ELY4OFF

PEM ELECTROLYSERS FOR OPERATION WITH OFFGRID RENEWABLE INSTALLATIONS

Objectives at system and subsystem level

Deliverable 2.4

GRANT AGREEMENT
700359

D2.4 Objectives at system and subsystem level

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Author(s)	Nick van Dijk (ITM)
Participant(s)	Pedro Casero (FHA), Esther Albertín (FHA)
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Abstract summary

This deliverable sets out the techno-economic objectives for the electrolyser system., which are broken down to energies and efficiencies of the various components. This report is set out as a table outlining these technical objectives

Note. In the Grant Agreement and in the DoA, the deadline of this report is M14 (may 2017). It has been notified that it should be M7 (October 2016)

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FIGURE INDEX

1. INTRODUCTION

This brief report sets out the techno-economic objectives of the ELY4OFF off grid electrolyser project. We have defined the techno-economics of the system as essentially the cost of hydrogen in terms of energy (kWh/kg H_2). There are some financial objectives included in this document but these are high because we are producing an R&D piece of equipment, not a production piece.

The real cost of a production system (true cost) will be a function of the size of the system which will be defined by the business modelling that will be performed as part of the ELY4OFF project.

Of importance in an off grid solar hydrogen system is maximising the amount of hydrogen produced using the available solar radiation by having a highly responsive system that can rapidly follow a load and by minimising any losses in the system.

Figure 1 shows the different elements of the system being developed as part of this project. and the scope of each partners in the project, together with the interfaces (physical, electrical and control) between them.

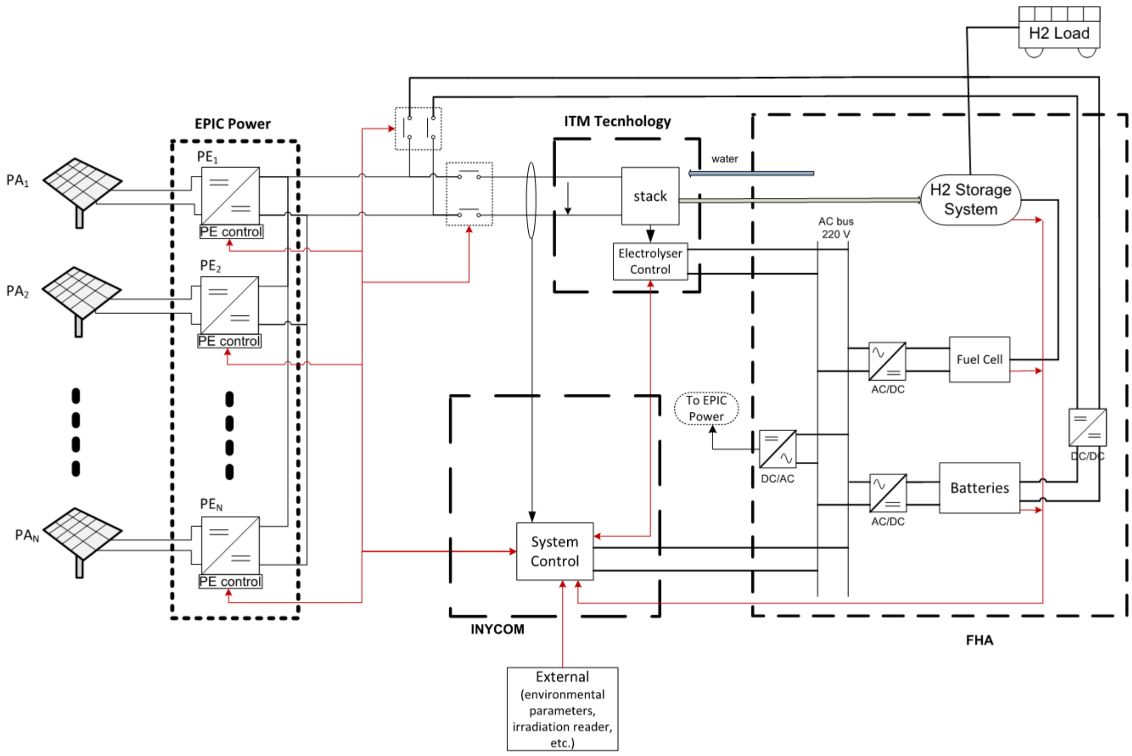

Figure 1. Scheme of demo installation

A schematic of the electrolysis system for this project is given in figure 2 below.

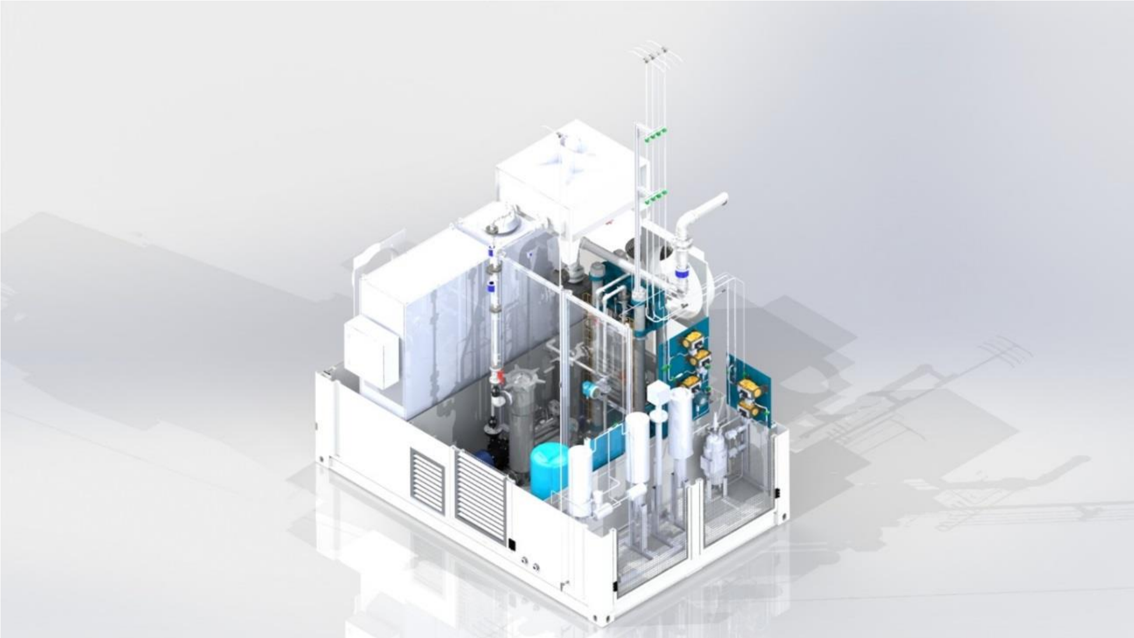

Figure 2: Schematic of the electrolyser system

The techno-economic objectives are broken down to energies and efficiencies of the various components. This report is set out as a table outlining these technical objectives.

2. TECHNO-ECONOMIC OBJECTIVES

The techno-economic objectives are given in table 1 below.

Objective	Quantity
Production rate of hydrogen - rated - daily weight	27.9 kg/d
Production rate of hydrogen - rated - hourly volume	14.2 Nm3/h
Capacity of the system - rated	56 kW
Capacity of the stack - rated	49.8 kW
Efficiency of the PSU	>96%
Power of the control system when off	<0.9 kW
Average efficiency of hydrogen production (stack)	<42 kWh/kg
Average efficiency of hydrogen production (system)	<50 kWh/kg
Footprint - hydrogen production unit	4 m^2
Volume	8 m^3
Nature of the electricity source	SOLAR
Fraction of renewable energy input	100%
Durability / Lifetime of the system - rated	160000 h
Durability / lifetime of the stack(s) - rated	60000 h
Quality required for water	<1 µS
Purity of the produced hydrogen - rated	99.9995
Type of power converter	DC-DC
Input voltage	800 V*
Power usage of auxiliary equipment - idle	0.9 kW
Power usage of auxiliary equipment - max production	7 kW
Electrical efficiency of the stack(s) (rated - HHV - DC current)	92.5%
Electrical efficiency of the system (rated - HHV - AC current)	82%
Efficiency degradation (%/8000h)	2
Planned maintenance - duration	24 h/yr
Cost - capital cost of the system (per kW)	6000 €/kW
Cost - capital cost of the system (per ton/day)	0.1 M€/t/d
Cost - capital cost of the system (per ton/day) @ mass production (estimate)	0.015 M€/t/d
Operating time per day	12
Transient response time	< 1 s
Time for hot start to 100% H2 output rate	< 30 s
Time for hot start to 100% power	< 3 s
Time for cold start to 100% H2 output rate	< 300 s
Time for cold start to 100% power	<30 s
Part-load operation - minimum	10 %
Ramping flexibility - minimum power	5%
Ramping flexibility - maximum power	150%
Operating pressure	20 bar
Operating temperature	55 °C

*This value is a good candidate (to be determined in WP4)

Table 1: Techno-economic objectives of the system.

The costs of the system given in the table are the actual costs to produce a one off research electrolysis system with all the associated non-recurring engineering costs. A second identical system would of course be a lot cheaper. A mass manufactured system would likely be an order of magnitude cheaper.

An off grid hydrogen electrolysis system will need to actively follow the solar profile and respond instantly, for example in the event a cloud goes over the sun. The nominal current for this system is 300A but the stack will be tested to 600A (200% of nominal power). The PSU will be limited to 450A (150% of nominal power density). This extra power is available to be used in extremely sunny days.

Electrolysis systems are necessarily designed for operation at maximum power density because the system needs to be able to handle that quantity of gas produced at maximum power and the pumps need to be powerful enough to cool the stack at maximum power density. This has the negative effect that when the power is low.

The energy cost of hydrogen is a function of the operating parameters. The stack has an operating current voltage (IV) curve that defines the power of the stack. When operating a low power, the energy cost of hydrogen is cheaper. The target IV curve for the stack in the ELY4OFF project is given in figure 3 below.

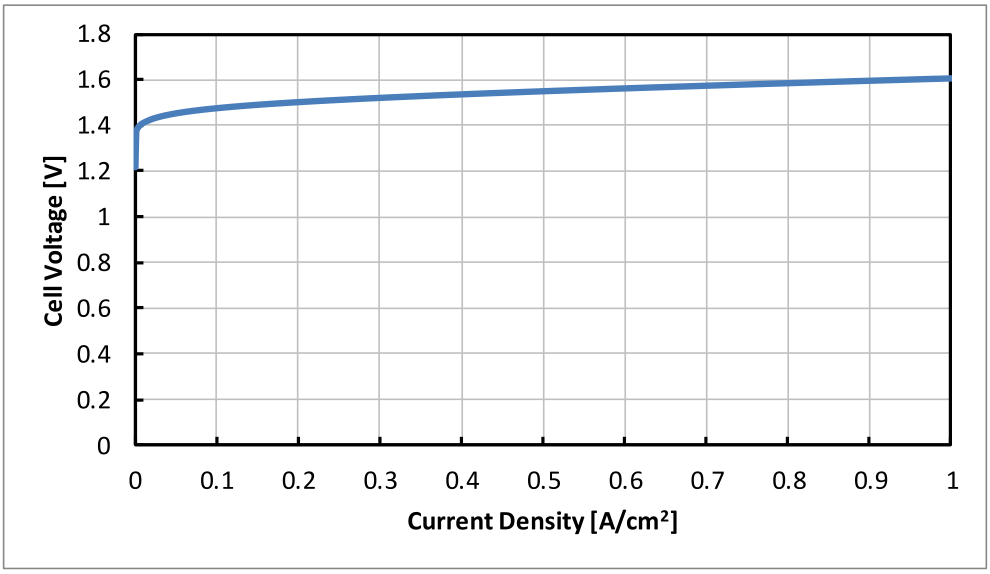

Figure 3: Target IV curve for the stack

Replotting this IV curve into an efficiency of hydrogen (based on the HHV of hydrogen), we end up with figure 4. Figure 4 shows it is best to operate the stack at low current densities to maximise efficiency; however, this changes when we add a constant load (balance of plant energy) to the system.

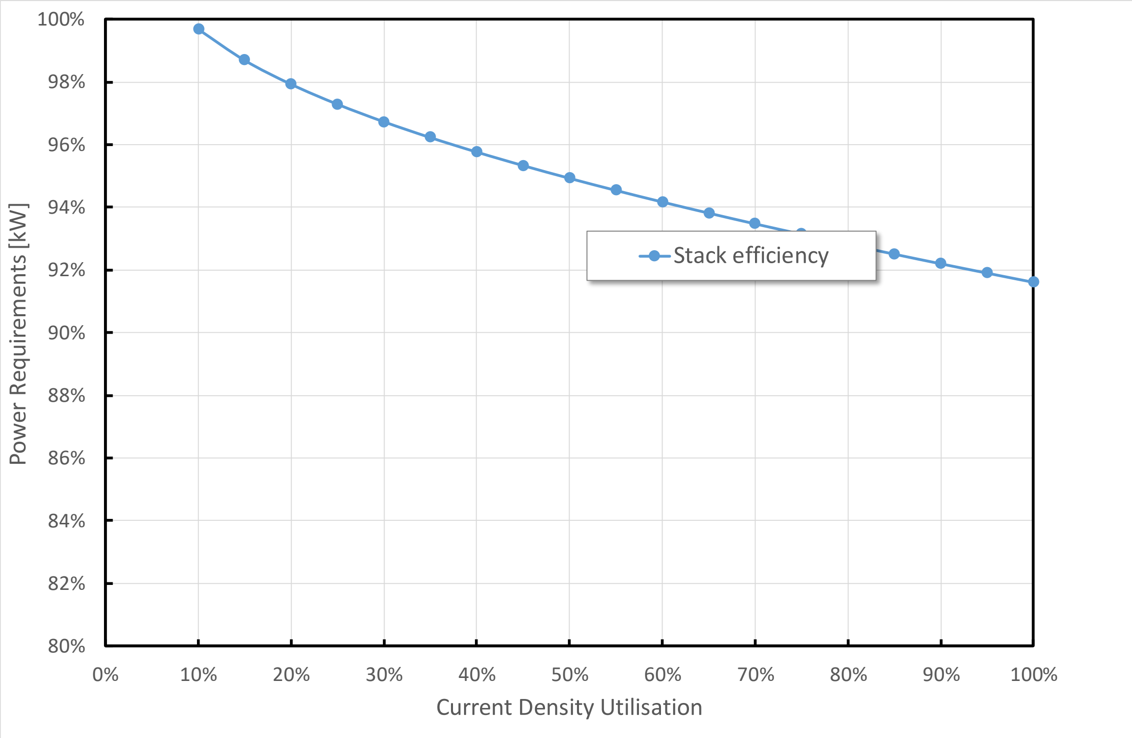

Figure 4: Stack efficiency as a function of current density.

A constant balance of plant load significantly affects the efficiency of the system. At low current densities, very little hydrogen is produced but energy is still required to operate the balance of plant, therefore the energy cost of hydrogen is high. The lower the current density the higher the energy cost of the hydrogen produced. The minimum value (optimum power density) is above 100% power density as this project is targeted with producing a highly efficient stack. This is shown in Figure 4 where the system power density never reaches a minimum.

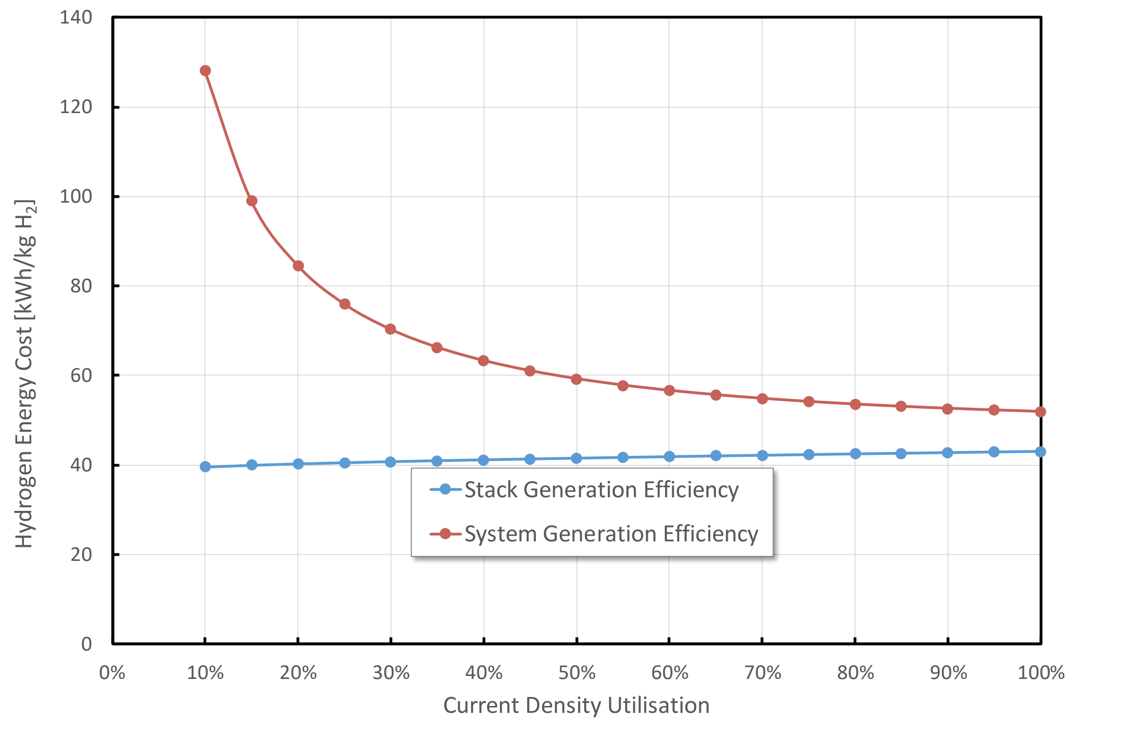

Figure 5: Cost of hydrogen as a function of current density

One further techno-economic objective of this project is to design a system where the balance of plant energy requirements follows the load profile of the stack. Certain elements like the control system will require a constant energy feed independent of the power density but other systems such as cooling pumps will follow the load profile. Often the PSU is less efficient and low power densities but a technical objective of this project to maintain a high efficiency throughout the load cycle. If this is achieved, it is the energy cost of the hydrogen as a function of power density is aimed to be that given in figure 5.

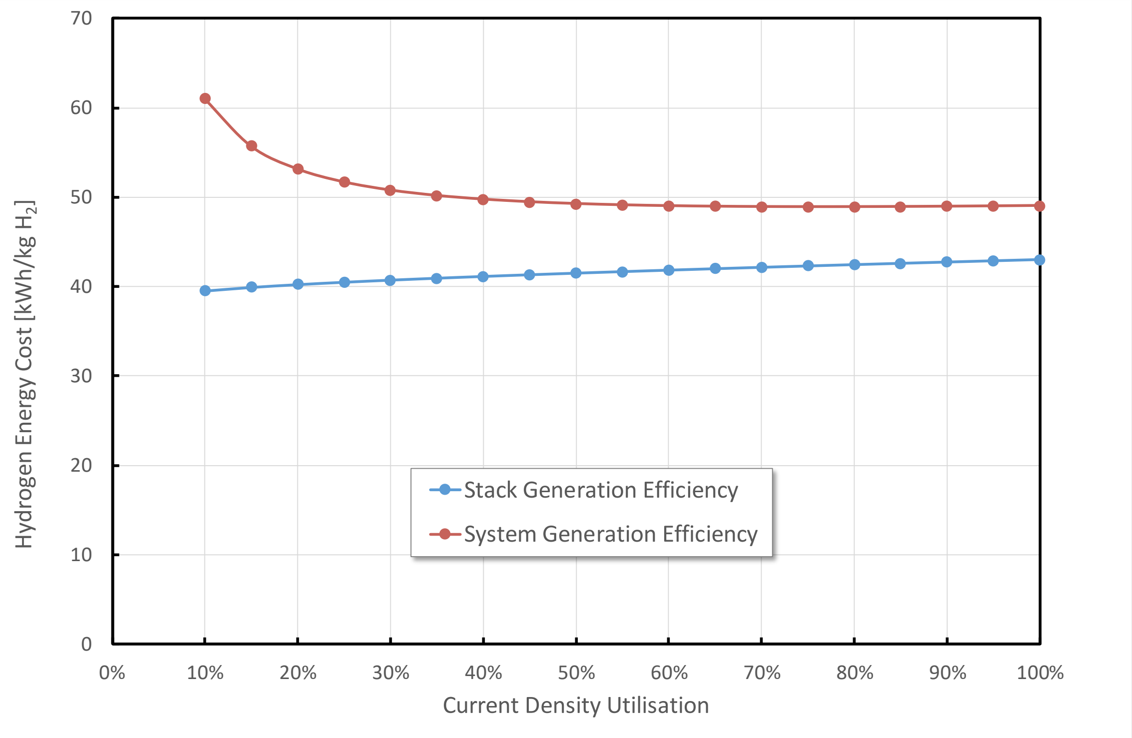

Figure 6: Cost of hydrogen as a function of current density

As can be seen the cost of hydrogen becomes a lot cheaper throughout the whole of the current density cycle.

The system will require periodic maintenance, specifically the parts requiring annual maintenance are:

1. Ion exchange resins
2. Water filters
3. Particulate filters

The target is 24 hours maintenance per year but it is expected that this planned maintenance will be scheduled for a day where no solar is expected so it does not impact in availability.

3. CONCLUSIONS

The techno-economic objectives of the ELY4OFF project have been outlined in table form. However, as discussed this does is given at the maximum current density of the system and further objectives of this project aim to lower this as the electrolyser follows the solar profile (using less energy at lower current densities).

Typically, the efficiency of power electronics lowers as the power density lowers so there is a techno-economic object to maintain the efficiency of the PSU throughout the solar cycle.

These are all aimed at lowering the energy cost (and therefore the financial cost) of the hydrogen produced, maximising the hydrogen produced for a given amount of solar panels.