

Development of Business Cases for Fuel Cells and Hydrogen Applications for Regions and Cities

Electricity grid services





This compilation of application-specific information forms part of the study ***"Development of Business Cases for Fuel Cells and Hydrogen Applications for European Regions and Cities"*** commissioned by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU), N° FCH/OP/contract 180, Reference Number FCH JU 2017 D4259 .

The study aims to **support a coalition of currently more than 90 European regions and cities** in their assessment of fuel cells and hydrogen applications to support project development. Roland Berger GmbH coordinated the study work of the coalition and provided analytical support.

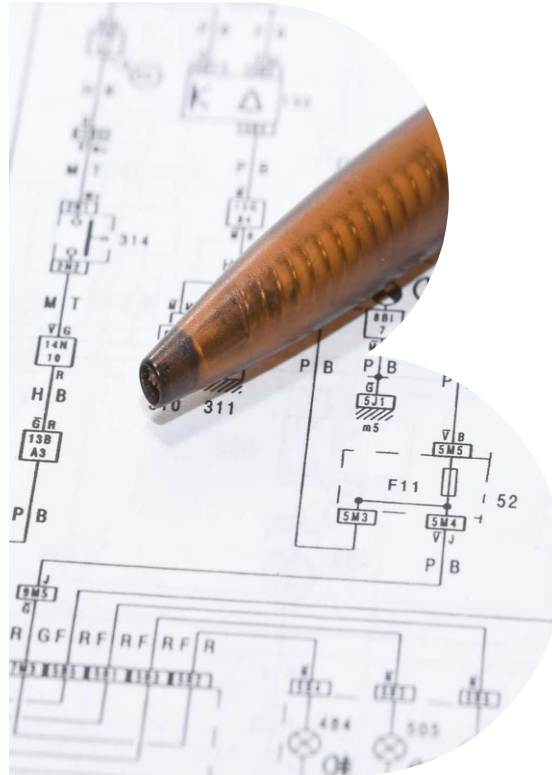
All information provided within this document **is based on publically available sources** and reflects the **state of knowledge as of August 2017**.



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A. Technology Introduction



Electrolysers are already technically capable for services to stabilize the electricity grid and to generate additional revenues

Electricity grid services¹

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		Frequency Containment Reserve (FCR)	Frequency Restoration Reserve (FRR)	Replacement Reserve (RR)
Definition		FCR automatically and continuously regulates the positive and negative frequency fluctuations; electrolysers can support the system via increased/decreased demand	FRR can automatically or manually restore the frequency via operating reserves to replace FCR; electrolysers can support the system via increased/decreased demand	RR is used to restore the required level of operating reserves; supersedes FCR and FRR to be prepared for further disturbances in the grid
Suitable electrolyser technology²		PEM / Alkaline (until now, only tested under lab conditions)	PEM / Alkaline (when operated adequately)	PEM / Alkaline
Requirements		Activation time ≤ 30 s; utilisation for 15 min max; minimum bid size ±1 MW; 1 week commitment per auction	Activation time 2-15 min depending on country-specific regulations; no standardized technical requirements	Activation time (≥ 15 min) depending on country-specific regulations; no standardized technical requirements
Procurement		FCR activation is a joint action of all TSOs in Continental Europe; quite homogeneous technical requirements; joint procurement in Central Europe via auctions organised by TSOs	Fragmented regulation across the European Union; procurement via auctions organised by TSOs in various European countries	Fragmented regulation across the European Union, procurement via auctions organised by TSOs in various European countries

Activation time;
operating time

1) Based on regulation in Continental Europe; power grid frequency of 50.00 Hz

2) Dependent on regulation and requirements in each country

Source: FCH2 JU, Roland Berger

Numerous projects have already been deployed all over Europe using various electrolyser technologies for electricity grid services







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Overall technological readiness: Depending on technology used, system in prototype phase or at pre-commercial / commercial stage; given the significant interest from industry and policy makers alike, there are significant efforts in demonstration projects and deployment initiatives all over Europe



Demonstration projects / deployment examples (selection)

Project	Country	Start	Scope	Project volume
Demo4Grid		2017	Demonstration of 4MW pressurized alkaline electrolyser for grid balancing services under market conditions; demonstration site in Austria and project partners in ES, AT and CH; funded by the FCH2 JU with EUR 2.9 m	EUR 7.7 m
QualiGridS		2017	Establishment of a standardised test for electrolysers performing electricity grid services; performance and business case analysis for (50 – 300 kW) PEM as well as Alkaline electrolysers; funded by the FCH2 JU with EUR 1.9 m and project partners in DE, NO, UK, FR, DK, NL and CH	EUR 2.8 m
H2Future		2017	Joint project of energy suppliers, the steel industry, technology providers and research partners; 6 MW PEM electrolyser, funded by the FCH2 JU with EUR 12m. Hydrogen used for rapid response to provide grid balancing services and supply to hydrogen markets; project partners in AT, DE and NL	EUR 18 m
Ingrid		2016	1.2 MW Alkaline electrolyser for renewable energy electricity with a solid hydrogen storage system and a fuel cell for flexibility services and grid balancing in general	n.a.
HyBalance		2015	PEM electrolyser designed for combined operation providing both grid balancing services and hydrogen for industry and as a fuel for transport; funded by FCH2 JU with EUR 8 m; project partners in DE, DK, FR, BE	EUR 15 m
Myrte		2010	PEM Electrolyser and storage system on the island of Corsica used for electricity grid services	n.a.

*) Technology Readiness Level ▼ ≤ 5 ▼ 6-7 ▼ 8-9

Optimal use of renewable energy electricity and an additional revenue stream for plant operators as key potential benefits

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Use case characteristics

Stakeholders involved



- > Energy supplier, TSO, DSO
- > Operator of electrolyser and ancillary infrastructure (if applicable)
- > Public authority (e.g. regulator, etc.)

Demand and user profile



- > Based on the type of electricity grid service supplied, quick activation time required
- > Reliability of technical equipment to operate in case of electricity grid fluctuations

Deployment requirements



- > Various technical requirements depending on the type of electricity grid service supplied and the regulation in the specific country

Key other aspects



- > n/a

Benefit potential for regions and cities

Environmental



- > Optimal use of generated renewable energy electricity
- > Grid services supplied with hydrogen using electricity that has been generated via renewable energy; potentially replacing conventional plants that grid services

Social



- > Reduced retail electricity prices as cost for re-dispatch reduce with large-scale deployment. Therefore positive effects for especially low income households that are increasingly affected by rising electricity prices
- > Increased stability of power supply

Economic



- > Depending on regulatory framework, opportunity for additional revenues through supplying (negative or positive) operating reserve aside the revenues through hydrogen sales
- > Remuneration for grid services might rise in the coming years through the increasing share of fluctuating renewables in the electricity mix

Other



- > Supplying electricity grid services can be seen as a "secondary revenue stream"; additional revenues on top of a primary revenue stream at low marginal cost

Cost competitiveness and regulation as key challenges for the supply of electricity grid services with electrolyser technologies

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Hot topics / critical issues / key challenges:

- > Increasing **technical performance** (higher efficiencies will enable significantly lower OPEX and thus, higher allowable electricity prices, making the case even with higher initial CAPEX; lower activation time needed to supply specific grid services)
- > **Cost competitiveness** (electricity grid services mostly remunerated via auctions in the European Union, therefore direct competition with other suppliers through pay-as-bid auction)
- > **Regulation** (highly regulated electricity grid services market which is only partly harmonised within the European Union; access to the market for electrolysers varies depending on the country)
- > **Total electricity cost** as key input factor (rising electricity cost reduce competitiveness; business case highly dependent on electricity prices)
- > **System size** (influences the project CAPEX and equipment related OPEX)
- > **Remuneration for operating reserve** (through the liberalisation of the operating reserve market and the allowance of smaller bid sizes, remuneration decreased on average over the last years; however opposite developments possible with increasing share of renewables in the market)

Further recommended reading:



- > FCH 2 JU: "Study on early business cases for H2 in energy storage and more broadly power to H2 applications"; June 2017: [Link](#)
- > FCH 2 JU: "Commercialisation of Energy Storage in Europe"; March 2015: [Link](#)

Key contacts in the coalition:



Please refer to working group clustering in stakeholder list on the share folder

<https://sharefolder.rolandberger.com/project/P005>

B. Preliminary Business Case

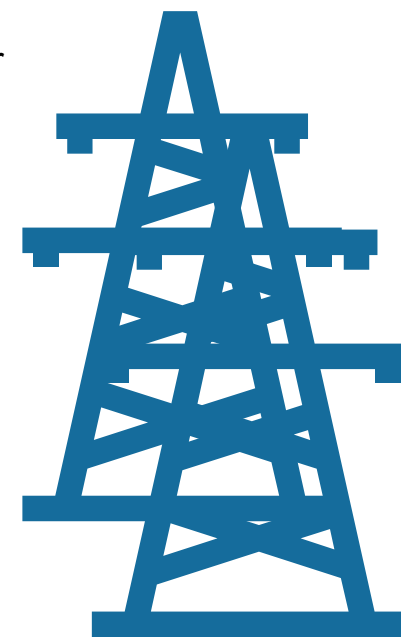


Electrolysers offer strategic value to an electricity grid that increasingly requires balancing – Add. revenue streams for green H₂

Main potential of electrolysers in the context of grid balancing services

- > **With growing shares of renewables in the electricity mix, strategic opportunities for electrolysers are expected to grow as well**, mainly through the more frequent (timely and spatial) convergence of ...
 - Decreasing marginal cost of electricity
 - Increasing need for flexible loads for grid balancing services / higher willingness to pay for load flexibility





... **resulting in overall reduced cost of production for green hydrogen**
- > By shifting (in advance or in delay) from a planned hydrogen production schedule, **electrolysers can adapt its electricity consumption to variable RES production** – and thus provide grid balancing services
- > **Electrolysers can provide low/zero-carbon demand-side grid services** (as secondary revenue stream) – i.e. as new type of "negative load" in the system – vs. supply-side grid services that are currently dominating the grid service markets
- > **Regional differences matter**, when considering electrolysers as grid service providers :
 - Systemic need for balancing grids (and type of balancing services) – e.g. dependent on interconnectivity, scale and type of renewables installed
 - Market mechanisms as shaped by (national) regulations, product definition, procurement rules, technical requirements and remuneration



In principle, electrolysers are technically capable for all three major types of electricity grid services

Typology of electricity grid services¹

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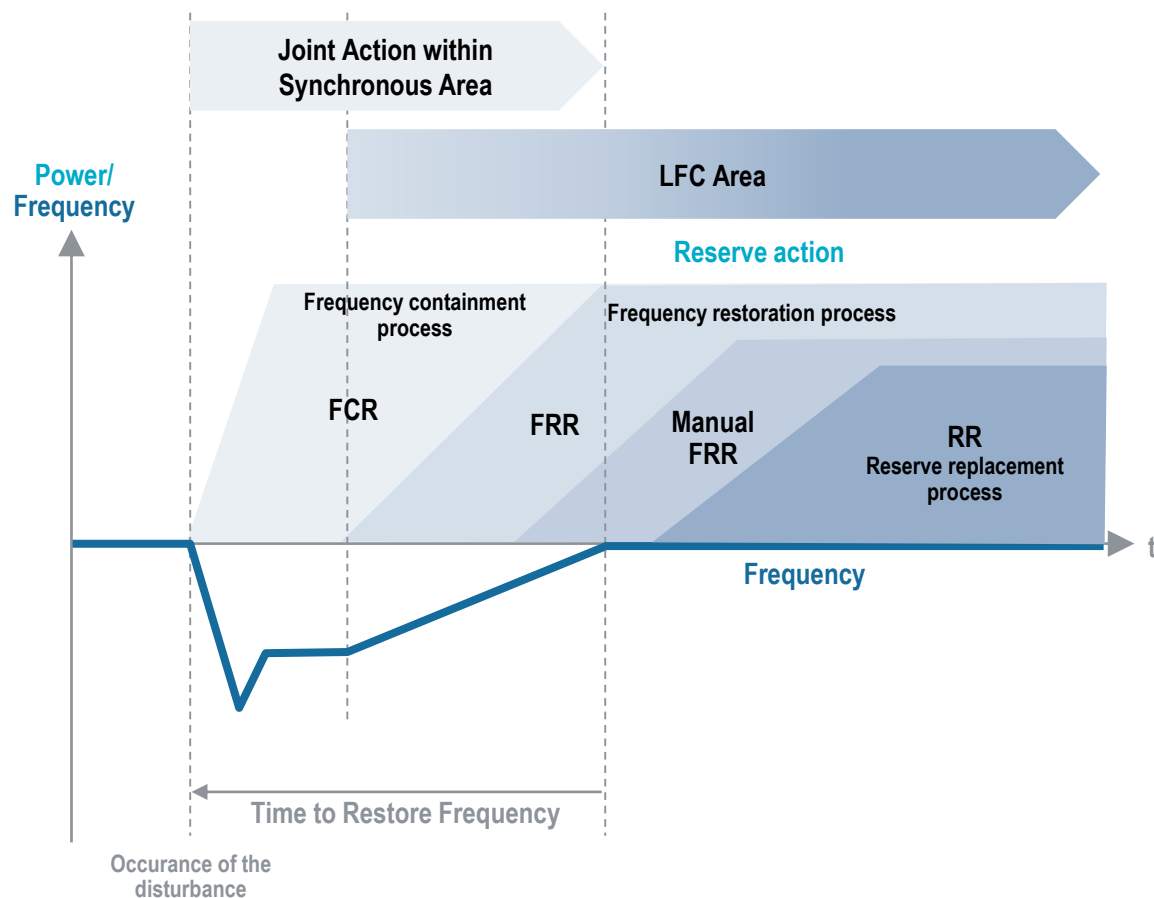
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Activation time; operating time

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The market for grid services presents a significant, albeit secondary, business opportunity

Typology of electricity grid services by activation sequence

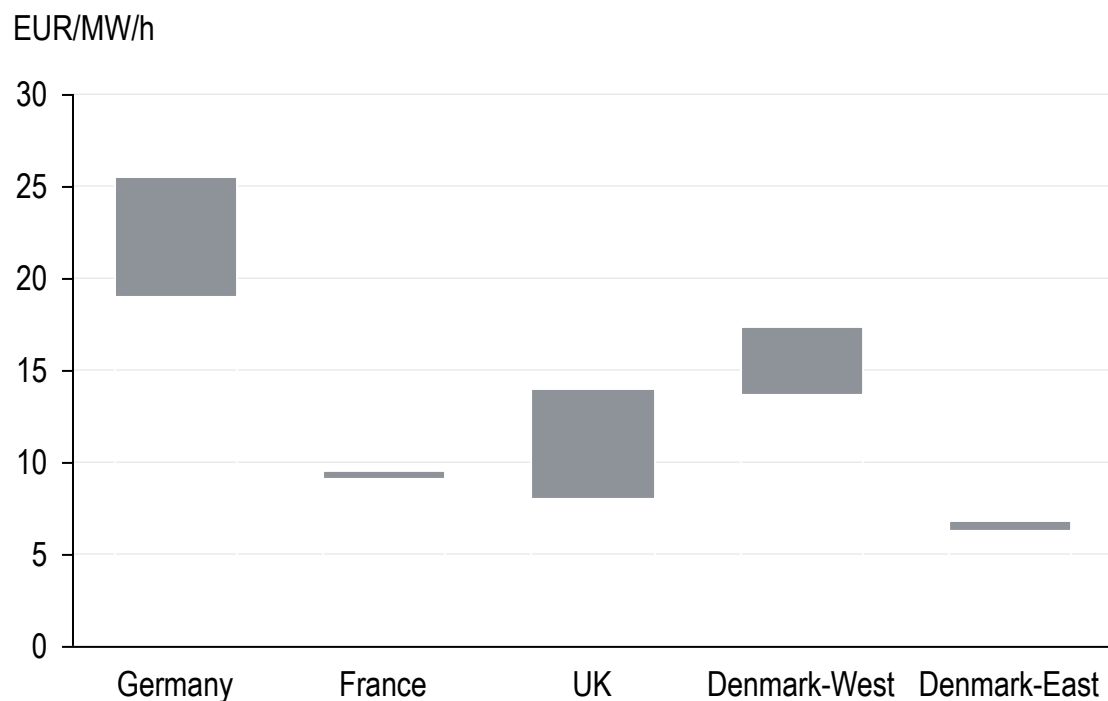


- > **Total market for load frequency services is closely correlated to the size of the power sector** of a country, e.g. in Germany roughly 5 GW of services are procured, i.e. ca. 6% of peak demand
- > **FCR** is activated within max. 30 seconds (during the frequency containment regulation process) to contain frequency changes caused by a disturbance. It is followed by the activation of **FRR** to restore the frequency to 50 Hz and later replaced by the slower **RR** so that FCR resources are disengaged and again available to tackle potential new disturbances
- > **Market is heavily determined by national regulation** for electricity sectors

Regulation is largely national; allocation and remuneration schemes (and thus expected revenues) vary from country to country

Regulation and remuneration

Example: FCR remuneration in 2015 – 2016



> Grid services regulation comprises for example:

- Procurement forms, e.g. organised market ("auctions") vs. mandatory provision
- Forward and commitment periods, e.g. week ahead and 1 week respectively
- Product type, e.g. symmetrical vs. asymmetrical (re. upward/downward load)
- Minimum bid sizes, e.g. 1 MW

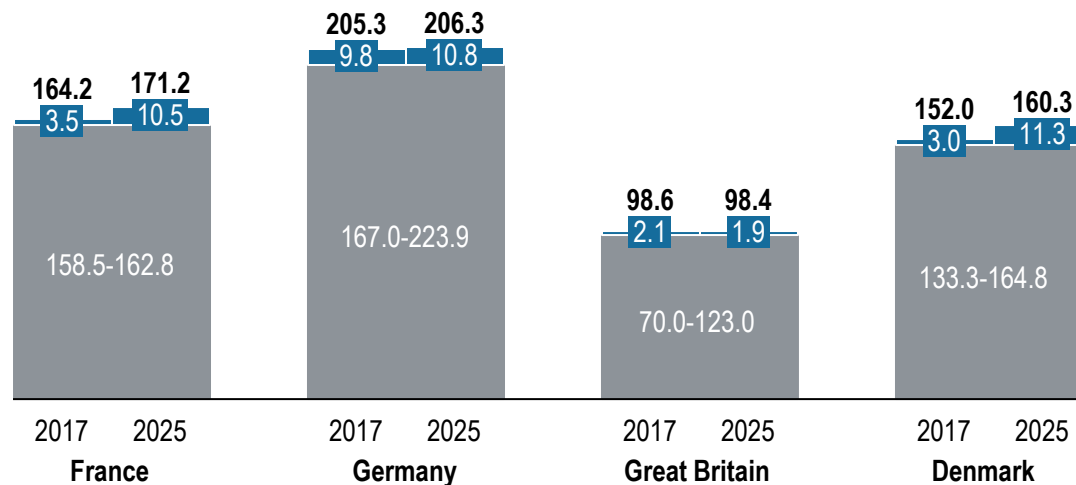
> Remuneration is typically offered on a capacity basis or (capacity + energy activated, settlements occur e.g. based on "pay-as-bid" or regulated prices)

> Thus, the revenue potential from grid services critically depends on the location of the electrolyser (and hence the reduction of the effective cost of green hydrogen production)

Grid services can bring in significant revenues, but electrolysers will look to other H₂ monetisation options as primary source of income

Electrolysers and the economics of grid services

Hypothetical example: expected income from a 1 MW PEM electrolyser [k EUR / MW / year]¹



- > Assuming no conflicts of usage with primary monetisation options (e.g. hydrogen sales to mobility or industrial users)
- > Focus on PEM technology due to ability to supply frequency services with fast reaction times (full activation < 30 sec)

■ Balancing (15 EUR/MWh) ■ Frequency

- > **Critical challenge: interoperability** between secondary provision of grid services (i.e. "flexibility") and hydrogen production targets for primary sales, esp. in terms of
 - Reaching hydrogen production targets and
 - Ensuring cost-efficient production at lowest-possible marginal cost of electricity
- > Revenues for **frequency reserve participation** vary with the electrolyser size, technology and operation time, but tend to generally not interfere with the targeted primary hydrogen production – significant revenue potential
- > For **balancing services**, interoperability with the supply of hydrogen for primary applications reduces the expectable revenue potential (in this example to less than 50% across all countries and time scenarios), e.g. because of load shifting to operating hours with higher electricity cost, activation prices failing to cover add. cost
- > **Thus: focus on frequency services as secondary value stream re. grid services**
- > Future and sustained challenges might give rise to add. grid service products that electrolysers can service

1) Under historical regulation / remuneration, excl. comparatively low revenues from grid services in the distribution grid

Please do not hesitate to get in touch with us

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