ely4OFF

PEM ELECTROLYSERS FOR OPERATION WITH OFFGRID RENEWABLE INSTALLATIONS

First version of new business model for electrolysers in off-grid installations

Deliverable 6.3

GRANT AGREEMENT 700359

D6.3 First version of new business model for electrolysers in off-grid installations

Grant agreement	Fuel Cells and Hydrogen 2 Joint Undertaking
Project no.	700359
Project full title	PEM ElectroLYsers FOR operation for OFFgrid renewable facilities
Project acronym	ELY4OFF
Deliverable no.	6.3
Title of deliverable	First version of new business model for electrolysers in off-grid installations
Contractual date of delivery	M14
Actual date of delivery	M20
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Work Package contributing to the deliverable (WPx)	WP6
Dissemination level (PU/CO/CI)	PU
Type (R/DEM/DC/OTHER)	R
Total number of pages	14

Abstract

This report is a preliminary report asking the questions to find a new business model for off-grid electrolysis. This report will be completed at the end of the project.

Table of contents

1. Introduction

The European Union has set ambitious targets related to energy efficiency, renewable energy and greenhouse gases emissions to reach long-term climate change goals. By 2030 the EU aims to reduce GHG emissions by 40%, to increase the share of RE in the member states energy mix to 27%, and to reach a 27% energy efficiency target**¡Error! No se encuentra el origen de la referencia.**. To accommodate this share of RES without overloading transmission and distribution grids, an economically viable solution is the conversion of surplus renewable energy into hydrogen which may be used in a wide range of applications: (1) chemical industry, to generate other products, (2) fuel cell electric vehicles refueling, (3) injection into the natural gas grid, using gas networks as storage system for electric grids, and (4) re-electrification to inject electricity in weak grids where faults are common or in isolated micro-grids where access to the main grid is not possible and a combination of RES and fossil fuel based generation is present.

The fourth scenario, with off-grid generation of hydrogen from RES, is especially attractive because: (a) it allows replacement of diesel engines in isolated regions to back-up the existing RES and there are currently 600 GW available for substitutions worldwide, (b) global efficiency is not a key issue as in the case of grid-connected systems, as hydrogen is produced avoiding curtailed energy that would be otherwise wasted, (c) hydrogen uses are varied and not only re-injection can be studied, but also feeding FCEVs or stationary fuel cells to cover also heat demand, (d) hydrogen is competitive with other energy storage equipment such as electrochemical batteries which show problems related to self-discharging and maintenance in the case of seasonal storage, offering long-term security of supply.

ELY4OFF is a project to develop and exploit off-grid electrolysis. This report is a preliminary report asking the questions to find a new business model for off-grid electrolysis. This report will be completed at the end of the project.

Background on business models

There are several well-known business models, examples of which can be shown in the off-grid compatibility table:

Model Type	Description	Suitability to Off-Grid
Add-On	In this instance, the core offering is priced competitively but there are numerous extras that drive the final price up so the consumer is not getting the deal they initially assumed. Low-cost airlines often use this model. Whilst this may make the cost of an electrolyser look cheaper and help to win business in the short term, this can have a detrimental effect on ongoing business when the final costs are realised.	No

Advertising	The advertising model became popular with the growth of radio and TV where the TV stations earned revenue indirectly from people looking to promote services to the audience they attracted, rather than via consumers paying radio and TV stations for the consumption of their TV programmes. This is now common with internet businesses but is difficult to justify if it is your main revenue stream so not appropriate to off-grid electrolysis (which is capital expensive). However, raising money by getting a local business to pay for some branding on vehicles may help offset costs.	No
Affiliate	An affiliate is simply someone who helps sell a product in return for a commission. However, they may never actually take ownership of the product (or even handle it). This is used now around the world to attract business in local regions, however, as completely off-grid sites are spread throughout the world, it is likely that in the first instance salespeople will to travel to meet potential customers. If the best business plan showed a small scale "farm electrolyser" for running farm vehicles from renewables (for example) then a local salesperson who can visit farms is appropriate.	Yes
Auction	The auction model is synonymous with eBay, these days, but of course, auctions have existed for hundreds and hundreds of years. This is not appropriate for capital-intensive equipment such as electrolysis.	No
Bait and Hook	This is essentially the razor blade analogy listed above, where disproportionate amounts of the value are captured on components, refills and the like. Anyone who regularly buys ink cartridges for printers will recognise this model where customer lock-in and switching costs result in monopolistic pricing on the component side. The mobile phone business also grew rapidly on the back of this model as handsets were often supplied free of charge when you signed up for a contract. With large-scale investment in a thing like car technology, this might work by offering low-cost hydrogen vehicles. However, the business plan needs to be scrutinized to ensure a good ROI.	Yes
Direct Sales	While direct selling was initially the primary 'route to market', production efficiencies coupled with improvements in transportation meant producers could reach a much bigger market and this resulted in the pre-eminence of the retail distribution model for many years. The emergence of the Internet as a distribution channel means this is the most commonly used model for electrolysis today.	Yes
Franchise	Opening a franchise is essentially buying a working business model in a particular industry. You pay royalties for the privilege but get access to a winning recipe, a support network and an established brand. This would require a guaranteed market for hydrogen and might be appropriate in the future.	Yes

Freemium	This is where the business gives away something for free in return for your personal details so they can then market to you and hope to build up a relationship so that you buy from them in the future. It is typically used in service-based businesses where the lifetime value of the average customer is high. A similar model is used for fuel cell vehicles now where manufacturers offer free hydrogen if a car is purchased or leased.	Yes
Internet Bubble	At one point, 'unique visitor' numbers to a site had a large perceived value. Many businesses offered free Internet services and businesses were valued on the basis of potential rather than underlying profit and loss metrics. This is not appropriate to electrolysis, however, something similar could be used to get the technology into the mainstream.	No
Low-Cost	This is an extremely well-established business model, where the aim is to drive significant volumes of customers (at a low customer acquisition cost) and by charging a very low price. The model is not simply about trying to extract a whole myriad of extra cash from consumers, but also configuring every single aspect of their business model so as to drive out the cost. Getting the costs down in electrolyser manufacture is extremely important for future uptake but requires building a large market.	Yes
Pay as You Go	With this model, actual usage is metered and you pay on the basis of what you consume. This is capital intensive and the business plan will show whether there is an ROI.	Yes
Recurring Revenue (Subscription model)	With the recurring revenue model, the aim is to secure the customer on a long-term contract so that they are consuming your product or service well into the future. This could be an important model for the electrolyser operators.	Yes

Table 1. Suitability of different business models to ELY4OFF

Target Markets

In general, there are two off-grid situations where hydrogen energy storage is applicable. One where there is no grid and the only way to extract renewable energy is to convert it to hydrogen as a renewable fuel. And another where there is a grid nearby, but the costs of connection are very high due to distance or grid capacity to absorb more renewable electricity.

For any model to make economic sense, there must be an end user who is able to utilize hydrogen generated. There are four potential markets for the hydrogen. These are: (1) the chemical industry, to generate other products, (2) fuel cell electric vehicles refuelling, (3) injection into the natural gas grid, using gas networks as a storage system for electric grids, (4) re-electrification to inject electricity in weak grids where faults are common or in isolated micro-grids where access to the main grid is not possible.

Regulations, codes and standards (RCS)

Off-grid production of hydrogen through water electrolysis and its associated applications (isolated site electrification through fuel cells, mobility, gas grid injection…) are subject to regulations, codes and standards (RCS) as any industrial application. Main relevant RCS documents related to application envisioned in ELY4OFF were identified and are presented in the deliverable D6.1 submitted in June 2017.

Difficulties and barriers related to RCS that may exist for off-grid hydrogen production and utilization were identified through literature study (as example, key documents are presented in Table 1) and discussion with hydrogen stakeholders.

It appears that RCS panorama is relatively clear for equipment design but remains unclear and inhomogeneous for hydrogen applications at European level. This may lead to delays due to required administrative processes and therefore extra costs which penalize hydrogen systems implementation. Unclear regulations for on-going development of off-grid or grid connected hydrogen applications may also be barriers to hydrogen energy applications by generating extra cost and limiting competitiveness

Reference	Author	Publication date
Sector Forum Energy Management / Working Group Hydrogen – Final Report [1]	CEN-CENELEC	2016
Handbook for Hydrogen Refuelling Station Approval [2]	HyApproval Project	June 4, 2008
Approval requirements in five EU countries and the USA [27]	HyApproval Project	December 4, 2007
Installation permitting guidance for hydrogen and fuel cell stationary applications: UK version (RR715) [28]	Health and Safety Laboratory	2009
Standards, codes and regulations of Hydrogen Refueling Stations and Hydrogen Fuel Cell Vehicles – Final Degree Project [29]	P.Huertas Gaja M.del Mar Llompart	Unknown

Table 2: Key documents about RCS in hydrogen field

Some additional work on RCS is planned in task 2.2. Following deliverable D6.1 submitted inJune 2017, it was decided among partners that additional work on RCS to be carried out will build upon general recommendations already identified part IV of D6.1 report and on on-going demonstration projects and experience in Europe. For the most promising off-grid hydrogen markets to be identified in WP 6, the work to be carried out will contribute to identify the most relevant and efficient incentives and recommendations (at RCS level, economic level and communication level) to foster the deployment of hydrogen technologies.

Although further discussions with partners will clarify it, a proposed content of D2.2 could be:

1) Identification of most promising markets applications
2) Identification of main barriers and difficulties for each application
3) Incentives and recommendations for each application

Through their strong expertise in hydrogen energy field, partners of ELY4OFF project will all contribute to the construction of this report by sharing their experience, analyzing difficulties associated to each market and suggesting incentives and recommendations to overcome them.

Reference studies

Regarding business models for off-grid hydrogen production, it can be worth mentioning five recent studies about hydrogen production from electrolysis business models and business cases:

(i) SBC Study (2014): "Hydrogen based energy conversion"

(ii) AT Kearney study (2015): "Hydrogen based energy conversion"

(iii) Certifhy study (2015) : "Generic estimation scenarios of market penetration and demand forecast for "premium" green hydrogen in short, mid and long term"

(iv) ENEA study (2015) : "The Potential of Power to Gas"

(v) FCH-JU Study (2017) "Study on early business cases for H2 in energy storage and more broadly power to H2 applications"

2. Key Stakeholders in New Business Models

Who is who in the new business model and who are the key actors that may be included in it.

For a business model to be successful all key parties must be successful. The key parties are discussed below and a visual representation is given in figure 1.

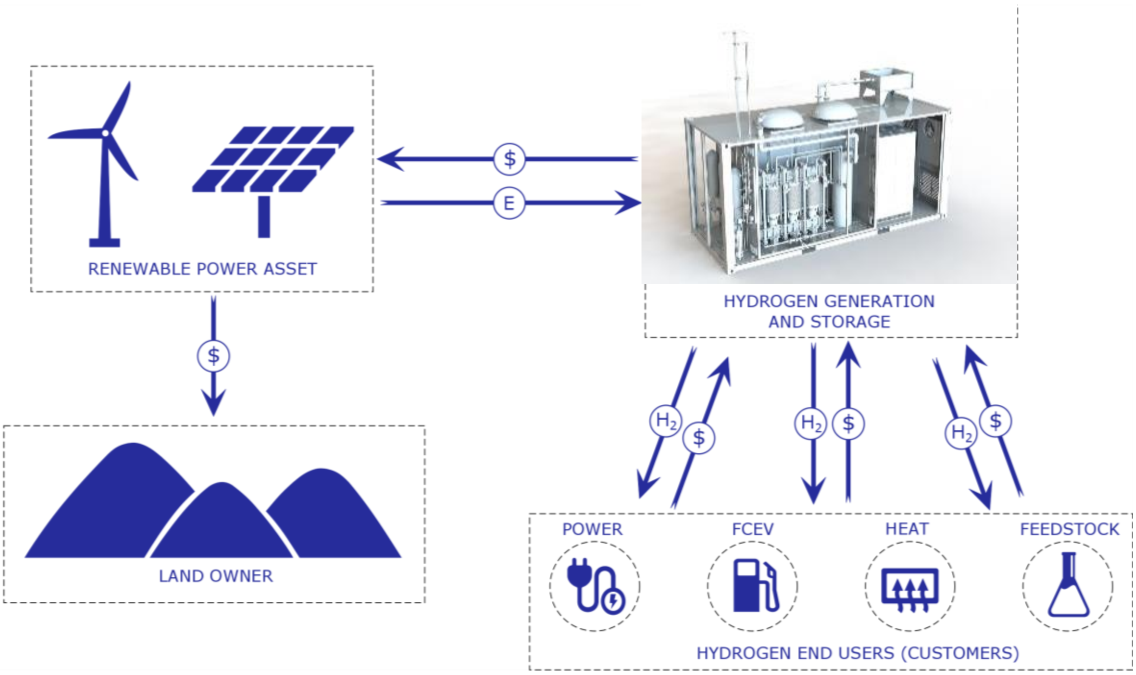

Figure 1. Key partners involved in a business model

On the supply side, the main stakeholder in both cases is the landowner or developer who is looking to deploy a renewable power source but is unable to do so. If the energy can be transformed to hydrogen then this stakeholder can be a provider of renewable energy at the location in question. Technologically they must deploy a renewable power source and electrolyser and often need to deploy hydrogen storage and hydrogen utilisation equipment in order to satisfy the energy demand. Technology providers/operators in the chain may also be stakeholders.

On the demand side, there are several potential stakeholders depending on the application. These split into the use of hydrogen to generate power or heat, and the direct use of hydrogen as a transport fuel or chemical feedstock (e.g. fertiliser). In remote areas, the local community often needs a combination of these and is a stakeholder. In addition, there are locations which are off-grid with respect to electricity but close to the gas grid. In this scenario, an off-grid power-to-gas application can serve to capture and transfer renewable energy to distant end users by injecting a hydrogen admixture or synthetic methane into the gas grid. Accordingly, both the gas network operator and gas consumers are stakeholders.

Depending on the decarbonisation or air pollution objective, the local and central government may encourage stepping away completely from fossil fuels to renewable energy and therefore act as a stakeholder to enable off-grid solutions. This may involve Capex and Opex support. Unlike a conventional on-grid electrolyser, no income can be earned from providing balancing services.

There isn't a single business model to cover all off-grid hydrogen applications. There are several applications and each involves a set of stakeholders with a lead operator. A template table like the following one will be used in the final report of new business models (D6.7, M32).

Market opportunity	Lead Operator	Supply-side stakeholders	Demand-side stakeholders

We need to take a view on who will/should be the lead actor/operator in each application. In general either the renewable power source owner buys all necessary hardware and operates it, or the electrolyser operator buys all necessary hardware including the power source and operates it. In some cases the lead operator is clear but in others less so - new businesses/partnerships may need to be formed to make some applications real. It would seem to depend to a large extent on whether the renewable electricity providers want to become renewable energy providers (by converting to hydrogen), or the electrolyser providers want to become hydrogen system operators and just buy and install the RPS as one component of the system. Other stakeholders could move to take the lead including gas network operators and even electricity suppliers.

Which is the role of the end users and how to boost an active participation, either at the individual level or as virtual clusters of customers, and how are they going to be engaged in this model.

Heat and power tend to be expensive in remote off-grid areas due to the need to import diesel or LPG. The off-grid hydrogen approach has excellent sustainability credentials and zeroes atmospheric emissions. The model may place a value on these, but as an energy solution, it cannot be significantly more expensive for end users than existing solutions if it is to be applied widely. When the required hydrogen technologies are in volume production (e.g. by 2030) the model must show energy cost parity with heat, power, fuel or chemical supplies based on fossil fuels. Active participation of end users can be promoted by emphasising the sustainability and security of supply features and by implementing appropriate government policies (in particular to incentivise early adopter communities and individuals).

Concepts to develop in the next report:

- What is incentivising the customer – what is going on within Spain/Uk/France etc; Norwegian example VAT
- Free fuel but disrupts model? Is there a benefit for using entirely green fuel? What mechanisms are available to discount fuel?
- Role of the end user is to use all of the hydrogen produced. Demand needs to be greater than can be supplied = certainty of revenue.

How is the relationship between the actors involved in the off-grid installation operation and management and how should they interact to optimize efforts and reduce losses.

Unless bound by contract relationship or has to be based on mutual trust – each player relies on revenue stream to pay off assets. Who will step in if a partner defaults (left with the stranded asset)?

This is application specific:

a) Off-grid HRS - actors are: the solar/wind power source (RPS) owner, the landowner, the HRS operator, the hydrogen vehicles in the region who fill up there, local/national government if incentives exist to deploy HRS to enable renewables expansion without the grid. Lead operator = HRS operator (buy/rent the land and all hardware) or possibly the RPS operator.
b) Off-grid P2G - RPS owner, landowner, gas network operator, government if a policy exists to decarbonise the gas grid, the owner of the green CO2 supply if doing methanation (such as the company owning anaerobic digesters at a biomethane injection site). Lead operator = biomethane injection company or gas network operator. This application will only work if the model employs an appropriate value per kWh for the H2 or SNG injected into the gas network (feed-in tariff).
c) Off-grid heat - RPS owner, landowner, heat network operator or owners of the buildings to be heated or some local community organisation. Lead operator = heat network operator or hydrogen system operator. The combination of low capacity factor and low turn round efficiency makes this application a very tough ask economically.
d) Off-grid power - the electricity can't enter a grid as such (it may just be a single transformer with some distribution cables in order to displace an existing diesel generator). Two applications to consider would be (i) electrification of a remote village

that wants/deserves power, and (ii) displacing an existing diesel generator that currently provides backup power during periods of low renewables availability. Again the combination of low capacity factor and low turn round efficiency makes this application a very tough ask economically.

e) Off-grid hydrogen storage in salt caverns - RPS owner, landowner, cavern owner/operator, hydrogen pipeline owner, hydrogen gas turbine owner or gas network operator. Lends itself to very large electrolysers and very cheap storage. Hydrogen can be fed into gas grid or used to run H2 GTs and this is the only form of storage that can reasonably provide seasonal storage. Lead operator = salt cavern owner.
f) Off-grid heat and power - RPS owner, landowner, heat network operator or commercial heat user (e.g. swimming pool), the owner of the distribution transformer/line already in use (or that becomes part of the system install). Lead operator = RPS owner. Recover heat from the electrolyser and the FC CHP unit.
g) Off-grid telecom power - RPS, landowner, a telecom company. Lead operator = telecoms company. This is a very clear application for kW scale electrolysers; on-site H2 generation needs to show that it's cheaper than delivered H2 as being used at present.
h) Off-grid fertiliser - RPS, farmer, delivery truck operator to distribute it to other farmers in the region.

The RPS owner needs to optimise efforts and reduce losses. He provides the input energy and needs to earn a similar amount to that which would be achieved if connected to a grid (~10 €cents/kWh) in order to raise the finance. For example, the operator of the hydrogen system needs to sell hydrogen at a price sufficient to satisfy the RPS plus pay back the cost of deploying and operating the electrolyser and H2 storage system. The sale price for hydrogen refuelling is ~30 cents/kWh; off-grid telecom power will be at this price or higher. On-site generation reduces the number of stakeholders required and simplifies the challenge, so the case pivots around the input and output energy costs. Other applications will involve more stakeholders who want their cut and subsidies such as feed-in tariffs.

Which are the incentives and benefits to make the model economically viable

The margin between hydrogen sale price and energy input price is the principal means to achieve an economically viable model. Some markets can accept a high value per kWh of hydrogen energy (telecoms, HRS), while some can only accept a much lower value (fertiliser production, heat, hydrogen injected into the gas grid). In the situation where the off-grid system obviates the need to implement an expensive grid connection and there is an imperative to increase the renewables penetration in the region, then the avoided grid connection cost becomes a financial incentive to deploy the hydrogen system. The model will need to employ Capex and Opex subsidies for some applications. The scale of the incentive required to achieve a given payback period can be calculated and government policies implemented so that all energy consumers and taxpayers bear appropriate fractions of the costs, especially during the first years of market development.

Who is responsible for the failures, outages or any other issue that may come up and how should they been solved

The lead operator for the application and the contractual arrangements in place with maintenance subcontractors and the technology manufacturers. The H2 storage component of the system provides inherent security against outages, both with respect to hydrogen generation and utilisation, so oversizing the store can serve to provide extra protection.

There can be two types of outages: forced and unforced outages; they should be clearly defined in power purchase agreement. It is strongly related to project customer demand for hydrogen over year 1 2 3 etc.

How to commit public authorities

Ely4Off offers a complete step change in emissions, energy security and sustainability. The decarbonisation policies of public authorities can be enhanced by containing a category encouraging off-grid renewable energy capture via hydrogen. Being able to switch the GHG emissions of end users to zero in one step is a persuasive option to have in the policy portfolio.

Aspects to explore can be: transport/power and air quality, support for rural communities, etc

Barriers for the new business model up taking and recommendations to overcome them, considering RCS obstacles detected in Task 6.1.

Price is fundamental but new technologies are difficult to implement. Need demonstration customers imagine technology not robust enough or reliable enough.

Target markets and end applications and current as well as long-term trends affecting them

Qualitative and quantitative analysis are to be done. These initial target markets to be considered will be (see section 2.1) the following ones, not precluding to detection of new additional scenarios during project execution:

Ref	Comments	Drivers
A	EU (highly electrified)	Telecoms - this is a big potential market in terms of production volume at ~10kW scale P2G - depends on where the gas transmission pipes are but potentially a huge market for remote/rural areas with lots of solar and wind potential (parts of Germany, Italy, Spain, Scotland). Remote regions of very high renewables where more renewables could be exploited but the electricity grid is saturated and curtailment is prevalent (Orkney). HRS on remote arterial highways (A roads in rural Scotland, Wales)

B	Energy system for isolated areas (e.g. mountains)	The main driver in these applications is the availability of renewable energy sources, and the openings period. In mountain huts for example, the main aspects to consider are: scarcity of sunlight due to high surrounding mountains, non-steady wind regime (gusts of wind are usual), and availability of hydro turbines. Also the opening periods affect enormously the potential solutions to implement, as some installations are closed during 2/3 of the year. The solution has to be assessed case by case.
C	Replacement of diesel engines in off-grid installations to support existing/new installed RES isolated installations	This is the main topic of the first business case developed in one of the deliverables of the project (D6.8). A comparison is done for: PV-BAT, PV-BAT-H2, PV-Diesel generator, and diesel generator. Some elements are being identified that may give economic advantage to hydrogen, like locations with higher sunlight hours or type of load demand during day/night.
D.	Backup system for failure events in weak grids; and	The electrolyser would be on-grid but only during off-peak periods to produce hydrogen for backing up the grid during peak periods.
E.	Off-grid HRS to supply to FCEVs.	The electricity input is only being available ~ 15% of the year for solar and ~ 25% for wind, so it needs to be well dimensioned to have sense.
F.	International, including developing countries (low/weakly electrified scenario). (1) Weak grids; and (2) Replacement of diesel engines.	The goal is to take advantage of the great market opportunities for off-grid installations in these countries and to export the EU electrolysis developments, adding value to the member states. The issue here is sizing into appropriate modules for developing countries. What sizes of diesel engine kWe are we going to consider - what sizes are typically employed by developing countries in remote areas and how many hours per day? Probably sub-MW electrically but there'll be numerous sites so a big market - it could require a multi MW RPS and electrolyser to make enough hydrogen for an FC to deliver sub-MWe (Ely4off capacity factor is low and turn round efficiency is low) The goal is to take advantage of the great market opportunities for off-grid installations in these countries and to export the EU electrolysis developments, adding value to the member states.
G.	Other: (1) Catastrophic events, (2) Industrial niche applications, (3) Power to Gas	Fertiliser production application on a large farm.

3. Conclusion

The use of electrolyser technology for the production of hydrogen is advancing at a rapid rate thanks to the FHC funding mechanisms that have allowed companies such as ITM power to develop new pathways in efficiency and low plant costs that are starting to reap the benefits from R&D continuous improvement modelling that is now becoming commercially viable as a fuel source that reduces the tradition heavily weighted carbon foot associated with industry. A major key economic driver is the use of renewable energy to deliver green power to green gas. Using direct renewable energy that is off grid like the ELY4OFF project will demonstrate on a small scale that the deployment of large-scale off-grid electrolysis will allow developing countries with little to no electrification networks to produce a primary fuel source that can deliver heat, mobility and power; as well as manufacturing of fertilisers (ammonia) to allow continued to grow as well storing and selling the fuel commercially to other uses.