# Enhancing off-grid energy security trough reversible solid oxide cell systems economic analyses of case studies and business models

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30.11.2024

Co-funded by the European Union

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24_7 ZEN is supported by the Clean Hydrogen Partnership and its members Hydrogen Europe and Hydrogen Europe Research under grant agreement No 101101418.
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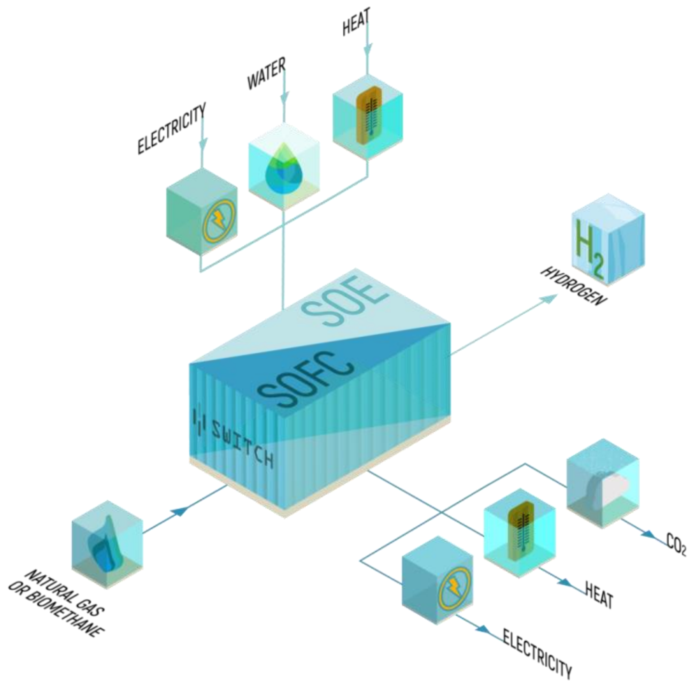
# Key advantages of RSOCs

- ✓ Dual functionality: Electrolysis (hydrogen production) + Fuel cell (electricity generation).
- ✓ Support renewable energy integration and decarbonization.
- ✓ Address challenges of off-grid reliability and cost efficiency
- ✓ Sustainability by producing mostly green H2 in a flexible and reversible way
- ✓ Security of H2 supply




(Switch-FCH, 2023)

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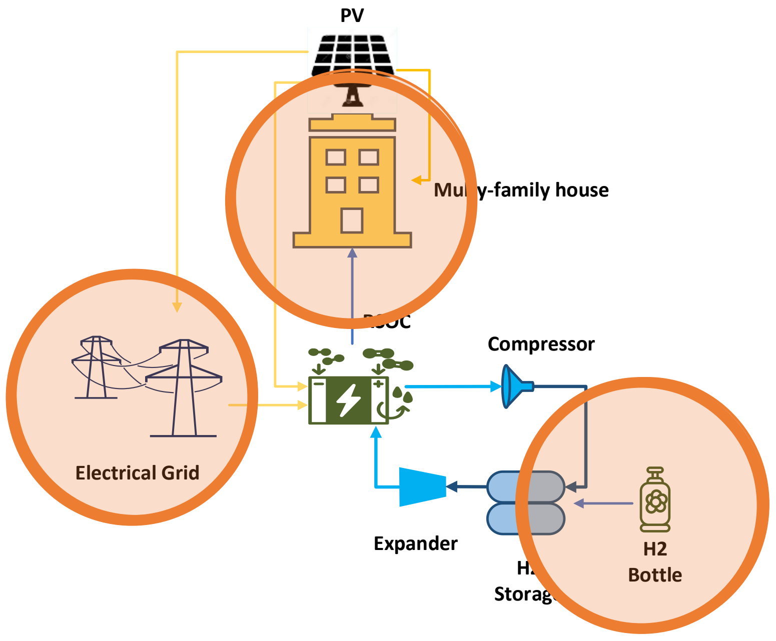
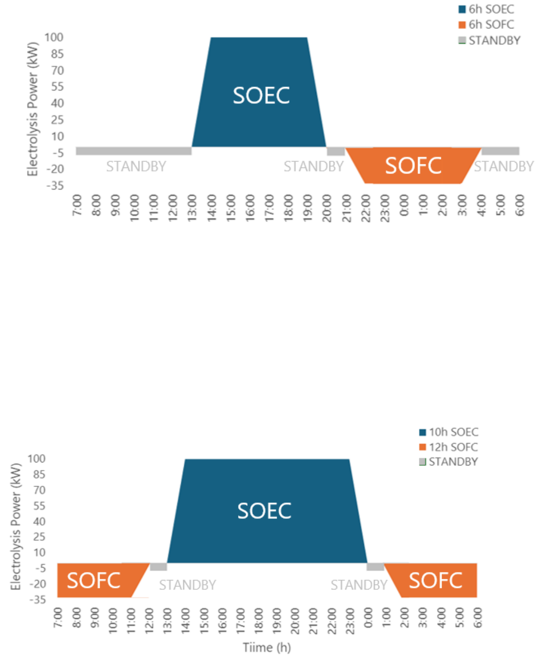
# Methodology

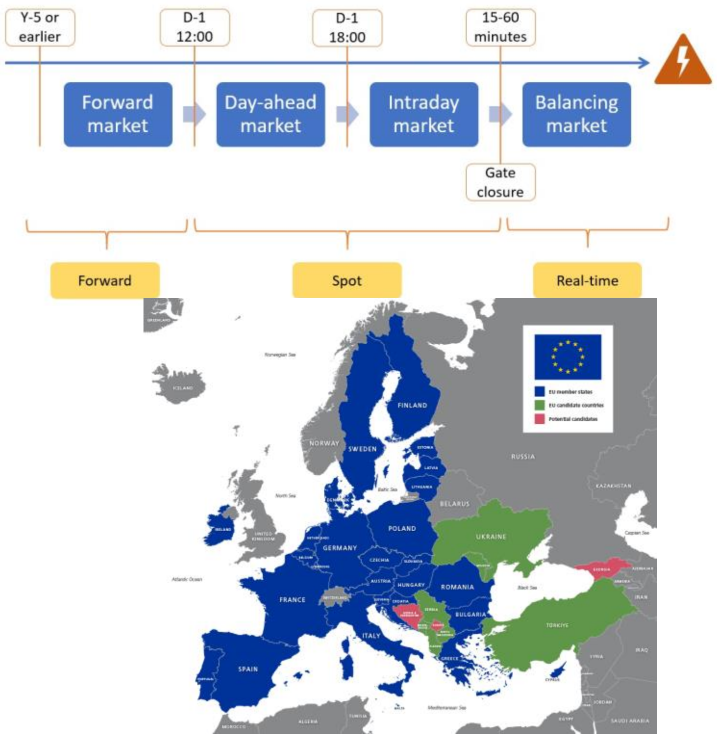
### Different constellations




### Different operational modes




### Different markets (where connected)

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# Detailed Energy Systems Requirements Definition

- ✓ The primary goal is to **evaluate various configurations** and determine the system's feasibility parameters.
- ✓ The scenarios serve as a **tool for decision-making**.
- ✓ Key criteria for the analysis **CAPEX, OPEX**, **operational schedule**/capacity factor, **levelized cost of hydrogen (LCOH)** and economic factors such as **subsidies** and **tariffs**.
- ✓ The aim is to identify the **configuration** that optimally balances technical efficiency with economic feasibility, considering also the factors associated with the **installation location**.

| Parameter | Value |
|---|---|
| CAPEX (€/KW) | 3500 |
| OPEX (€) | 2.0% of CAPEX per year + cost of energy |
| SOEC efficiency (%) | 80 |
| Discount rate (%) | 2.5 |
| Lifetime period (y) | 20 |

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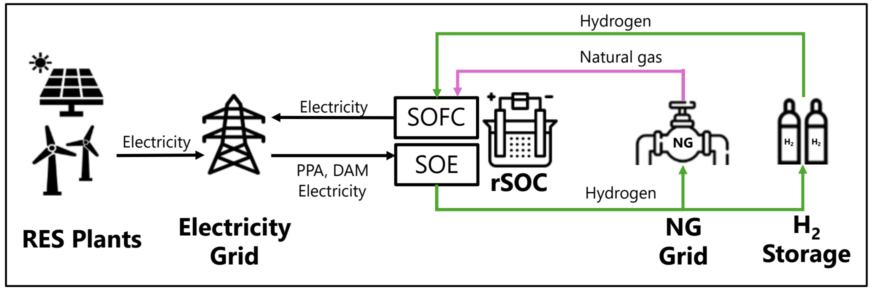
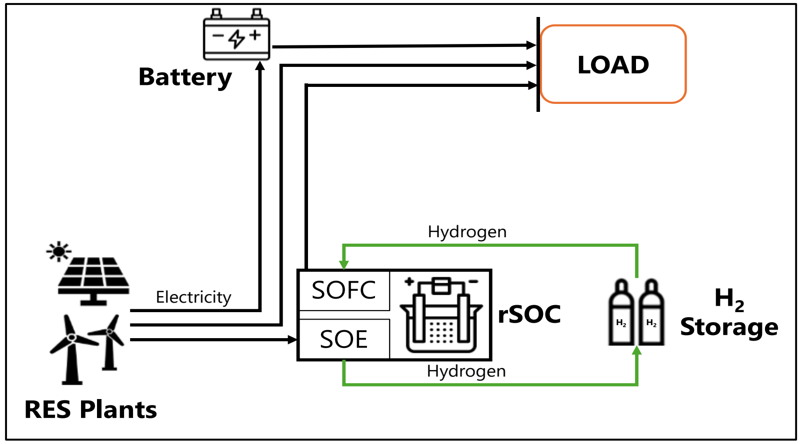
# Scenario topologies:
# General rSOC On-grid / Off-grid Integration




**ON-GRID**

- ✓ Inputs and outputs of rSOC for both SOE and SOFC.
- ✓ SOEC required energy consumed from the grid. (PPA, DAM).

**OFF-GRID**

- ✓ Micro-grid configuration
- ✓ Demonstrate technical feasibility of rSOC implemented in an off-grid case.
- ✓ Goal is to achieve complete autonomy (minimize external power sources like diesel).

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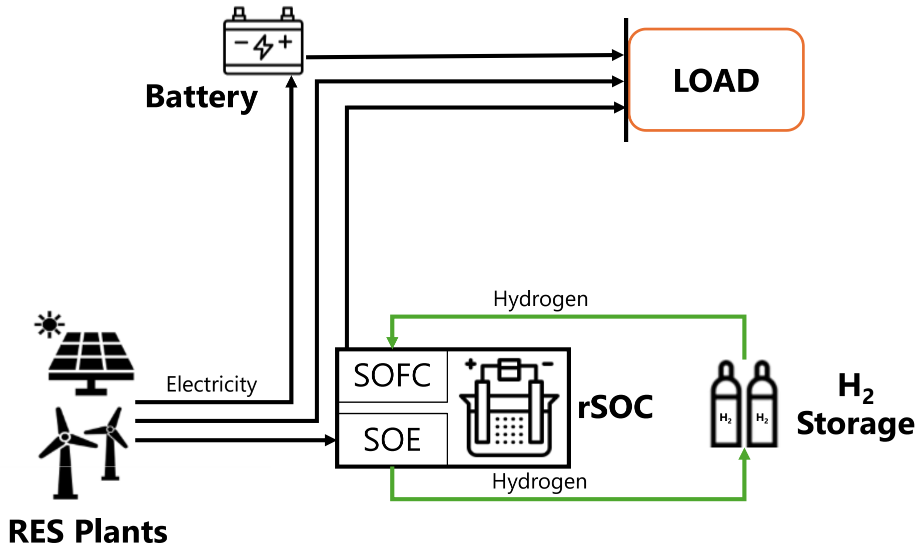
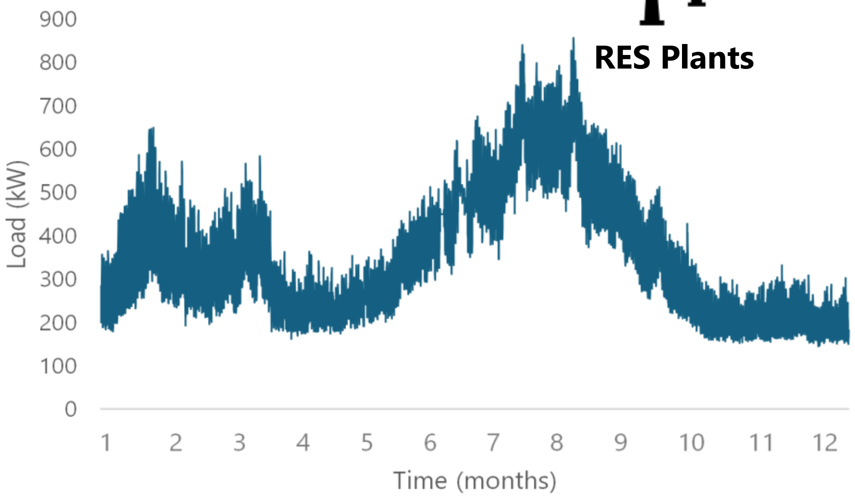
# Off-grid integration of rSOC on an island

- ✓ Micro-grid configuration (non-interconnected)
- ✓ Demonstrate technical feasibility of rSOC implemented in an off-grid case.
- ✓ Goal is to achieve complete autonomy (minimize external power sources like diesel).
- ✓ Data for RES and Load (2022).
  - ✓ 3050 MWh annual load
  - ✓ ~800 kW peak load
  - ✓ 4905 MWh annual RES production



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# Results Off-grid integration of rSOC on an island

- ✓ Energy Management Strategy (EMS)
- ✓ Assessment of performance with Key Performance Indicators

| Component | | Capacity | | | |
|---|---|---|---|---|---|
| | | Case 1 | Case 2 | Case 3 | Case 4 |
| RES | PV (MW) | 2 MW | | | |
| | Wind | 1 MW | | | |
| rSOC | SOEC | 2 MW | | | |
| | SOFC | 0.66 MW | | | |
| Battery (MWh) | | 2.5 | 2.5 | 2.5 | 5 |
| $H_2$ storage (MWh) | | 15 | 25 | 50 | 50 |

| KPI | Value (%) | | | |
|---|---|---|---|---|
| | Case 1 | Case 2 | Case 3 | Case 4 |
| Surplus to battery | 15.8 | 15.8 | 15.8 | 29.4 |
| Surplus to hydrogen | 33.4 | 36.5 | 39.5 | 26.4 |
| Surplus to curtailment | 49.4 | 47.7 | 44.7 | 44.2 |
| Load satisfied by FC | 10.7 | 11.7 | 12.6 | 7.2 |
| Load satisfied by DSG | **6.0** | **5.0** | **4.1** | **3.7** |
| Load satisfied by BAT | 15.3 | 15.3 | 15.3 | 21.1 |
| Load satisfied by RES | 68.0 | 68.0 | 68.0 | 68.0 |

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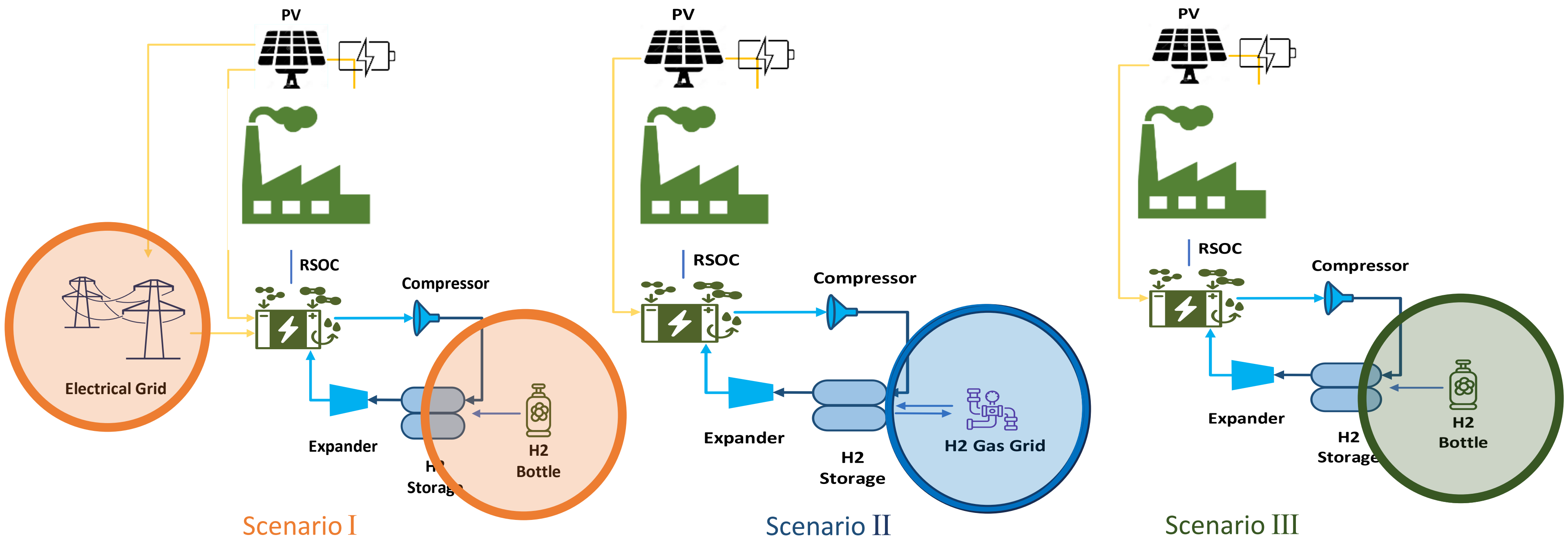
# Scenario topologies: Industrial case study
# rSOC On-grid / Off-grid Integration

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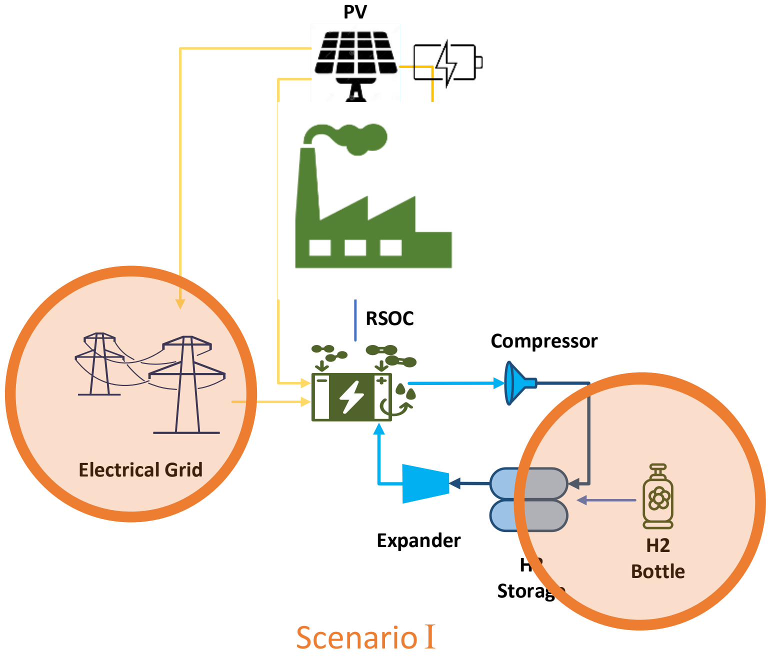
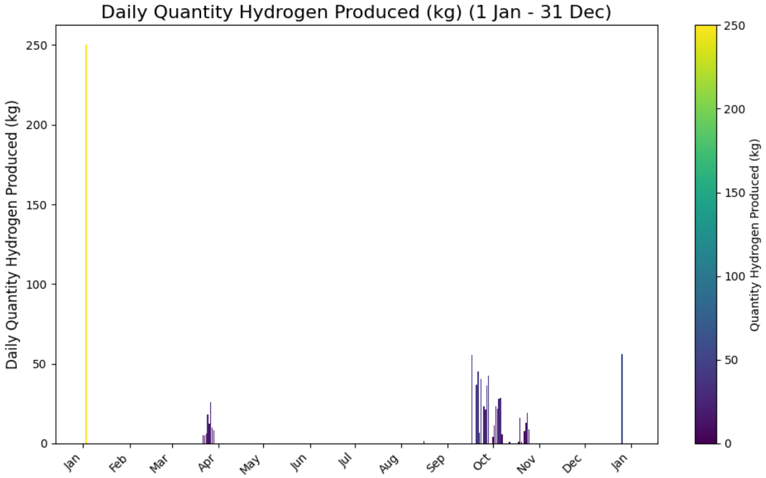
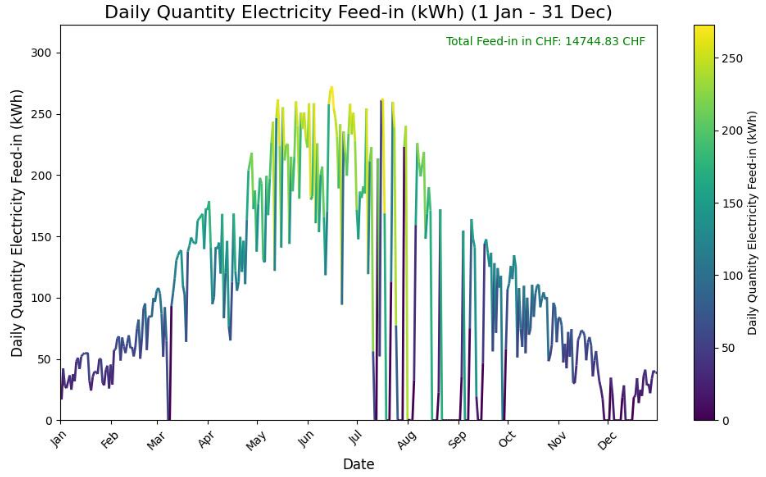
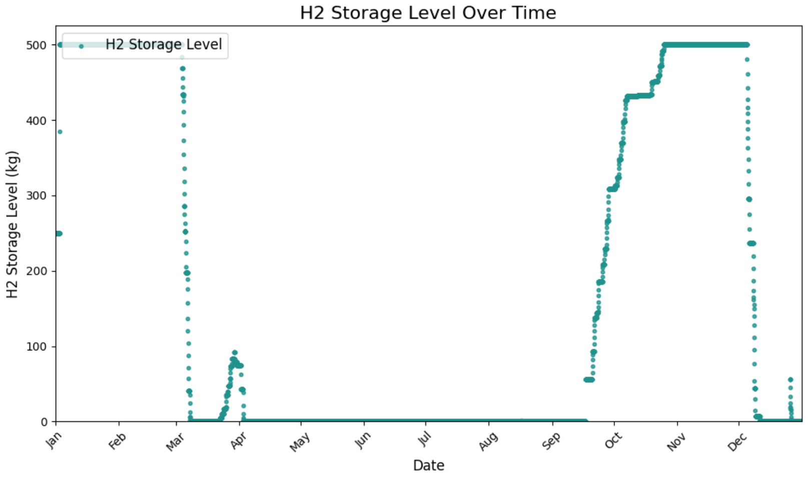
# Results – Industrial case study

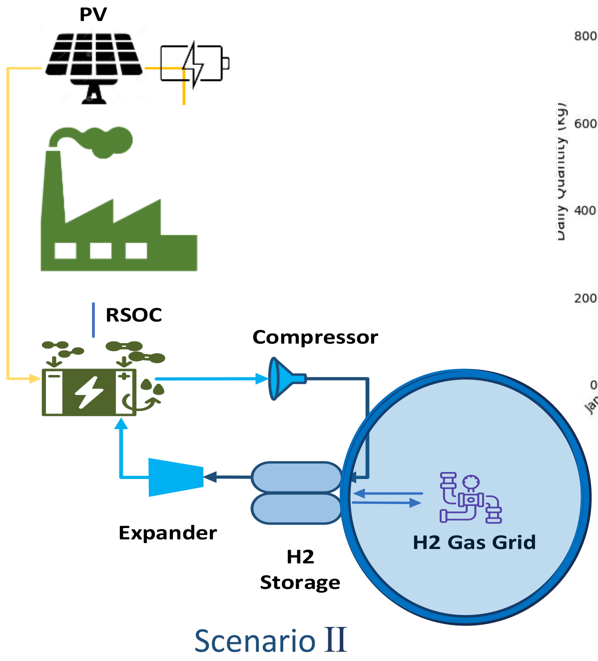


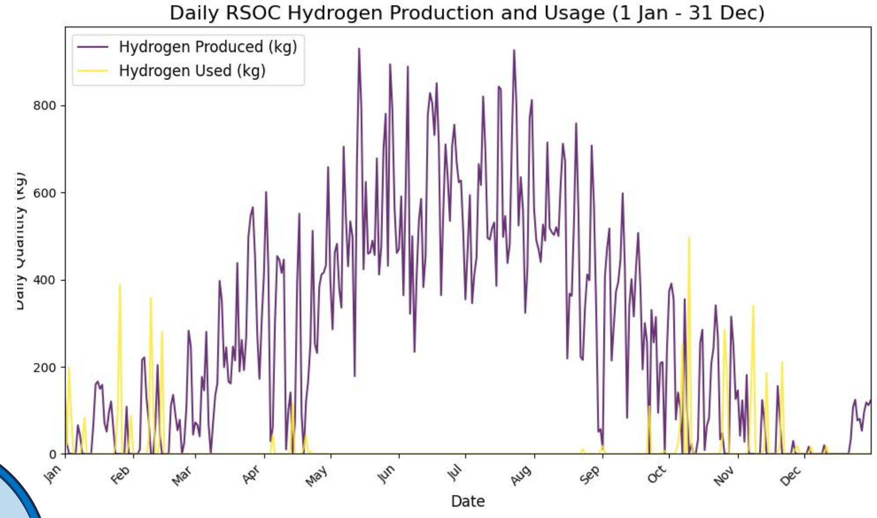



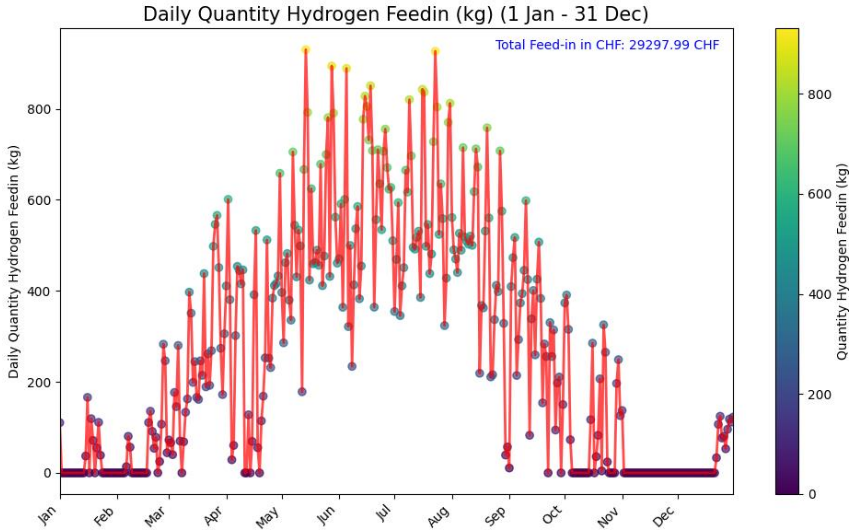



# Results – Industrial case study

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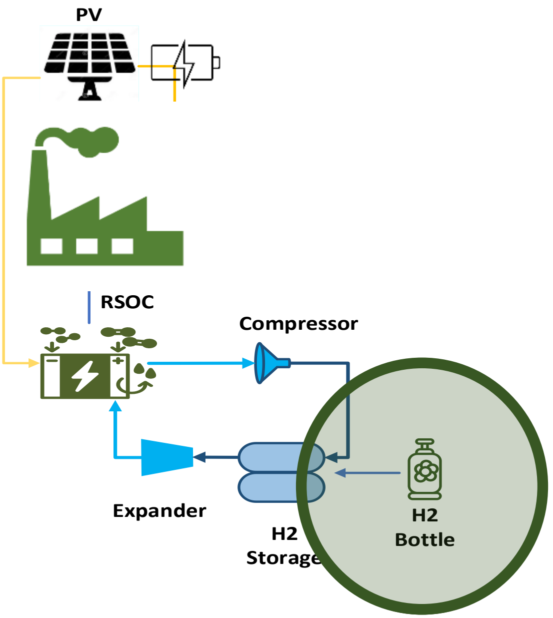
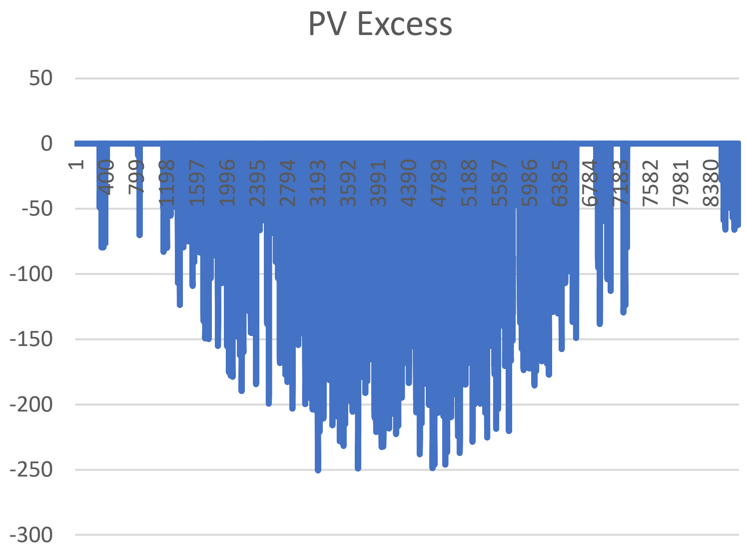
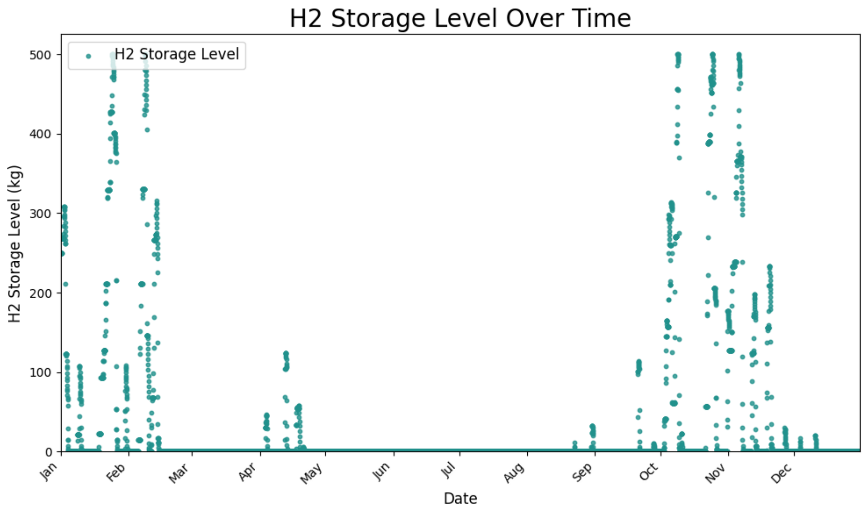
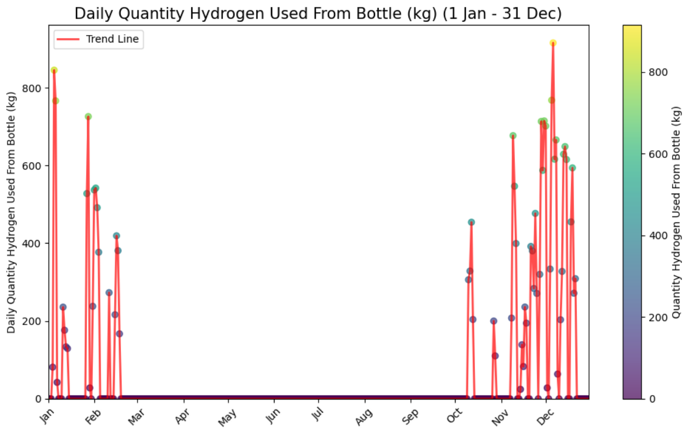
# Results – Industrial case study




Scenario III




- ✓ Hydrogen storage level must be 15 t in order to be fully self- sufficient (30x the current storage)

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# Results – Comparison Utilisation Hours

| Percentage of utilisation hours per year | Elec grid Industry | Gas grid Industry | Island grid Industry |
|---|---|---|---|
| Fuel Cell | 0% | 3% | 3% |
| Electrolyser | 3% | 29% | 11% |
| Battery Charge | 6% | 20% | 20% |
| Battery Discharge | 31% | 45% | 45% |
| Backup | 0% | 0% | 7% |
| Energy from Grid | 61% | 7% | 0% |
| Energy  to Grid | 54% | 26% | 0% |

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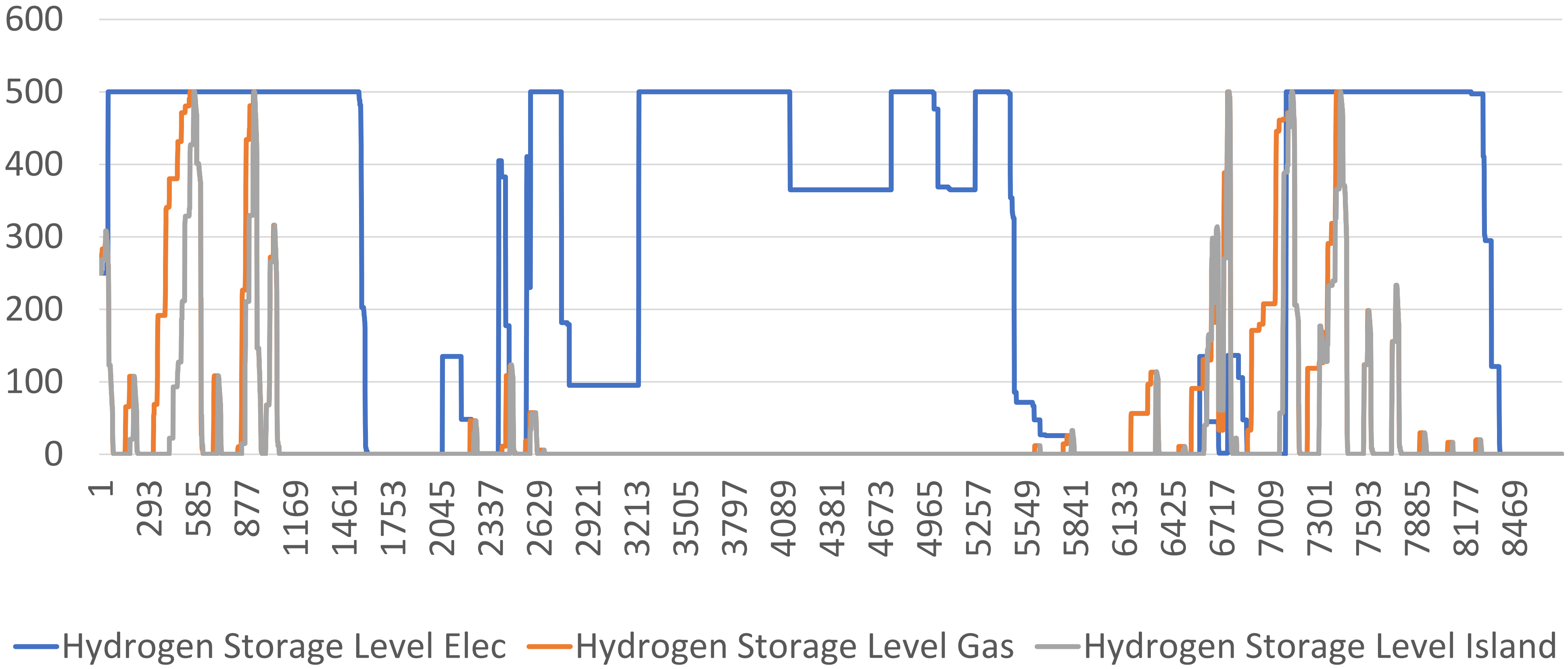
# Results – Comparison Hydrogen Storage Level

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# Business models to enhance Off-Grid Energy Security

| Business Case | Description | Economic Benefits | Business Models |
|---|---|---|---|
| **1. Remote Industrial Operations** | Powering mining, oil & gas, and other remote sites with renewable energy and local hydrogen production. | - OPEX savings (diesel logistics). | - Energy-as-a-Service<br>- Hydrogen hub for nearby industries. |
| **2. Disaster-Resilient Microgrids** | Reliable energy for vulnerable/off-grid communities using solar/wind with hydrogen storage for outages. | - Reduced downtime costs.<br>- Carbon offset revenue. | - Public-private partnerships.<br>- Community cooperatives. |
| **3. Renewable Hydrogen for Industry** | Producing green hydrogen onsite for industrial processes like ammonia synthesis and steelmaking. | - Green product premium.<br>- Cost-competitive with grey $H_2$. | - Hydrogen-as-a-Service.<br>- Carbon credit monetization. |
| **4. Maritime & Island Energy** | Transitioning islands and maritime vessels from diesel power to renewable energy with r-SOC systems. | - Fuel import cost savings.<br>- Lower emissions. | - Hybrid power provider. |
| **5. Industrial Grid Stabilization** | Storing surplus energy for peak shaving and backup power, ensuring grid stability for energy-intensive industries. | - Avoided peak demand charges.<br>- Demand response revenue. | - Energy arbitrage.<br>- Integrated energy solutions. |

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# Conclusion

- ✓ Explored **integration configurations** for the hybrid rSOC system.
- ✓ Identified the operation profiles.
- ✓ Examined key factors in the scenarios, like **deployment scale** and **country-specific regulations**.
- ✓ Examined the techno-economic feasibility or rSOC's integration to the grids.
- ✓ Investigated case studies on off-grid scenarios for rSOC's
- ✓ rSOC is a compact solution with a single CAPEX investment: a single conversion unit operating on an integrated multisource mode.

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# Future research

- ✓ Analyse further industrial configurations
- ✓ Optimal sizing of system components in various scenarios
- ✓ In-depth analysis of relevant business models for reversible fuel cells

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# Thank you


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