

# Fuel cells and Hydrogen Joint Undertaking (FCH JU) - Knowledge management data collection

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## 1. Introduction

The FCH JU finances research and innovation projects aiming at bringing fuel cells and hydrogen technologies to market readiness. To this end, it publishes calls for proposals, manages proposal evaluations and ultimately follows project implementation.

In order to assess the effectiveness of its research programme and the needs for further technological developments (to be translated into new calls for proposals), the FCH JU has been mandated to collect data on relevant technologies in a systematic and uniform way.

This need was identified early after the set-up of the FCH JU and follows the explicit request of the FCH JU governing board, reflecting the will of all 3 members of the FCH JU: the European Commission, Hydrogen Europe, representing the industrial stakeholders and N.ERGHY, representing the research community.

The FCH JU has built a Knowledge Management system (TEMONAS) to securely collect and store the data that it collects. The system is intended to yield comparable data from the projects funded by the FCH JU by clearly setting the relevant:

- parameters
- units
- reference period/ date (annual granularity)

FCH JU-supported projects have a contractual obligation to comply with the submission of these data points according to article II.10 of FP7 grant agreements (selected under calls 2008 to 2013) and to dedicated project deliverables in Horizon 2020 projects (selected under calls 2014 onwards).

The outcome as a coherent and comprehensive vision of the fuel cells and hydrogen sector is critical for its further development and visibility, and for fostering political and financial support

## 2. Data collection

Data is to be collected through a series of template questionnaires tailored to the various technologies and their readiness level, to be answered annually by the funded projects: each project is to be divided into one or more “research object” defining a specific reporting item within the project scope. Each of these research objects will be associated to a specific template questionnaire.

The existing template questionnaires are listed below:

- Car demonstration
- Bus demonstration
- Material handling vehicle demonstration
- Auxiliary power unit demonstration
- Hydrogen refueling station demonstration
- Hydrogen refueling station research
- Electrolysis demonstration
- Electrolysis – research at system level
- Electrolysis – research at stack level or lower
- Hydrogen production other than electrolysis – demonstration
- Hydrogen production other than electrolysis – research
- Hydrogen storage
- Stationary fuel cell system demonstration
- Fuel cells – research at system level
- Fuel cells – research at stack level or lower
- Diagnostic systems
- Pre-normative research

The template questionnaire within each research object is divided into descriptive and variable parameters, and for each parameter, the intended meaning / calculation method is specified.

Descriptive parameters define the item addressed in the questionnaire and set the scene for the variable parameters which will report the project progress/results. In principle, descriptive parameters do not change during the project lifetime. On the other hand, variable parameters evolve

and will be different from one data collection exercise to the next according to progress achieved during the reference period.

The parameters have been defined in view of allowing a comprehensive overview of the technology status and contain the Key Performance Indicators (KPIs) defined in the FCH JU Multi-Annual Work Plan 2014-2020 (MAWP) or Multi-Annual Implementation Plan 2008-2013 (MAIP).

The parameters requested in each template are listed in Annex 1 – parameter templates.

For transport applications, the parameters are widely in line with the handbooks produced under project “Hylights” funded under FP6 (they can be downloaded from [the FCH JU website](#)).

Each project is expected to provide, to the best of its capabilities, a value for *every* parameter requested. For each parameter, there is also the possibility (optional) to add a comment if it is relevant to give additional information.

The filled questionnaire can only be submitted if, for every single parameter, a value or a comment is provided. This offers the possibility of leaving a parameter unanswered in the case that there is an impossibility to provide a value, for instance because the parameter is not relevant to the project or has not yet been obtained. In such cases, the reason should be given in the comment field.

In general, it will not be acceptable that parameters that are either FCH JU multi-annual KPIs or specified in the “expected impact” section of the call for proposals to which the project has successfully applied are marked as irrelevant to the project itself.

### Data provider

For each project, the coordinator, or another person specifically assigned by the coordinator, will be given access to the TEMONAS interface for reporting and is hereby referred to as “data provider”. To access the system, the data provider will receive a log in name and a starting password (the password can be changed once logged in).

If needed, several data providers can be assigned to a same research object and different data providers can be assigned to different research objects of the same project.

### Input method

The data will be collected online, through a secured connection, in TEMONAS. This program was developed through a project financed by the FCH JU itself, according to the needs defined by the FCH JU Governing Board.

For each research object, the data provider has the possibility (optional) to enter a generic comment, e.g. specifying information relevant to the whole set of data concerned, in addition to the values and comments for the individual parameter.

### Confidentiality

Each single parameter in the template questionnaires can be defined by the data provider as either public or confidential.

Public data will be treated as such and the FCH JU will consider that it can disclose them accordingly. This should be the case for data already public on the internet (e.g. certain product specifications or general information, such as hydrogen refueling station or electrolyser locations etc.).

Confidential data will be treated with extreme care and information will not be made public in any form that could lead to the identification of its origin. Confidential data will be visible exclusively by the FCH JU Programme Office staff and will not be made available to either the FCH JU members or its governing bodies.

More information on data treatment is given in section 3.

### Data aggregation

Research objects in TEMONAS refer either to single items or a group of equivalent items. This is defined individually for each project according to its nature, its description of work and the type of questionnaire concerned. For instance, reporting is expected individually for single

hydrogen refueling stations, electrolysers or industrial-scale CHP units, while aggregated data would be sufficient for a fleet of the same vehicles in a given region or small CHP units deployed in a given region. An intended “rule of thumb” on aggregation levels expected according to the template questionnaires is provided in Annex 2 – data aggregation.

### **Date perimeter**

The questionnaires are to be entered every year through the online TEMONAS interface with results and data relevant to the previous calendar year (e.g. the 2016 data collection concerns data from Jan. 1, 2015 to Dec. 31, 2015). This is required until the full project duration has been covered with data in TEMONAS, i.e. until the year after end date.

## **3. Data utilisation**

Data provided in TEMONAS by the projects will be collected and treated by the FCH JU Programme Office only.

No raw data will be disclosed publicly unless they are provided as “public” in TEMONAS.

### **Data validation (authorization)**

In a first phase, the data will be validated by the relevant Project Managers which will authorise or reject the entire form or the single values provided for the parameters. In this step, the values will be verified in terms of whether they are realistic, whether there is no clerical mistake (order of magnitude, units,...) and whether the “confidential” label (if applicable) is justified (e.g. a vehicle specification available online is expected to be labeled as public in TEMONAS). The Project Manager will also authorise or reject, as appropriate, the reasons put forward for failed delivery of any parameter.

### **Data rejection**

In the case that a parameter is rejected, the data provider will be informed (through an email notification) with an explanation of the reasons for rejection. The data provider will be thus asked to revise the value / comment and resubmit.

Cost claims related to tasks that would lead to parameters that have been rejected may be suspended until an agreement is found between the FCH JU and the project consortium.

### **Data exploitation**

The FCH JU Programme Office will analyse the data obtained and will form a view on technology status.

In comparison with public values obtained through continued technology watch and state of the art values, it will also be able to assess the positioning of FCH JU projects in the global picture.

In time, through comparison of data obtained for different periods, the achievements of the FCH JU will also be traced in terms of technology progress yielded through the projects financed.

### **Data disclosure**

The FCH JU Programme Office is often assisting its members in defining the state of the art or providing information on project progress.

As is customary with deliverables and reports, only public data will be disclosed in this context, unless aggregation of several comparable data is possible to provide anonymized and unrecognisable output.

## Annex 1 – parameter templates

The parameters request in the various template questionnaires (see list below) are detailed in this annex.

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**Descriptive parameters**

- 1 System location - country/cluster
- 2 System location - city
- 3 Start date(s) of operation
- 4 Manufacturer/supplier of the vehicle(s)
- 5 Model of the vehicle(s)
- 6 Type of vehicle
- 7 Date of production (year)
- 8 Power - drivetrain
- 9 Power density - drivetrain
- 10 Driving range
- 11 Speed - Maximum
- 12 Acceleration time 0-50 km/h
- 13 Acceleration time 0-100 km/h
- 14 Weight
- 15 Height
- 16 Length
- 17 Width
- 18 Capacity- number of seated passengers
- 19 Hydrogen storage capacity (on-board)
- 20 Pressure of the on-board hydrogen tank - rated
- 21 Efficiency - tank-to-wheel - rated
- 22 Efficiency of the fuel cell - rated
- 23 Durability / lifetime of the fuel cell vehicle - rated
- 24 Durability / lifetime of the fuel cell system - rated
- 25 Ambient temperature - Minimum
- 26 Ambient temperature - Maximum
- 27 Cost - specific cost/price of the fuel cell system - actual
- 28 Cost - specific cost of the fuel cell system @ mass production (estimate)
- 29 Cost/price of the vehicle
- 30 Cost of the vehicle @ mass production (estimate)
- 31 Cost - total cost of ownership (TCO)

**Variable parameters**

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Number of vehicles deployed - in service
- 4 Number of vehicles deployed - total
- 5 Hours of operation - total
- 6 Hours of operation - cumulative
- 7 Distance driven
- 8 Distance driven - cumulative in the project
- 9 Distance driven - cumulative overall
- 10 Distance driven - between refuellings/rechargings - average
- 11 Number of hydrogen refuellings
- 12 Quantity of hydrogen per refuelling
- 13 Quantity of hydrogen consumed
- 14 Quantity of hydrogen consumed - cumulative in the project
- 15 Rate of hydrogen refuelling - average
- 16 Consumption - hydrogen
- 17 Number of electric recharges
- 18 Quantity of electricity per recharge
- 19 Quantity of electricity fed
- 20 Quantity of electricity fed - cumulative in the project
- 21 Consumption - electricity from recharges
- 22 Availability of the vehicle(s) - average
- 23 Distance between failures - mean (MDBF) - average
- 24 Downtime - overall
- 25 Downtime due to scheduled maintenance/upgrades
- 26 Downtime of vehicles due to stack issues
- 27 Downtime of vehicles due to peripheric mechanical components
- 28 Downtime of vehicles due to electrical components
- 29 Downtime of vehicles due to the on-board hydrogen storage tank
- 30 Downtime of vehicles due to the high voltage battery
- 31 Number of safety incidents - total
- 32 Number of events - type 1
- 33 Number of events - type 2
- 34 Number of events - type 3
- 35 Number of events - type 4
- 36 Number of events - type 5
- 37 Cost - operational and maintenance costs

## Descriptive parameters

- 1 System location - country/cluster
- 2 System location - city
- 3 Start date(s) of operation
- 4 Manufacturer/supplier of the vehicle(s)
- 5 Model of the vehicle(s)
- 6 Date of production (year)
- 7 Operator of the bus(es)
- 8 Power - drivetrain
- 9 Power density - drivetrain
- 10 Speed - Maximum
- 11 Acceleration time 0-50 km/h
- 12 Driving range
- 13 Weight
- 14 Height
- 15 Length
- 16 Width
- 17 Capacity- number of seated passengers
- 18 Capacity - number of standing passengers
- 19 Hydrogen storage capacity (on-board)
- 20 Pressure of the on-board hydrogen tank - rated
- 21 Efficiency - tank-to-wheel - rated
- 22 Efficiency of the fuel cell - rated
- 23 Durability / lifetime of the fuel cell vehicle - rated
- 24 Durability / lifetime of the fuel cell system - rated
- 25 Ambient temperature - Minimum
- 26 Ambient temperature - Maximum
- 27 Cost/price of the vehicle
- 28 Cost of the vehicle @ mass production (estimate)
- 29 Cost - specific cost/price of the fuel cell system - actual
- 30 Cost - specific cost of the fuel cell system @ mass production (estimate)
- 31 Cost - total cost of ownership (TCO)

## Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Number of vehicles deployed - in service
- 4 Number of vehicles deployed - total
- 5 Hours of operation - total
- 6 Hours of operation - cumulative
- 7 Distance driven
- 8 Distance driven - cumulative in the project
- 9 Distance driven - cumulative overall
- 10 Distance driven - between refuellings - average
- 11 Distance between failures - mean (MDBF) - average
- 12 Durability / lifetime of the fuel cell system - observed
- 13 How many fuel cell stack(s) has (have) been replaced on the vehicle(s)?
- 14 Durability / total distance driven with the fuel cell system - observed
- 15 Consumption - hydrogen
- 16 Quantity of hydrogen consumed
- 17 Quantity of hydrogen consumed - cumulative in the project
- 18 Quantity of hydrogen per refuelling
- 19 Rate of hydrogen refuelling - average
- 20 Number of hydrogen refuellings
- 21 Availability of the vehicle(s) - average
- 22 Cost - operational and maintenance costs
- 23 Downtime - overall
- 24 Downtime due to scheduled maintenance/upgrades
- 25 Downtime of vehicles due to stack issues
- 26 Downtime of vehicles due to peripheral mechanical components
- 27 Downtime of vehicles due to electrical components
- 28 Downtime of vehicles due to the on-board hydrogen storage tank
- 29 Downtime of vehicles due to the high voltage battery
- 30 Number of safety incidents - total
- 31 Number of events - type 1
- 32 Number of events - type 2
- 33 Number of events - type 3
- 34 Number of events - type 4
- 35 Number of events - type 5

## Material handling

### Descriptive parameters

- 1 System location - country
- 2 System location - city
- 3 Start date(s) of operation
- 4 Manufacturer/supplier of the vehicle(s)
- 5 Date of production (year)
- 6 Model of the vehicle(s)
- 7 Type of material handling vehicle
- 8 Class of material handling vehicle
- 9 Load capacity
- 10 Power - drivetrain
- 11 Power density - drivetrain
- 12 Weight
- 13 Height
- 14 Length
- 15 Width
- 16 Hydrogen storage capacity (on-board)
- 17 Pressure of the on-board hydrogen tank - rated
- 18 State of the hydrogen in the storage tank
- 19 Efficiency of the fuel cell - rated
- 20 Durability / lifetime of the fuel cell vehicle - rated
- 21 Durability / lifetime of the fuel cell system - rated
- 22 Ambient temperature - Minimum
- 23 Ambient temperature - Maximum
- 24 Cost/price of the vehicle
- 25 Cost of the vehicle @ mass production (estimate)
- 26 Cost - specific cost/price of the fuel cell system - actual
- 27 Cost - specific cost of the fuel cell system @ mass production (estimate)
- 28 Cost - hydrogen storage system cost
- 29 Cost - total cost of ownership (TCO) - MHV

## vehicle demonstration

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Number of vehicles deployed - in service
- 4 Number of vehicles deployed - total
- 5 Hours of operation - total
- 6 Hours of operation - cumulative
- 7 Hours of operation between refuellings
- 8 Consumption - hydrogen (hourly)
- 9 Quantity of hydrogen consumed
- 10 Quantity of hydrogen consumed - cumulative in the project
- 11 Rate of hydrogen refuelling - average
- 12 Number of hydrogen refuellings
- 13 Availability of the vehicle(s) - average
- 14 Mean time between failures (MTBF)
- 15 Downtime - overall
- 16 Downtime due to scheduled maintenance/upgrades
- 17 Downtime of vehicles due to electrical components
- 18 Downtime of vehicles due to the high voltage battery
- 19 Downtime of vehicles due to the on-board hydrogen storage tank
- 20 Downtime of vehicles due to peripheric mechanical components
- 21 Downtime of vehicles due to stack issues
- 22 Number of events - type 1
- 23 Number of events - type 2
- 24 Number of events - type 3
- 25 Number of events - type 4
- 26 Number of events - type 5
- 27 Cost - operational expenditure (OPEX) - MHV

## Auxiliary

## power

## unit

## demonstration

### Descriptive parameters

- 1 System location - country
- 2 Vehicle for the APU
- 3 Start date of operation
- 4 Manufacturer/supplier of the APU
- 5 Manufacturer/supplier of the stack(s)
- 6 Technology of the fuel cell
- 7 Type of fuel
- 8 Capacity of the system - rated
- 9 Capacity of the stack - rated
- 10 Weight (APU)
- 11 Volume
- 12 Noise
- 13 Operating pressure
- 14 Operating temperature
- 15 Ambient temperature - Minimum
- 16 Ambient temperature - Maximum
- 17 Durability / lifetime of the fuel cell system - rated
- 18 Durability / lifetime of the stack(s) - rated
- 19 Electrical efficiency of the stack(s) (rated - LHV)
- 20 Total Efficiency of the system - (rated - LHV)
- 21 Cost - capital cost of the system (per kW)
- 22 Cost - capital cost of the system (per kW) @ mass production (estimate)
- 23 Time for break-even

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total
- 4 Hours of operation - cumulative
- 5 Operating time per day
- 6 Time for cold start to rated power (from - 20°C)
- 7 Time for cold start to rated power (from +20°C)
- 8 Amount of fuel consumed
- 9 Electrical efficiency of the stack(s) (observed - LHV)
- 10 Total Efficiency of the system - (observed - LHV)
- 11 Electricity produced - total
- 12 Useful heat output
- 13 Availability of the system(s)
- 14 Mean time between failures (MTBF)
- 15 Emissions - CO<sub>2</sub> emissions per electricity output
- 16 Emissions - SO<sub>x</sub> emissions per electricity output
- 17 Emissions - NO<sub>x</sub> emissions per electricity output
- 18 Number of safety incidents - total
- 19 Cost - operational expenditure (OPEX)

## Hydrogen

## refueling

## station

## demonstration

### Descriptive parameters

- 1 System location - country
- 2 System location - city
- 3 System location - post code
- 4 System location - surroundings
- 5 Start date of operation
- 6 Operator of the hydrogen refuelling station (HRS)
- 7 Hydrogen refuelling station access
- 8 Type of refuelling operation
- 9 Footprint - station
- 10 Number of hydrogen dispensers
- 11 Number of nozzles
- 12 Hydrogen storage capacity (on-site)
- 13 Pressure of the on-site storage tank - rated
- 14 Pressure of the hydrogen dispensed
- 15 Nominal dispensing capacity of the station - hourly
- 16 Nominal dispensing capacity of the station - daily
- 17 Refuelling protocol
- 18 Number of cars per hour
- 19 Number of cars per day
- 20 Number of buses per hour
- 21 Number of buses per day
- 22 Hydrogen supply logistics
- 23 Technology of the onsite hydrogen production
- 24 Fraction of renewable energy input
- 25 Source of renewable energy input
- 26 Production rate of hydrogen - on-site
- 27 Cost - capital expenditure (CAPEX)

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Vehicles refuelled
- 4 Operating time per day
- 5 Days of operation - total
- 6 Hours of operation - cumulative (HRS)
- 7 Quantity of hydrogen produced (HRS)
- 8 Quantity of hydrogen delivered to the hydrogen refuelling station
- 9 Distance from the hydrogen production site
- 10 Quantity of hydrogen dispensed daily - average
- 11 Quantity of hydrogen dispensed
- 12 Number of hydrogen refuelling operations
- 13 Number of daily refuellings - average
- 14 Refuelling time @200 bar - average
- 15 Refuelling time @350 bar - average
- 16 Refuelling time @700 bar - average
- 17 Utilisation rate of the hydrogen refuelling station
- 18 Availability of the hydrogen refuelling station - Average
- 19 Downtime - overall (HRS)
- 20 Downtime due to scheduled maintenance/upgrades (HRS)
- 21 Downtime of the hydrogen refuelling station due to the compressor/pump
- 22 Downtime of the hydrogen refuelling station due to the hydrogen storage facility
- 23 Downtime of the hydrogen refuelling station due to the refuelling dispensers
- 24 Downtime of the hydrogen refuelling station due to electrical components
- 25 Downtime of the hydrogen refuelling station due to software issues
- 26 Downtime of the hydrogen refuelling station due to the onsite hydrogen production unit
- 27 Mean time between failures (MTBF)
- 28 Number of safety incidents - total
- 29 Nr of safety incidents of level 1 - catastrophic
- 30 Nr of safety incidents of level 2 - severe loss
- 31 Nr of safety incidents of level 3 - major damage
- 32 Nr of safety incidents of level 4 - damage
- 33 Nr of safety incidents of level 5 - minor damage
- 34 Utilisation rate of the onsite hydrogen production unit
- 35 Availability of the onsite hydrogen production unit - Average
- 36 Cost - operational expenditure (OPEX)
- 37 Cost of hydrogen

## Hydrogen

## refueling

## station

## research

### Descriptive parameters

- 1 Nominal dispensing capacity of the station - hourly
- 2 Nominal dispensing capacity of the station - daily
- 3 Number of cars per hour
- 4 Number of cars per day
- 5 Number of buses per hour
- 6 Number of buses per day
- 7 Component addressed within the project
- 8 Footprint - station
- 9 Protocols and standards
- 10 Scalability & modularity
- 11 Hydrogen supply logistics
- 12 Technology of the onsite hydrogen production
- 13 Source of renewable energy input
- 14 Fraction of renewable energy input
- 15 Production rate of hydrogen - on-site
- 16 Volume - production unit
- 17 Hydrogen storage capacity (on-site)
- 18 State of the hydrogen in the storage tank
- 19 Pressure of the on-site storage tank - rated
- 20 Noise - compressor
- 21 State of the hydrogen at dispensing
- 22 Pressure of the hydrogen dispensed
- 23 Cost - capital expenditure (CAPEX) - estimated
- 24 Cost - capital expenditure (CAPEX) (estimate) - components
- 25 Cost - capital expenditure (CAPEX) (estimate) - components @ mass production

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Technology readiness level (TRL) - station
- 4 Vehicles refuelled
- 5 Days of operation - total
- 6 Hours of operation - cumulative (HRS)
- 7 Number of daily refuellings - average
- 8 Number of hydrogen refuelling operations
- 9 Refuelling time @200 bar - average
- 10 Refuelling time @350 bar - average
- 11 Refuelling time @700 bar - average
- 12 Utilisation rate of the hydrogen refuelling station
- 13 Availability of the hydrogen refuelling station - Average
- 14 Quantity of hydrogen delivered to the hydrogen refuelling station
- 15 Quantity of hydrogen produced (HRS)
- 16 Quantity of hydrogen dispensed
- 17 Quantity of hydrogen dispensed daily - average
- 18 Metering accuracy
- 19 System energy consumption for hydrogen compression
- 20 Technology readiness level (TRL) - components
- 21 Cost of hydrogen
- 22 Cost - operational expenditure (OPEX) - estimate

## Electrolysis

### Descriptive parameters

- 1 System location - country
- 2 System location - city
- 3 System location - post code
- 4 Start date of operation
- 5 Manufacturer/supplier
- 6 Manufacturer/supplier of the stack(s)
- 7 Technology of the electrolyser
- 8 Production rate of hydrogen - rated - daily weight
- 9 Production rate of hydrogen - rated - hourly volume
- 10 Capacity of the system - rated
- 11 Capacity of the stack - rated
- 12 Footprint - hydrogen production unit
- 13 Volume
- 14 Nature of the electricity source
- 15 Fraction of renewable energy input
- 16 Durability / Lifetime of the system - rated
- 17 Durability / lifetime of the stack(s) - rated
- 18 Quality required for water
- 19 Purity of the produced hydrogen - rated
- 20 Type of power converter
- 21 Input voltage
- 22 Power usage of auxiliary equipment - idle
- 23 Power usage of auxiliary equipment - max production
- 24 Electrical efficiency of the stack(s) (rated - HHV - DC current)
- 25 Electrical efficiency of the system (rated - HHV - AC current)
- 26 Planned maintenance - duration
- 27 Cost - capital cost of the system (per kW)
- 28 Cost - capital cost of the system (per ton/day)
- 29 Cost - capital cost of the system (per ton/day) @ mass production (estimate)

## demonstration

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total (system)
- 4 Hours of operation - cumulative (system)
- 5 Operating time per day
- 6 Transient response time
- 7 Time for hot start to 100% H2 output rate
- 8 Time for hot start to 100% power
- 9 Time for cold start to 100% H2 output rate
- 10 Time for cold start to 100% power
- 11 Part-load operation - minimum
- 12 Ramping flexibility - minimum power
- 13 Ramping flexibility - maximum power
- 14 Operating pressure
- 15 Operating temperature
- 16 Quantity of hydrogen produced
- 17 Electricity consumed - total (system)
- 18 Availability of the system(s)
- 19 Efficiency degradation
- 20 Degradation rate in  $\mu\text{V}/\text{h}$
- 21 Degradation rate in  $\%/ \text{kh}$
- 22 Electrical efficiency of the stack(s) (observed - HHV - DC current)
- 23 Electrical efficiency of the system (observed - HHV - AC current)
- 24 System energy consumption for hydrogen production
- 25 System energy consumption for hydrogen compression
- 26 Operating profile
- 27 Number of safety incidents - total
- 28 Price/cost of electricity
- 29 Cost of electricity consumed - levelised (LCOE)
- 30 Cost - operational expenditure (OPEX)
- 31 Cost of the hydrogen produced

## Electrolysis – research at system level

### Descriptive parameters

- 1 Manufacturer/supplier
- 2 Manufacturer/supplier of the stack(s)
- 3 Technology of the electrolyser
- 4 Number of units per system
- 5 Number of stacks per unit
- 6 Number of cells per stack
- 7 Production rate of hydrogen - rated - daily weight
- 8 Production rate of hydrogen - rated - hourly volume
- 9 Capacity of the system - rated
- 10 Capacity of the stack - rated
- 11 Durability / Lifetime of the system - rated
- 12 Durability / lifetime of the stack(s) - rated
- 13 Quality required for water
- 14 Type of power converter
- 15 Input voltage
- 16 Power usage of auxiliary equipment - idle
- 17 Power usage of auxiliary equipment - max production
- 18 Catalyst at the anode
- 19 Catalyst at the cathode
- 20 Cell area - active
- 21 Purity of the produced hydrogen - rated
- 22 Electrical efficiency of the system (rated - HHV - AC current)
- 23 Electrical efficiency of the stack(s) (rated - HHV - DC current)
- 24 Cost - capital cost of the system (per kW)
- 25 Cost - capital cost of the system (per ton/day)
- 26 Cost - capital cost of the system (per ton/day) @ mass production (estimate)
- 27 Cost - balance of plant (BoP)

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total (system)
- 4 Hours of operation - cumulative (system)
- 5 Operating time per day
- 6 Transient response time
- 7 Time for hot start to 100% H2 output rate
- 8 Time for hot start to 100% power
- 9 Time for cold start to 100% H2 output rate
- 10 Time for cold start to 100% power
- 11 Part-load operation - minimum
- 12 Operating pressure
- 13 Operating temperature
- 14 Quantity of hydrogen produced
- 15 Electricity consumed - total (system)
- 16 Availability of the system(s)
- 17 Availability of the stack(s)
- 18 Efficiency degradation
- 19 Electrical efficiency of the system (observed - HHV - AC current)
- 20 Electrical efficiency of the stack(s) (observed - HHV - DC current)
- 21 System energy consumption for hydrogen production
- 22 System energy consumption for hydrogen compression
- 23 Stack energy consumption for hydrogen production
- 24 Operating profile
- 25 Current density
- 26 Heat loss density
- 27 Power density
- 28 Cell voltage
- 29 Degradation rate in  $\mu\text{V/h}$
- 30 Degradation rate in  $\%/kh$
- 31 Catalyst loading - Anode (in  $\text{mg/cm}^2$ )
- 32 Catalyst loading - Cathode (in  $\text{mg/cm}^2$ )
- 33 Catalyst loading - Overall (in  $\text{mg/cm}^2$ )
- 34 Catalyst loading - Anode - in  $\text{g}/(\text{kg H}_2/\text{day})$
- 35 Catalyst loading - Cathode - in  $\text{g}/(\text{kg H}_2/\text{day})$
- 36 Catalyst loading - Overall - in  $\text{g}/(\text{kg H}_2/\text{day})$

## Electrolysis – research at stack level

### Descriptive parameters

- 1 Technology of the fuel cell
- 2 Type of fuel
- 3 Number of stacks per unit
- 4 Number of cells per stack
- 5 Capacity of the stack - rated
- 6 Durability / lifetime of the stack(s) - rated
- 7 Purity required for the fuel
- 8 Cell area - active
- 9 Catalyst at the cathode
- 10 Catalyst at the anode
- 11 Cost - capital cost of the stack (per kW)
- 12 Cost - capital cost of the stack (per kW) @ mass production (estimate)

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total (stack)
- 4 Hours of operation - cumulative (stack)
- 5 Operating time per day
- 6 Transient response time
- 7 Time for cold start to rated power (from +20°C)
- 8 Time for cold start to rated power (from -20°C)
- 9 Operating pressure
- 10 Operating temperature
- 11 Ambient temperature - Minimum
- 12 Ambient temperature - Maximum
- 13 Availability of the stack(s)
- 14 Fuel utilisation rate
- 15 Electricity produced - total
- 16 Electrical efficiency of the stack(s) (observed - LHV)
- 17 Total efficiency of the stack - (observed - LHV)
- 18 Current density
- 19 Power density
- 20 Cell voltage
- 21 Degradation rate in  $\mu\text{V/h}$
- 22 Degradation rate in  $\%/kh$
- 23 Catalyst loading - Anode (in  $\text{mg/cm}^2$ )
- 24 Catalyst loading - Cathode (in  $\text{mg/cm}^2$ )
- 25 Catalyst loading - Overall (in  $\text{mg/cm}^2$ )
- 26 Catalyst loading - Anode (in  $\text{g/kW}$ )
- 27 Catalyst loading - Cathode (in  $\text{g/kW}$ )
- 28 Catalyst loading - Overall (in  $\text{g/kW}$ )

## Hydrogen production other than electrolysis - demonstration

### Descriptive parameters

- 1 System location - country
- 2 System location - city
- 3 System location - post code
- 4 Start date of operation
- 5 Description of the demo object
- 6 Manufacturer/supplier of the H2 production unit
- 7 Feedstock
- 8 Main energy source
- 9 Secondary energy input/parasitic losses - if applicable
- 10 Purification of hydrocarbon feed before reactor
- 11 Purification of water feed before reactor
- 12 Catalyst(s)
- 13 Hydrogen purification method
- 14 Footprint - hydrogen production unit
- 15 Volume
- 16 Production rate of hydrogen - rated - daily weight
- 17 Durability / Lifetime of the system - rated
- 18 Purity of the produced hydrogen - rated
- 19 Conversion efficiency @ start of operations
- 20 Technology readiness level (TRL) @start of operations
- 21 Cost - capital cost of the system (per ton/day)
- 22 Cost - capital cost of the system (per ton/day) @ mass production (estimate)

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total (system)
- 4 Hours of operation - cumulative (system)
- 5 Operating time per day
- 6 Time for hot start to 100% H2 output rate
- 7 Time for cold start to 100% H2 output rate
- 8 Part-load operation - minimum
- 9 Operating pressure
- 10 Operating temperature
- 11 Quantity of hydrogen produced
- 12 Availability of the system(s)
- 13 Conversion efficiency @ start of reporting period
- 14 Efficiency degradation
- 15 Number of times the catalyst was replaced
- 16 Number of times the reactor was replaced
- 17 Number of times the fermenting/biological agents were replaced
- 18 Number of times hydrogen purification membrane was replaced
- 19 Purity of the produced hydrogen before purification
- 20 Purity of the produced hydrogen after purification
- 21 System energy consumption for hydrogen production
- 22 System energy consumption for hydrogen compression
- 23 Number of safety incidents - total
- 24 Technology readiness level (TRL) @start of timeframe
- 25 Cost of the hydrogen produced
- 26 OPEX

## Hydrogen production other than electrolysis - research

### Descriptive parameters

- 1 Feedstock
- 2 Main energy source
- 3 Secondary energy input/parasitic losses - if applicable
- 4 Purification of hydrocarbon feed before reactor
- 5 Purification of water feed before reactor
- 6 Catalyst(s)
- 7 Hydrogen purification method

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total (system)
- 4 Hours of operation - cumulative (system)
- 5 Time for hot start to 100% H2 output rate
- 6 Time for cold start to 100% H2 output rate
- 7 Part-load operation - minimum
- 8 Operating pressure
- 9 Operating temperature
- 10 Quantity of hydrogen produced
- 11 Conversion efficiency @ start of timeframe
- 12 Efficiency degradation
- 13 Number of times the catalyst was replaced
- 14 Number of times the reactor was replaced
- 15 Number of times the fermenting/biological agents were replaced
- 16 Number of times hydrogen purification membrane was replaced
- 17 Purity of the produced hydrogen
- 18 Technology readiness level (TRL) @start of timeframe
- 19 Cost of hydrogen

## Hydrogen

### Descriptive parameters

- 1 State of the hydrogen in the storage tank
- 2 Storage application
- 3 Storage vessel material
- 4 Internal lining (if applicable)
- 5 Hydrogen volumetric capacity
- 6 Hydrogen gravimetric capacity
- 7 Supporting/carrier substrate: nature
- 8 Supporting/carrier substrate: cost
- 9 Supporting/carrier substrate: hydrogen gravimetric capacity
- 10 Maximum pressure - rated
- 11 Minimum temperature - rated
- 12 Maximum temperature - rated
- 13 Volume
- 14 Weight
- 15 Hydrogen storage system cost (CAPEX) per kg of capacity
- 16 Hydrogen storage system cost (CAPEX) per kg capacity @ mass production (estimate)
- 17 Additional CAPEX needed

## storage

### Variable parameters

- 1 Durability / lifetime of the storage system (observed)
- 2 Durability / lifetime of the storage system (projected/estimated)
- 3 Number of charging/discharging cycles achieved
- 4 Maximum number of charging/discharging cycles (estimate)
- 5 Energy to load the hydrogen
- 6 Peak hydrogen charging rate
- 7 Energy to discharge the hydrogen
- 8 Peak hydrogen discharging rate
- 9 Total amount of hydrogen discharged
- 10 Boil-off
- 11 Operational cost

## Stationary fuel cell system demonstration

### Descriptive parameters

- 1 System location - country
- 2 System location - city
- 3 System location - post code
- 4 Start date(s) of operation
- 5 Manufacturer/supplier
- 6 Manufacturer/supplier of the stack(s)
- 7 Technology of the fuel cell
- 8 Type of fuel
- 9 Capacity of the system - rated
- 10 Capacity of the stack - rated
- 11 Volume
- 12 Operating pressure
- 13 Operating temperature
- 14 Ambient temperature - Minimum
- 15 Ambient temperature - Maximum
- 16 Durability / lifetime of the fuel cell system - rated
- 17 Durability / lifetime of the stack(s) - rated
- 18 Electrical efficiency of the system (rated - LHV)
- 19 Total Efficiency of the system - (rated - LHV)
- 20 Emissions - CO<sub>2</sub> emissions per electricity output
- 21 Emissions - SO<sub>x</sub> emissions per electricity output
- 22 Emissions - NO<sub>x</sub> emissions per electricity output
- 23 Noise
- 24 Cost - capital cost of the system (per kW)
- 25 Cost - capital cost of the system (per kW) @ mass production (estimate)

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Number of demonstration systems deployed
- 4 Hours of operation - total
- 5 Hours of operation - cumulative
- 6 Operating time per day
- 7 Durability / lifetime of the fuel cell system - observed
- 8 How many fuel cell stack(s) has (have) been replaced on the vehicle(s)?
- 9 Transient response time
- 10 Time for cold start to rated power (from - 20°C)
- 11 Time for cold start to rated power (from +20°C)
- 12 Operating profile
- 13 Electricity produced - total
- 14 Useful heat output
- 15 Availability of the system(s)
- 16 Electrical efficiency of the system (observed - LHV)
- 17 Total Efficiency of the system - (observed - LHV)
- 18 Number of safety incidents - total
- 19 Cost - operational expenditure (OPEX)
- 20 Cost/price of the hydrogen fuel
- 21 Cost of other fuel
- 22 Cost of electricity generated - levelised (LCOE)

## Fuel cells – research at system level

### Descriptive parameters

- 1 Manufacturer/supplier
- 2 Manufacturer/supplier of the stack(s)
- 3 Technology of the fuel cell
- 4 BoP component of interest
- 5 Type of fuel
- 6 Number of units per system
- 7 Number of stacks per unit
- 8 Number of cells per stack
- 9 Capacity of the system - rated
- 10 Durability / lifetime of the fuel cell system - rated
- 11 Durability / lifetime of the stack(s) - rated
- 12 Purity required for the fuel
- 13 Catalyst at the cathode
- 14 Catalyst at the anode
- 15 Cell area - active
- 16 Electrical efficiency of the system (rated - LHV)
- 17 Total Efficiency of the system - (rated - LHV)
- 18 Electrical efficiency of the stack(s) (rated - LHV)
- 19 Total efficiency of the stack - (rated - LHV)
- 20 Cost - capital cost of the system (per kW)
- 21 Cost - capital cost of the system (per kW) @ mass production (estimate)
- 22 Cost - balance of plant (BoP)

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total (system)
- 4 Hours of operation - cumulative (system)
- 5 Operating time per day
- 6 Transient response time
- 7 Time for cold start to rated power (from - 20°C)
- 8 Time for cold start to rated power (from +20°C)
- 9 Operating pressure
- 10 Operating temperature
- 11 Ambient temperature - Minimum
- 12 Ambient temperature - Maximum
- 13 Fuel utilisation rate
- 14 Electricity produced - total
- 15 Useful heat output
- 16 Electrical efficiency of the system (observed - LHV)
- 17 Total Efficiency of the system - (observed - LHV)
- 18 Electrical efficiency of the stack(s) (observed - LHV)
- 19 Total efficiency of the stack - (observed - LHV)
- 20 Current density
- 21 Power density
- 22 Cell voltage
- 23 Availability of the system(s)
- 24 Availability of the stack(s)
- 25 Degradation rate in %/kh
- 26 Degradation rate in  $\mu\text{V/h}$
- 27 Catalyst loading - Anode (in  $\text{mg/cm}^2$ )
- 28 Catalyst loading - Anode (in  $\text{g/kW}$ )
- 29 Catalyst loading - Cathode (in  $\text{mg/cm}^2$ )
- 30 Catalyst loading - Cathode (in  $\text{g/kW}$ )
- 31 Catalyst loading - Overall (in  $\text{mg/cm}^2$ )
- 32 Catalyst loading - Overall (in  $\text{g/kW}$ )
- 33 Cost/price of the hydrogen fuel
- 34 Cost of other fuel
- 35 Cost of electricity generated - levelised (LCOE)

## Fuel cells – research at stack level or lower

### Descriptive parameters

- 1 Technology of the fuel cell
- 2 Type of fuel
- 3 Number of stacks per unit
- 4 Number of cells per stack
- 5 Capacity of the stack - rated
- 6 Durability / lifetime of the stack(s) - rated
- 7 Purity required for the fuel
- 8 Cell area - active
- 9 Catalyst at the cathode
- 10 Catalyst at the anode
- 11 Cost - capital cost of the stack (per kW)
- 12 Cost - capital cost of the stack (per kW) @ mass production (estimate)

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total (stack)
- 4 Hours of operation - cumulative (stack)
- 5 Operating time per day
- 6 Transient response time
- 7 Time for cold start to rated power (from +20°C)
- 8 Time for cold start to rated power (from -20°C)
- 9 Operating pressure
- 10 Operating temperature
- 11 Ambient temperature - Minimum
- 12 Ambient temperature - Maximum
- 13 Availability of the stack(s)
- 14 Fuel utilisation rate
- 15 Electricity produced - total
- 16 Electrical efficiency of the stack(s) (observed - LHV)
- 17 Total efficiency of the stack - (observed - LHV)
- 18 Current density
- 19 Power density
- 20 Cell voltage
- 21 Degradation rate in  $\mu\text{V/h}$
- 22 Degradation rate in  $\%/kh$
- 23 Catalyst loading - Anode (in  $\text{mg/cm}^2$ )
- 24 Catalyst loading - Cathode (in  $\text{mg/cm}^2$ )
- 25 Catalyst loading - Overall (in  $\text{mg/cm}^2$ )
- 26 Catalyst loading - Anode (in  $\text{g/kW}$ )
- 27 Catalyst loading - Cathode (in  $\text{g/kW}$ )
- 28 Catalyst loading - Overall (in  $\text{g/kW}$ )

## Diagnostic

### Descriptive parameters

- 1 Targeted sector/application
- 2 Manufacturer/supplier of the stack(s)
- 3 Technology of the system
- 4 Type of fuel
- 5 Purity required for the fuel
- 6 Number of units per system
- 7 Number of stacks per unit
- 8 Number of cells per stack
- 9 Capacity of the system - rated
- 10 Capacity of the stack - rated
- 11 Power usage of the diagnostic/control tool
- 12 Diagnostic tool
- 13 Does your tool measure the degradation?
- 14 Have you developed prognostics tools for remaining lifetime estimation?
- 15 Cost - capital cost of the system (per kW)
- 16 Cost - capital cost of the diagnostic/control system

## systems

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Hours of operation - total (stack)
- 4 Hours of operation - total (system)
- 5 Hours of operation - total (diagnostic)
- 6 Operating pressure
- 7 Operating temperature
- 8 Durability / Lifetime of the system - observed/predicted
- 9 Improvement of the system lifetime - estimate
- 10 Durability / lifetime of the stack(s) - observed/predicted
- 11 Improvement of the stack lifetime - estimate
- 12 Durability / Lifetime of the diagnostic system - observed
- 13 Degradation rate in %/kh (diagnosis)
- 14 Degradation rate in  $\mu\text{V/h}$  (diagnosis)
- 15 Improvement of the degradation rate - estimate
- 16 Electrical efficiency of the system
- 17 Improvement of the system electrical efficiency
- 18 Improvement of the mean time between failures (MTBF) - estimate
- 19 Improvement of the availability - estimate
- 20 Availability of the diagnosis/monitoring system
- 21 Number of fuel cell faults detected
- 22 Number of fuel cell failures detected
- 23 Performance indicator of the diagnostic tool
- 24 Performance indicator towards faults/failures detection due to fuel starvation
- 25 Performance indicator towards faults/failures detection due to air starvation
- 26 Performance indicator towards faults/failures detection due to flooding and dehydration
- 27 Performance indicator towards faults/failures detection due to changes in fuel composition
- 28 Performance indicator towards faults/failures detection due to sulphur poisoning
- 29 Performance indicator towards faults/failures detection due to breaks and/or leakages
- 30 Performance indicator towards faults/failures detection due to delamination
- 31 Performance indicator towards faults/failures detection due to other issues
- 32 Cost - operational expenditure - diagnosis/control
- 33 Cost - operational expenditure - system
- 34 Cost reduction - operational expenditure

## Pre-normative

### Descriptive parameters

- 1 Gap in knowledge addressed
- 2 Project objective
- 3 FCH JU pillar
- 4 Approach
- 5 Target regulation, code or standard
- 6 Targeted organisation
- 7 Targeted technical/working group
- 8 Other RCS addressing the issue tackled by the project
- 9 Foreseen means of improvement/revision of standard
- 10 Collaborations outside EU28

## research

### Variable parameters

- 1 Start date for data entries in the reference year
- 2 End date for data entries in the reference year
- 3 Newly detected relevant RCS activities
- 4 Progress vs knowledge gap
- 5 Standards: is consortium involved first-hand?
- 6 Standard developing organisation(s) contacted to date
- 7 Number of meetings with standard developing organisations
- 8 Number of workshops with standard developing organisations
- 9 Number of reports sent to standard developing organisations
- 10 Regulatory bodies contacted to date
- 11 Number of meetings with regulatory organisations
- 12 Number of workshops with regulatory organisations
- 13 Number of reports sent to regulatory organisations
- 14 Number of peer reviewed publications
- 15 Number of patents
- 16 Number of oral presentations at scientific seminars/conferences
- 17 Nr of posters at scientific seminars/conferences
- 18 Have the project results been integrated (to date) in in any regulation, codes or standards?
- 19 By what year would you expect that the project result become integrated in any regulation, code or standard?

## Annex 2 – data aggregation

The information given below is indicative. The aggregation is always done individually according to the exact nature of the project and its description of work

- Car demonstration: one research object for aggregated data per car model/location (typically this involves several cars within a single research object)
- Bus demonstration: one research object for aggregated data per bus model/location (typically this involves a few buses within a single research object)
- Material handling vehicle (MHV) demonstration: one research object for aggregated data per MHV model/location (typically this involves several MHVs within a single research object)
- Auxiliary power unit demonstration: one research object per unit
- Hydrogen refueling station demonstration: one research object per station
- Hydrogen refueling station research: one research object per project
- Electrolysis demonstration - one research object per unit
- Electrolysis – research at system level: one research object per system
- Electrolysis – research at stack level or lower: one research object per project
- Hydrogen production other than electrolysis - demonstration: one research object per unit
- Hydrogen production other than electrolysis - research: one research object per project
- Hydrogen storage - one research object per unit
- Stationary fuel cell system demonstration: one research objects for aggregated data per CHP unit model/location (typically this involves several CHP within a single research object for micro-CHP but may be for dingle units in case of larger systems)
- Fuel cells – research at system level - one research object per system
- Fuel cells – research at stack level or lower - one research object per project
- Diagnostic systems - one research object per system
- PNR: one research object per project