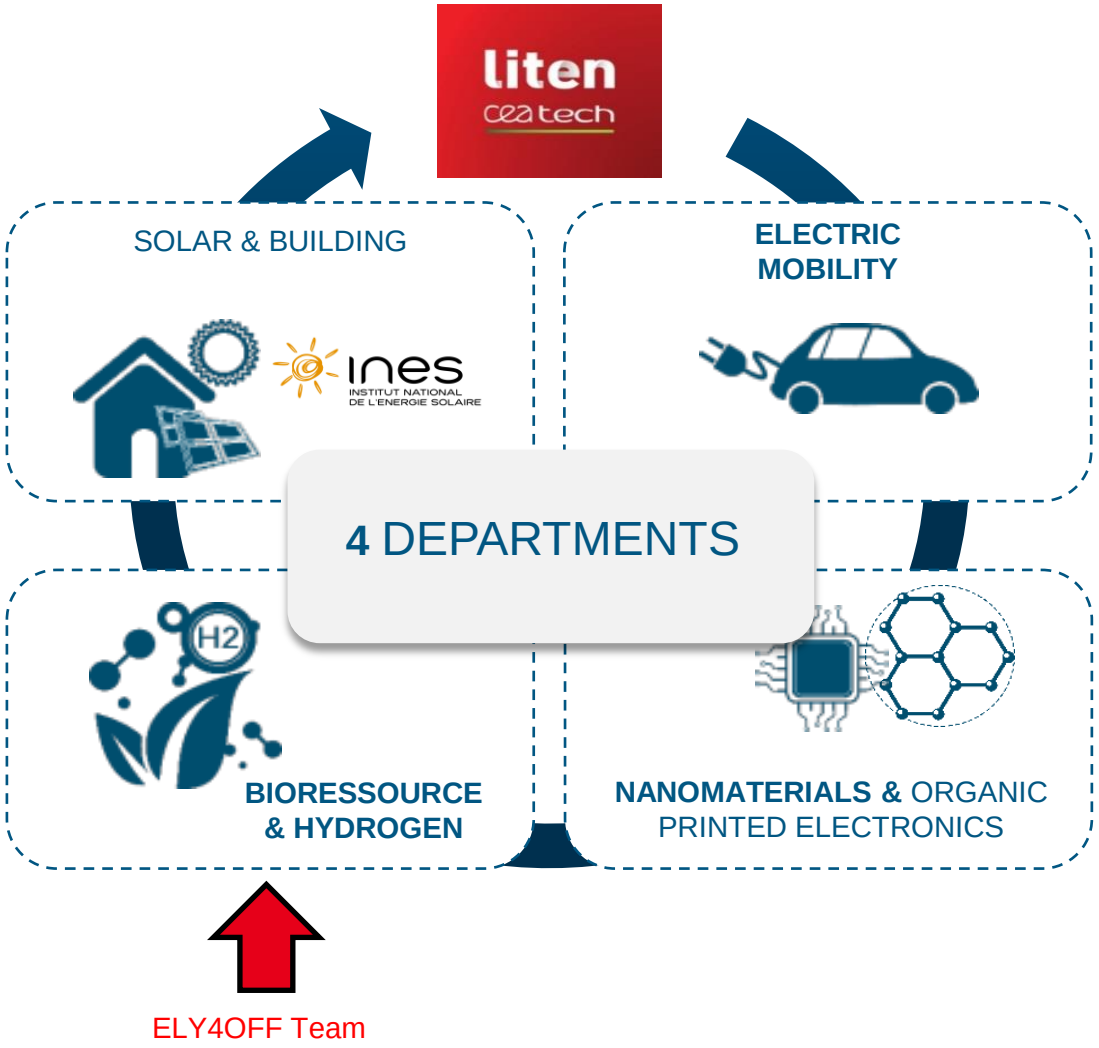
# ELECTROLYSIS WORKSHOP

ELY4OFF | Bourasseau Cyril

ELY4OFF
PEM ELECTROLYSERS FOR OPERATION WITH OFFGRID RENEWABLE INSTALLATIONS

# CEA LITEN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# RCS IN ELY4OFF

- **<u>Objective</u> : identify barriers and suggest recommandations to overcome them**

- **2 steps:**
  - Literature study
  - Use of HY4ALL database for specfic use cases

- **Use cases**
  - **Electrification** of isolated site in Denmark
  - **Gas grid injection** in Scotland
  - **Mobility** application in Sweden
  - **Industrial** application in France

- **Main conclusions**
  - **<u>Very interesting and useful database !</u>**
  - Very different barriers and risks depending on applications and countries
  - Hydrogen production is generally not the problem but application is !

| | Application | HYLAW topics | HYLAW: no barriers |
|---|---|---|---|
| 1 | Electrification | Stationary FC: Installation requirement | Norway, Sweden, Finland, Germany, Latvia, Denmark, Belgium, Netherlands, France and Spain. |
| | | Stationary storage: land use plan | Norway, Sweden, Belgium, Spain, Denmark, Romania, Bulgaria. |
| | | Stationary storage: permitting requirements | Norway, Sweden, Germany, Denmark. |
| | | Production H2 (localised): simplified process | Sweden, Germany |
| | | Production H2 (localised): land use plan | Norway, Sweden, Latvia, Germany, Netherlands, Belgium. |
| | | Production H2 (localised): permitting process | Norway, Sweden, Latvia, Germany, Denmark. |
| | | Production H2 (localised): permitting requirements | Norway, Sweden, Germany. |
| 2 | Gas grid injection | Legal framework: permissions and restrictions | None |
| | | Permission to connect/inject | Norway, Germany |
| | | Payment issues | Sweden, Germany |
| | | H2 quality requirements | Sweden, Germany, Denmark, Latvia |
| | | Safety requirements | France, Latvia |
| | | Safety requirements to end-use equipment | Norway, Latvia |
| | | Legal framework: permissions and restrictions | Norway |
| | | Permission to connect/inject | Norway, Germany |
| | | Payment issues | Norway, Sweden, Germany, Denmark, Netherlands, Belgium |
| | | H2 quality requirements | Norway, Sweden, Denmark, Netherlands, Belgium |
| | | Safety requirements | Norway, Denmark |
| | | Safety requirements to end-use equipment | Norway |
| 3 | Mobility | Stationary storage: land use plan | Norway, Denmark |
| | | Stationary storage: permitting requirements | Denmark, Norway, Germany, Belgium, Netherlands, France, Portugal, Italy, Austria. |
| | | Production H2 (localised): simplified process | Denmark |
| | | Production H2 (localised): land use plan | Norway, Sweden |
| | | Production H2 (localised): permitting process | Norway, Sweden, Austria, Denmark |
| | | Production H2 (localised): permitting requirements | Norway, Sweden, Germany, Netherlands, Spain |
| 4 | Industrial | Production H2 (centralised): land use plan | Norway, Sweden, Latvia, Germany, Netherlands, Belgium. |
| | | Production H2 (centralised): permitting process | Norway, Sweden, Latvia, Germany, Denmark. |
| | | Production H2 (centralised): permitting requirements | Norway, Sweden, Germany. |

**Fig: Countries with no barriers for each application**

| BARRIER | | Severity of the barrier | |
|---|---|---|---|
| **Legal** | Production H2 (localised): simplified process | Medium (structural barrier) | |
| **Administrative** | Production H2 (localised): land use plan | Medium (structural barrier) | |
| **(from HyLAW database)** | Production H2 (localised): permitting process | Medium (Economic barriers, Operational barrier) | |
| | Production H2 (localised): permitting requirements (including safety distances) | Medium (operational barrier) | |
| | Production H2 (centralised): land use plan | Medium (Structural barrier) | |
| | Production H2 (centralised): permitting process | Medium (Economic barriers, Operational barrier) | |
| | Production H2 (centralised): permitting requirements | Medium (operational barrier) | |
| | Stationary storage: land use plan | Low (operational barrier) | |
| | Stationary storage: permitting requirements | Medium | |
| | Road Transport : Road planning | No barrier | |
| | Road transport : permitting process / requirements | No barrier | |
| | Road transport : Quantity and pressure limitation | Medium (cost) | |
| | Grid connection : legal status of power to gas plant | High (regulatory gap) | |
| | Grid connection : Power-to-gas plants and their role in the electricity balancing market | Low (operational barrier) | |
| **Economic** | Cost of H2 | High | |
| | Cost of high pressure storage | Medium | |
| | Lack of infrastructure | low | |
| **Societal** | Green H2 for industrial applications | No barrier | |
| | | | |
| | | | |

**Fig: Illustration of barrier severity for 1 application**

# BUSINESS CASES : APPROACH FOR ELY4OFF

**Objective** : Techno-economic evaluation of 2 business cases through time-step simulation

- **3 business cases**
  - Electrification of isolated sites
  - H2 injection into the gas grid
  - Mobility application
- **Comparison of:**
  - Different locations (Northern and southern Europe)
  - Different renewable ressources (PV, Wind, Hydro)
  - Different load profiles for each considered application
- **Represented system**
  - ELY4OFF under operation in specific application
  - Integration of specific application constraint
- **Indicators**
  - **LCOE** : Levelized Cosot of Electricity
  - **$LCOH_2$** : Levelized Cosot of Hydrogen
  - **Unmet load** : Statisfaction
- **ODYSSEY Software**
  - **Simulation** the operation of the modelled system / hourly time step
  - **Optimisation** of the size of the component to satisfy the load while minimizing the cost
  - **Sentivity analysis** of

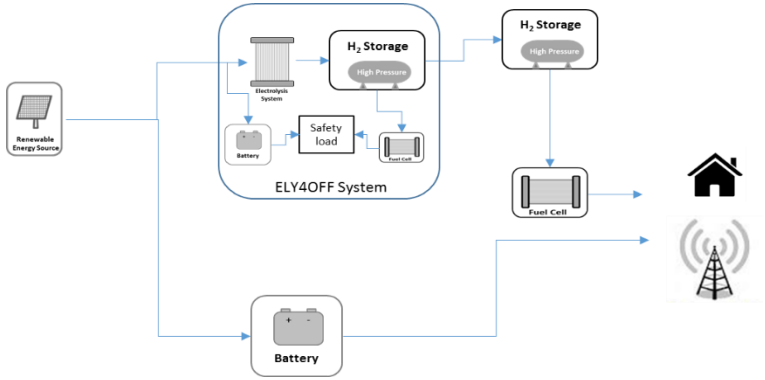


**Fig: illustration of ELY4OFF system for specific application**

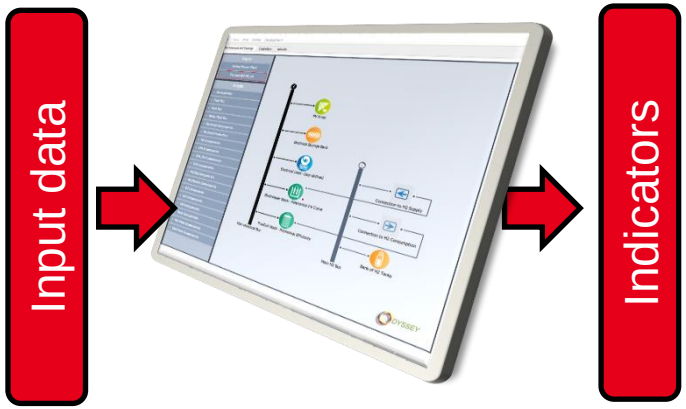


**Fig: ODYSSEY software for tehcnico-economic evaluation**

# BUSINESS CASES : RESULTS ILLUSTRATION

- **Electrification of isolated site (Scotland and Spain)**
  - LCoE for simulated isolated configurations. Observed LcoE range is from around 500 €/MWh to 5000€/MWh.
  - High values can be explained (i) by the small size of the considered system (5 kW peak power) and (ii) by the strict autonomy necessity leading to a massive oversizing installed PV surface.

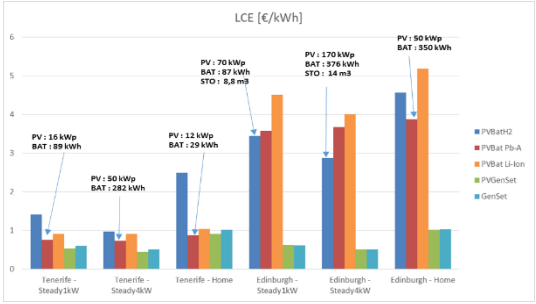


**Fig: LCOE for electrification application**

- **Gas grid injection (Scotland and France)**
  - Range of LCoH from 4.5 to 50 €/kg was observed and strong impact of (i) location, (ii) renewable source and (iii) size of electrolyzer appears.
  - They may compete with biomethane injection costs (Feed-in-Tariff reaches 5.5 €/kg in some European countries) but not with the natural gas price today (0.91 €/kg in hydrogen equivalent) although CO2 emissions comparison should be taken into account in this case.

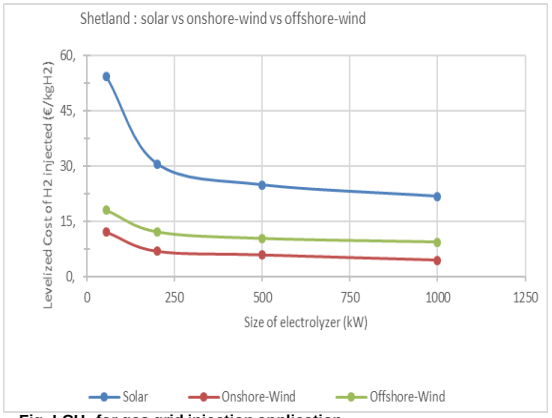


**Fig: $LCH_2$ for gas grid injection application**

- **Mobility (Iceland and France)**
  - In Millau, LCoH ranges from 200 €/kg for smallest PV installation to 35€/kg for larger hydro and wind installations.
  - In Iceland, from 260 €/kg for smallest PV installation to 34€/kg for larger wind installation.
  - For high LCoH, the cost of hydrogen refueling station is very important (up to 60% of the total cost in some cases).
  - Autonomy leads to an oversizing of renewable source (40 to 70% of renewable power is not used) and hydrogen storage to satisfy the load.

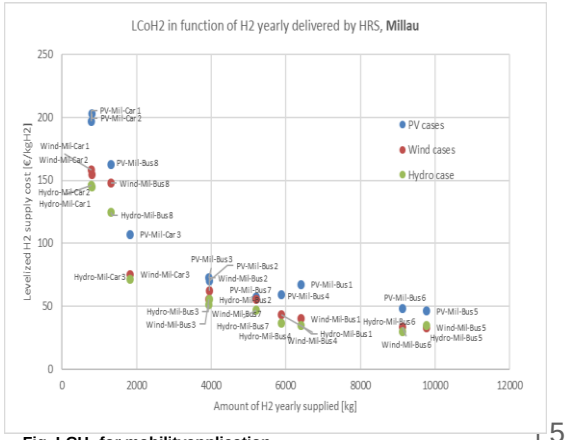


**Fig: $LCH_2$ for mobilityapplication**

# BUSINESS CASES : MAIN LEARNINGS

- **Based on the modelling and simulation work carried out in task 6.6: although cost of full off-grid hydrogen remains high, each of the three evaluated applications from a techno-economic point might be interesting under certain conditions.**

- **Off-grid hydrogen may represent benefits compared to competing technologies:**
  - For electrification of isolated site with high seasonality of renewable power is observed;
  - For gas grid injection when renewable power factor is high and gas grid constraints are limited;
  - For mobility when renewable power factor is high and low carbon mobility is valued.

- **Strict off-grid conditions AND 100% load satisfaction leads to important oversizing of the renewable power plant**

- **Strict off-grid conditions lead to significantly higher cost of electricity (LCoE) or hydrogen (LCoH) but may be, in the future, necessary to valorize important renewable power potential and guarantee low carbon hydrogen production for various applications.**

# MERCI POUR VOTRE ATTENTION

# THANKS FOR YOUR ATTENTION

Commissariat à l'énergie atomique et aux énergies alternatives
17 rue des Martyrs | 38054 Grenoble Cedex
www-liten.cea.fr

Établissement public à caractère industriel et commercial | RCS Paris B 775 685 019