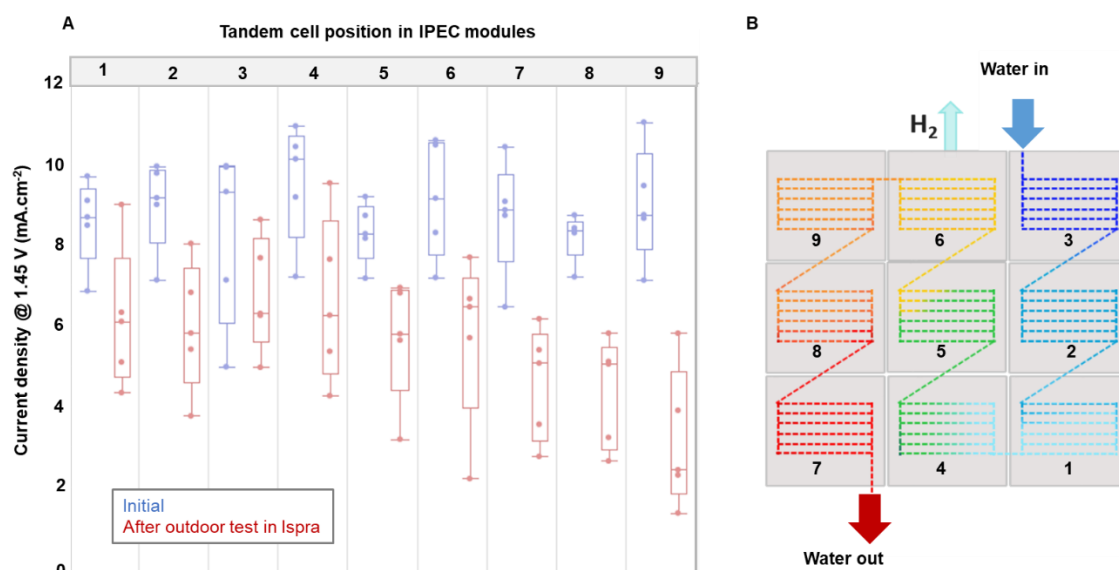


Figure S5. Solar cells position and ageing during the outdoor test of EASI Fuel device in Ispra (first campaign, in summer).

(A) Evolution of current density produced by the tandem Si/PK solar cells under 1 sun at 1.45 V (close to operating point) before (in blue) and after (in red) outdoor test in Ispra. To perform these measurements, the solar cells were decoupled from the electrolyzers. Data from the 45 Si/PK tandem solar cells are represented as a function of their location within the IPEC modules, shown in (B).

Table S1. Correlation between cell position and the delivered current density.

Average current density produced by the tandem Si/PK solar cells at 1.45 V and under 1 sun before / after the outdoor test in Ispra, as a function of the location of the solar cells within the IPEC modules (see Fig. S5). To perform these measurements, the solar cells were decoupled from the electrolyzers.

Position	1	2	3	4	5	6	7	8	9
Initial (mA.cm ⁻²)	8.55	8.98	8.24	9.56	8.29	9.12	8.69	8.18	8.98
After (mA.cm ⁻²)	6.16	5.96	6.75	6.60	5.67	5.74	4.59	4.37	3.16
Loss (%)	28	34	18	31	32	37	47	47	65

Additional details on the EASI Fuel device

Table S2. Nomenclature of the EASI Fuel device PID (used in Figure 4)

TAG	Equipment	Supplier - Ref
R111	Demineralized water supply tank	SECTORIEL - 425020006INX
R163	Demineralized water drainage tank	DENIOS - 266183W
VM112	Low drain valve for R111	HAM-LET - H800SSSL6MM
VM113	Electrolyser supply valve from R111	HAM-LET - H800SSSL6MM
VM114	Recirculation valve for R111	HAM-LET - H800SSSL6MM
VM115	Electrolysis water return valve in R111	HAM-LET - H800SSSL6MM
LIA116	Visual level for R111	RS PRO - 174-8427
FI117	Float flowmeter	KOBOLD - KSK-1015H P08 S0
FA118	Low flow sensor	KOBOLD - KSK-1015H P08 S0
VA119	Solenoid valve for water filling R111	BURKERT - TYPE 6281

VM116	Electrolyser bypass valve	HAM-LET - H300USSLV6MMRS
VM122	Low drain valve for R163	DENIOS - 266183W
VM125	Electrolysis water return valve in R163	HAL-LET - H800SSSL6MM
P130	Water supply pump for R111 tank	W ROBINSON AND SONS - 022-422
P131	Electrolyser water supply pump	SCHWARZER PRECISION - SP 622 EC-BL
VM141	Water inlet valve - electrolyser n°1	HAM-LET - H800SSSL6MM
VM142	Water inlet valve - electrolyser n°2	HAM-LET - H800SSSL6MM
VM143	Water inlet valve - electrolyser n°3	HAM-LET - H800SSSL6MM
VM144	Water inlet valve - electrolyser n°4	HAM-LET - H800SSSL6MM
VM145	Water inlet valve - electrolyser n°5	HAM-LET - H800SSSL6MM
VM151	Water outlet valve - electrolyser n°1	HAM-LET - H800SSSL6MM
VM152	Water outlet valve - electrolyser n°2	HAM-LET - H800SSSL6MM
VM153	Water outlet valve - electrolyser n°3	HAM-LET - H800SSSL6MM
VM154	Water outlet valve - electrolyser n°4	HAM-LET - H800SSSL6MM
VM155	Water outlet valve - electrolyser n°5	HAM-LET - H800SSSL6MM
TIR161	Electrolyser inlet water temperature	RS PRO - 397-1264
TIR162	Electrolyser inlet water temperature	RS PRO - 397-1264
K211	Electrolyser n°1	NON-COMMERCIAL EQUIPEMENT
K212	Electrolyser n°2	NON-COMMERCIAL EQUIPEMENT
K213	Electrolyser n°3	NON-COMMERCIAL EQUIPEMENT
K214	Electrolyser n°4	NON-COMMERCIAL EQUIPEMENT
K215	Electrolyser n°5	NON-COMMERCIAL EQUIPEMENT
VM221	Gas outlet valve - electrolyser n°1	HAM-LET - H800SSSL1/8
VM222	Gas outlet valve - electrolyser n°2	HAM-LET - H800SSSL1/8
VM223	Gas outlet valve - electrolyser n°3	HAM-LET - H800SSSL1/8
VM224	Gas outlet valve - electrolyser n°4	HAM-LET - H800SSSL1/8
VM225	Gas outlet valve - electrolyser n°5	HAM-LET - H800SSSL1/8
VM321	Inert gas inlet valve - electrolyser n°1	HAM-LET - H800SSSL1/8
VM322	Inert gas inlet valve - electrolyser n°2	HAM-LET - H800SSSL1/8
VM323	Inert gas inlet valve - electrolyser n°3	HAM-LET - H800SSSL1/8
VM324	Inert gas inlet valve - electrolyser n°4	HAM-LET - H800SSSL1/8
VM325	Inert gas inlet valve - electrolyser n°5	HAM-LET - H800SSSL1/8
AIC331	Oxygen composition analyzer	PANAMETRICS - OXY. IQ
VA332	Automatic drain valve (NF)	BURKERT - TYPE 0330
VA333	Inert gas supply valve (NO)	BURKERT - TYPE 0330
VM334	Inert gas pressure regulator	AIR LIQUIDE - REF 15658
VM335	3-way valve inlet O ₂ , H ₂ O filter	HAM-LET - H800SSSL1/8T
VM337	3-way valve outlet Filter O ₂ , H ₂ O	HAM-LET - H800SSSL1/8T
VM338	Inert gas isolation valve	HAM-LET - H800SSSL6MM
VM340	By-pass valve VA333	HAM-LET - H800SSSL6MM
FL411	H ₂ O / O ₂ filter	CRS - 202295-SS
FL412	H ₂ O / O ₂ filter	CRS - 202295-SS
FL413	H ₂ O / O ₂ filter	CRS - 202295-SS
FRC421	H ₂ flowmeter	BROOKS - SLA5850S
FIR422	CO ₂ flowmeter	BROOKS - SLA5850S
Y%423	H ₂ /CO ₂ proportional calculator	NON-COMMERCIAL EQUIPEMENT
VM341	By-pass valve Electrolyser	HAL-LET - H800SSSL6MM
VM424	Manual CO ₂ isolation valve	HAL-LET - H800SSSL6MM
VA431	H ₂ flow control valve	BROOKS - SLA5850S
VA432	CO ₂ flow control valve	BROOKS - SLA5850S
VA433	3-way H ₂ supply valve (NC)	BURKERT - TYPE 0330
PRC434	H ₂ overpressure control pressure switch	KELLER - SERIE 23
P441	H ₂ booster pump	SCHWARZER PRECISION - SP 622 EC-BL-DU
M451	Static mixer	COLE-PARMER - KOFLO 1/4-21 316 SS TUBE MIXER
FRC452	H ₂ + CO ₂ flowmeter	BROOKS - SLA5850S

VA453	H ₂ + CO ₂ flow control valve	BROOKS - SLA5850S
VS461	Gas check valve	H400ASSL6MM3PSI
VM471	H ₂ / CO ₂ gas supply manual drain valve	HAM-LET - H800SSSL6MMT
K511	Bioreactor	NON-COMMERCIAL EQUIPEMENT
TIR521	Bioreactor temperature measurement	METTLER-TOLEDO - INPRO3253i/SG/120
AIR522	pH and ORP measurement	METTLER-TOLEDO - INPRO3253i/SG/120
PRC523	Pressure measurement	KELLER - SERIE 23
VS531	Safety valve	HAM-LET - H900SSL6MMSL
VM541	Double jacket isolation valve	HAM-LET - H700SSL6MMTLD
VM542	Double jacket isolation valve	HAM-LET - H700SSL6MMTLD
VM543	Isolation valve in Gas/Liquide separator	HAM-LET - H800SSSL6MM
VM544	Isolation valve in Gas/Liquide separator	HAM-LET - H800SSSL6MM
VM545	K511 production output isolation valve	HAM-LET - H800SSSL6MM
VM546	Isolation valve recirculation gas	HAM-LET - H800SSSL6MM
FL551	Gas/Liquide separator	NON-COMMERCIAL EQUIPEMENT
E561	Gas condenser	NON-COMMERCIAL EQUIPEMENT
VM562	Water isolation valve condenser	HAM-LET - H700SSL6MMTLD
VM563	Water isolation valve condenser	HAM-LET - H700SSL6MMTLD
P571	Gas recirculation pump	SCHWARZER PRECISION - SP 622 EC- BL-DU
E572	K511 thermoregulator	NON-COMMERCIAL EQUIPEMENT
VS611	Gas check valve	HAM-LET - H400SSL6MM1/3PSI
VA621	Pressure control valves in K511	BROOKS - SLA5820S
VM631	R641 product gas isolation valve	HAM-LET - H800SSSL6MM
VM632	R641 inerting gas isolation valve	HAM-LET - H800SSSL6MM
VM633	Tank drain valve R641	HAM-LET - H800SSSL6MM
VS634	Safety valve	HAM-LET - H900SSL6MMSL
VM635	3-way valve inlet H ₂ O filter	HAM-LET - H800SSSL1/8T
VM637	3-way valve outlet H ₂ O filter	HAM-LET - H800SSSL1/8T
VM638	Gas circuit purge valve	HAM-LET - H800SSSL6MM
R641	CH ₄ storage tank	MUSTHANE - CUSTOMISED EQUIPMENT
FIR651	Production gas flowmeter	BRONKHORST - EL-FLOW F-201CV
AIR652	CH ₄ analyzer	SMARTGAS - F3-043108-05000
AIR653	CO ₂ analyzer	SMARTGAS - F3-214507-05000
FL661	Moisture filter	CRS - 202230-SS
FL662	Moisture filter	CRS - 202230-SS
VM670	Pressure regulator for industrial H ₂ / CO ₂ gases	AIR LIQUIDE - REF 15658
VM671	K511 H ₂ / CO ₂ industrial gas supply valve	HAM-LET - H800SSSL6MM
VA673	Flow control valve industrial H ₂ / CO ₂ gases	BRONKHORST - EL-FLOW F-201CV
FIR673	Mixing flow sensor for industrial gases H ₂ / CO ₂	BRONKHORST - EL-FLOW F-201CV
VM674	H ₂ /CO ₂ industrial gas bypass valve	HAM-LET - H800SSSL6MM

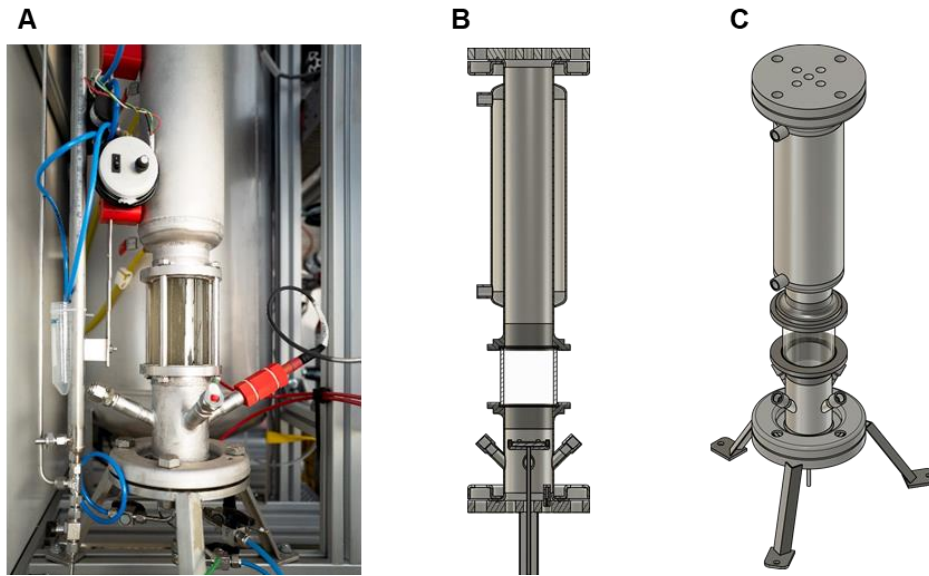


Figure S6. Views of the bioreactor.

- (A) Actual view
- (B) CAD sectional view
- (C) CAD isometric view.

Irradiance monitoring

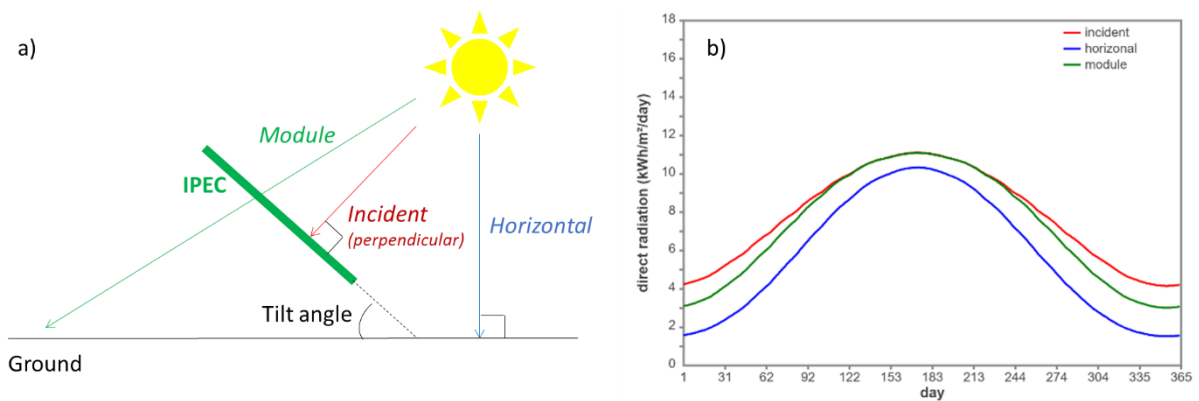


Figure S7. Influence of the reference surface on the incident power density measurement (adapted from C.B.Honsberg and S.G.Bowden, “Solar Radiation on a Tilted Surface” page on www.pveducation.org). Note that transposition from Global Horizontal Irradiance (GHI) to Global Normal Irradiance (GNI) or Direct Normal Irradiance (DNI) relies on complex mathematical models, that have to take into account scattering and albedo.