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Scoping Catalogue of Sites

PROFILING OF HYDROGEN COMMUNITIES IN EUROPE:

A FRAMEWORK FOR SELF-EVALUATION & ADVICE ON SUCCESS FACTORS

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SCOPING CATALOGUE OF SITES

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1. Introduction

In the past years, a number of initiatives and projects have been supported at European, national and regional levels, in relation to hydrogen and fuel cell (H_2FC) technologies. A larger-scale adoption of these technologies can play a role in achieving the European Union goal of a competitive, sustainable and secure energy supply.

The introduction of H_2FC technologies in the energy system implies a radical change in the way energy is produced, transported and consumed. Communities can play an important role in smoothing the path for the introduction of these technologies: they are disposed to long-term thinking, considering the wider potential benefits from H_2FC adoption, they have ready channels for increasing public awareness and support of these technologies, and they provide a natural framework for fostering similar activities in the field, leading to the development of innovation clusters. At the same time, these technologies are of strategic relevance to communities as a potential means of tackling a number of socio-economic goals: climate change mitigation, improvement of local air quality, creation of new industries and businesses to boost the local economy, exploitation of abundant renewable resources, energy security and, of course, meeting growing and/or changing energy needs. However, in order for H_2FC introduction to be valuable or “successful”, in the long term, for both the H_2FC industry and the community, certain conditions need to be present within the community.

The Roads2HyCom Scoping Catalogue aims to provide a basis upon which the “goodness of fit” of hydrogen and fuel cell technologies for defined community frameworks can be evaluated. This document is relevant for communities who are interested in developing hydrogen and fuel cell projects and larger initiatives, and who would benefit from knowing what circumstances or characteristics of their community are or will be important for “success”, given their specific socio-economic interests and energy characteristics. Moreover, the Scoping Catalogue can be a valuable tool, for community decision-makers and industry stakeholders alike, to evaluate and identify opportunities for H_2FC integration.

The Scoping Catalogue is organised into three main sections:

- **Overview of potential hydrogen communities in Europe** (chapter 3): This chapter presents some general findings on the geographical spread of potential “hydrogen communities” identified in Europe, the end-use sectors targeted, and the classification of different types of hydrogen communities
- **Assessment and profiling of potential hydrogen communities** (chapter 0): This chapter presents the methodology used to evaluate community potential for integration of H_2FC technologies, to form “hydrogen communities”. The results of applying the methodology are presented for three different types of community
- **Conclusions and recommendations** (chapter 5): This chapter outlines the measures that communities can undertake to improve their chances for successful integration of H_2FC technologies

2. Background

2.1 Hydrogen and fuel cells in the context of European Union energy policy

European Union energy policy is underpinned by three main pillars: sustainability, security and competitiveness. Hydrogen and fuel cells have been recognised as an important bridge to migrate from current unsustainable energy pathways to future sustainable energy systems. These technologies can "open the way to integrated 'open energy systems' that simultaneously address all of the major energy and environmental challenges, and have the flexibility to adapt to the diverse and intermittent renewable energy sources that will be available in the Europe of 2030" [1]. The development and deployment of hydrogen and fuel cell technologies have the potential to contribute to achieving the three energy supply goals:

- **Sustainability**: Hydrogen, produced from fossil fuels with Carbon Capture and Storage or from renewable or nuclear energy sources, can contribute to reduced CO_2 emissions in the energy supply chain, particularly if used in conjunction with energy efficient fuel cells

- **Security of supply**: Although in the short to medium term increased hydrogen production will be from natural gas reforming and could lead to an increase in imported fossil fuels, in the long term hydrogen could reduce natural import dependence when production from local resources (e.g. wind, biomass) will be more competitive

- **Competitiveness**: Development of the hydrogen and fuel cell sector could represent an important industry for European competitiveness, given its high-tech content and opportunity for export of technologies and know-how. If cost reduction expectations are realised it could contribute to a competitive energy supply in the EU internal market, and, through its synergies with other sectors such as renewable energy and transportation, facilitate development in other energy sectors

2.2 Towards sustainable energy communities

Communities are important testing grounds for more environmentally-friendly and sustainable energy technologies.

A concept of Sustainable Energy Communities (SECs) [2] has been developed within the context of the European Commission initiative **CONCERTO** [3]. The objective of CONCERTO is to "support local communities, as clearly defined geographical areas or zones, in developing and demonstrating concrete strategies and actions that are both sustainable and highly energy efficient". The main impulse for this European initiative is "the strong desire in all communities, among politicians, planners, energy service providers, and citizens to develop and demonstrate high degrees of decentralised energy supply, integrated with renewable energy sources as well as the conscientious application of leading energy efficiency measures in various end-use sectors"[3].

SECs are "local communities in which politicians, planners, project developers, market actors, and citizens actively cooperate to develop high degrees of intelligent energy supply, favouring renewable energy sources, with a conscientious application of energy efficient measures" [2]. SECs can be instrumental to the realisation of a sustainable energy system, since its participative approach can ease the transition from a current unsustainable energy system towards a future sustainable energy system. Moreover, SECs act as a showcase for the integration of innovative energy technologies. As potential SECs, all communities represent an important setting for the development and deployment of sustainable yet disruptive technologies.

With respect to hydrogen and fuel cell technologies, communities can play an important role in many ways:

- They are disposed to long term thinking, and thus consider the wider socio-economic and environmental implications of H_2FC technology
- As public institutions, they are an appropriate body to undertake the build-up of the infrastructure necessary to H_2FC adoption
- They control "captive fleets" of vehicles and public projects, which are key as early technology adopters and demonstrators of the technology
- They can foster public acceptance and influence consumer attitudes
- They can promote the formation of localised H_2FC "clusters", fostering expertise in the field

For the purpose of the Roads2HyCom project, it is fitting to define a special case of SEC, focused around the development and use of hydrogen and fuel cell technologies; these are referred to as "hydrogen communities".

2.3 The concept of hydrogen communities

A "**hydrogen community**" is a <u>geographic community</u> (e.g. a city or a region) <u>whose circumstances make it suitable to take a leading role in hydrogen and related technology</u>. It is characterised by a strong participative approach between stakeholders and an enabling framework for coordinated and accelerated uptake of hydrogen-related technologies within an overall sustainable energy framework. Typically, this type of community is driven by certain goals, such as energy security, job creation, local air quality, exploitation of abundant renewable resources etc., for which it sees that the integration of hydrogen and related technologies can play a role.

3. Overview of Potential Hydrogen Communities in Europe

3.1 General characteristics of potential hydrogen communities in Europe

In the absence of real-life “hydrogen communities” on which to base our analysis, “potential hydrogen communities” are used as the starting point of our analysis. Potential hydrogen communities, in the context of the Roads2yCom project, refer to sites that are “early adopters of Hydrogen and Fuel Cell technologies, having the potential to lead to a coordinated, larger-scale adoption of such technologies within a coherent end-user grouping”. Early adopter sites that have deployed fuel cells operating on a fuel *other* than hydrogen, have also been considered as potential hydrogen communities, where this can be considered as a transition phase towards the targeted use of hydrogen in the long term. The distinction of a site as a potential hydrogen community, rather than one that has simply implemented hydrogen and/or fuel cell technology(ies), is based on the fulfilment of the following main criteria:

- A clear focus on **deployment** and/or **directly meeting end-user energy needs** through **integrated** hydrogen-related energy conversion systems and pathways

- **Strong stakeholder participation** as demonstrated through an **ongoing cooperation** between local authorities, local agencies, economic operators and other local stakeholders

- Potential **long term sustainability** of the project/initiative

In order to identify potential hydrogen communities across Europe, a database of hydrogen and fuel cell projects and initiatives in Europe was compiled. The database contains information on 96 potential projects/initiatives in Europe (EU27, EEA, and acceding and candidate countries), related with the development and deployment of hydrogen and fuel cell technologies. Of these, 36 have been identified as potential hydrogen communities, based on the definition and criteria given above (see Annex 6.1 for full list of identified potential hydrogen communities in Europe).

Figure 1 shows the geographical spread of the 36 identified potential hydrogen communities across Europe. In the figure, the number of potential hydrogen communities identified for each country is shown by the purple columns (left-hand axis). For each country, an average “population per potential hydrogen community” – shown by the blue points on the graph (right-hand axis) – is determined by averaging the total population inhabiting all potential hydrogen communities identified in a given country over the number of potential hydrogen communities identified in that country.

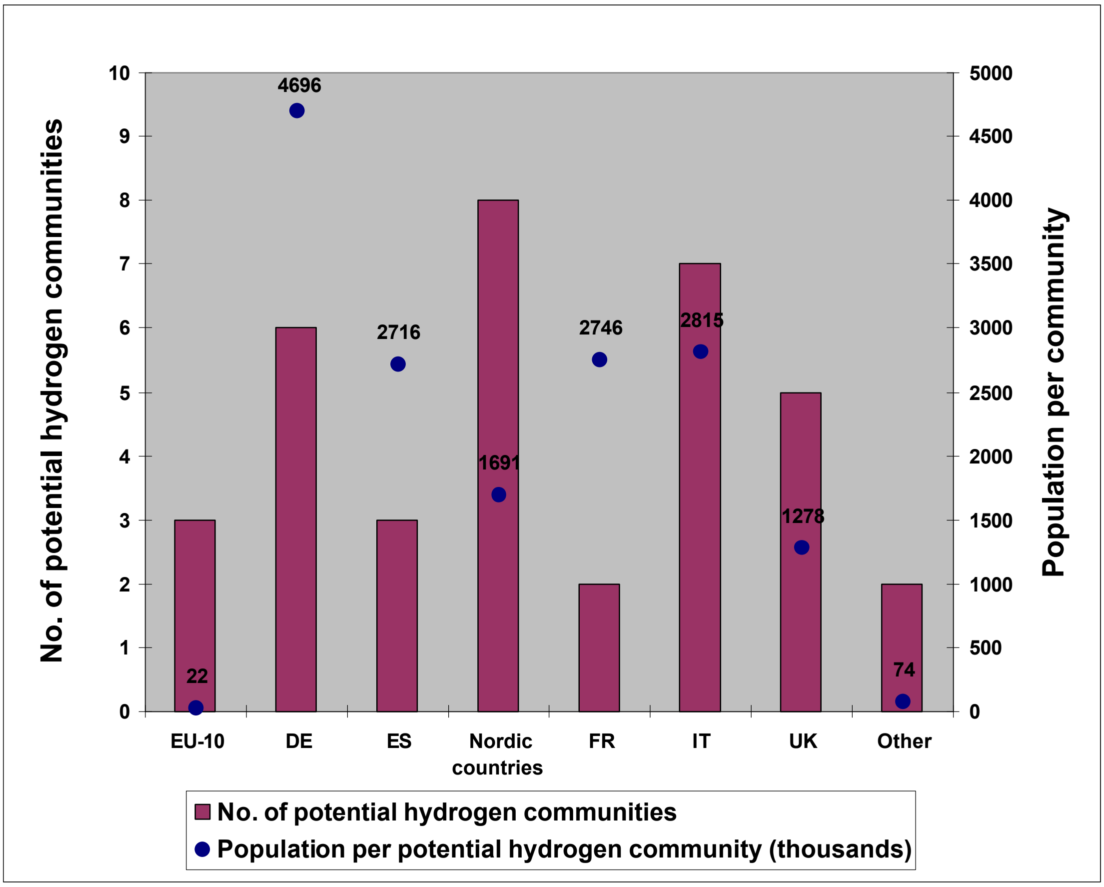


Figure 1: Geographic spread of potential hydrogen communities per country, and corresponding average community population

The majority of potential hydrogen communities (purple columns) are concentrated in the Nordic countries (Denmark, Sweden, Norway, Iceland, and Finland), Italy and Germany. The graph shows that the average population per community (blue points) is much higher in Germany than in the other countries. Germany thus appears to be characterised by larger, potential hydrogen communities, where several initiatives have been aggregated under a single coordinated community (often regional) activity, such as in the case of North Rhein Westphalia and Hamburg. On the other hand, countries such as Italy and those in the Nordic area appear to have a larger number, but relatively smaller communities.

Analysis of the 36 potential hydrogen communities indicates that three quarters of these are still in the planning phase (proposal or initiation) (see Figure 2). This reflects the status of technological development of the hydrogen and fuel cell field, which is just beginning to move from the development and demonstration phases to actual deployment. Although it should be noted that not all hydrogen and fuel cell technologies and applications are at the same stage of development, for example, stationary applications, such as CHP, are closer to commercialisation than transport applications, such as fuel cell buses.

3.2 Applications and end-use sectors targeted

Table 1 gives an overview of the end-use sectors targeted for hydrogen and fuel cell technology deployment and the corresponding type of application. The “transport” application includes: private/public passenger transport (e.g. hydrogen and fuel cell buses, cars, ships); private fleets (e.g. delivery van fleets, vehicles within the airport); niche applications (e.g. wheelchairs, scooters, forklifts). “Stationary” includes baseload power and combined heat and power (CHP) applications for: industrial processes or sale to a third party (e.g. the grid); residential and services sectors (e.g. homes, offices, hospitals). “Multiple applications” implies that both stationary and transport applications are being deployed within the considered site.

While the status of development has an impact on the application type(s) deployed by communities, preference (strategic or otherwise) clearly also has an impact. Figure 3 shows that transport applications are more widespread than stationary ones. The interest in transport applications could be driven by the fact that – unlike in the heat and power sectors (where stationary applications would be employed), where renewable and other alternative energy technologies are well-established and have started to make an impact in replacing fossil fuels – the transport sector lacks renewable options and is under pressure because of fears of increased oil prices and energy security considerations. Deployment of (not yet commercialised) hydrogen/fuel cell technologies in the transport sector could therefore be driven by the fact that:

- In the European transport sector there are, thus far, relatively few options for decreasing Europe’s dependence on fossil fuels and reducing carbon dioxide (and particulate) emissions. Hydrogen/fuel cell technologies offer a possibility to address these policy goals, particularly if renewable hydrogen is used

- The potential market for substitution by sustainable technologies, such as hydrogen/fuel cells, is more significant in transport than in the stationary sector (heat and power), as the latter already has a wide range of more cost-effective, renewable alternatives. Moreover, deployment in the transport sector is supported and accelerated by large commercial investments in fuel cell R&D for this sector

The majority of potential hydrogen communities have deployed both transport and stationary applications (see Figure 3). This is not surprising since wider-scale deployment in both transport and stationary sectors can result in economies of scale. Furthermore, once experience has been gained in the deployment of a given application or end-use sector, it opens the way for expanding deployment to other applications/sectors, which may capitalise on existing infrastructure and experience (whether in the administrative process or in technical/operational aspects of the technologies).

Table 1: Types of hydrogen and fuel cell applications and related end-use sectors

Application Type	End-use sector	Examples
Stationary	Industrial	Base load power, Combined Heat and Power (CHP) for industrial processes or within industrial sites
	Residential & Services sector	Base load power, CHP for buildings e.g. homes, offices, hospitals, recreation centres
Transport	Public/private transport	Public transport e.g. H2/FC buses, large-scale private transportation e.g. H2/FC cars, cargo transportation e.g. ships, related infrastructure e.g. fuelling stations
	Private fleets	Private fleets, coordinated by a single commercial or private operator (delivery van fleet), or for internal (on-site) transport e.g. FC vehicles within airport
	Niche applications	Specialised forms of transport (wheelchairs), or specialized vehicles (forklifts)
Multiple	Combination of above	A combination of transport and/or stationary

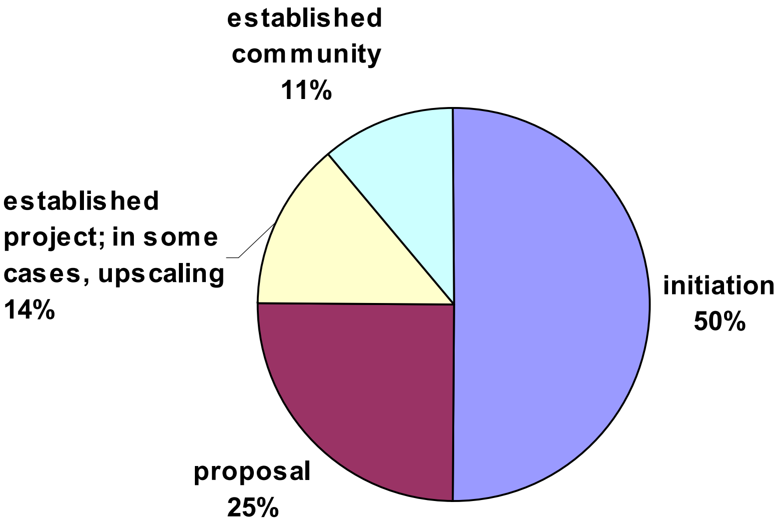


Figure 2: Proposal, Initiation, Established projects and upscaling, Established communities

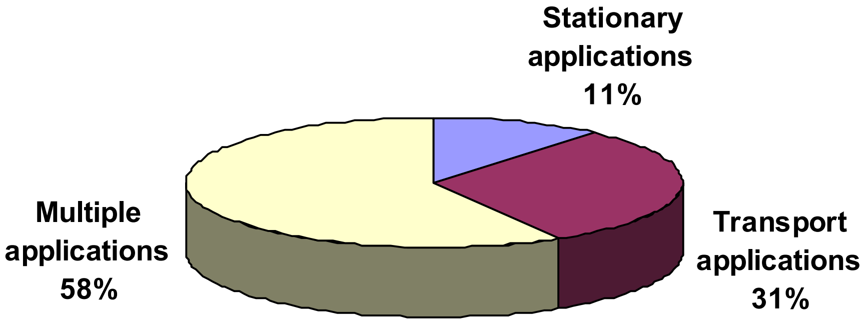


Figure 3: Classification of potential hydrogen communities according to the deployed application(s)

3.3 Main community types

Three main community types have been identified, based primarily on geographic size, population density (implied energy intensity), and remoteness (in terms of connection to energy networks). The community types: cities, regions, and islands/isolated areas. A potential hydrogen community is considered a *city-type community*, when it concerns stakeholders (companies, public authorities…) and end-users located in a city and its immediate surroundings. A *region-type community,* groups together hydrogen and fuel cell initiatives – and concerned stakeholders and end-users – in various towns and cities within the same regional administrative area. Normally, these initiatives arise out of a regional vision, supported by the regional authority. *Island-type* refers collectively to islands and remote or isolated areas. Although administratively-speaking they may be regions, cities or even countries, they are treated as a separate community type, since their remoteness has unique implications in terms of stakeholders' involvement, access to expertise and resources availability.

In looking at the prevalence of community types (regions, cities islands) (see Figure 4), islands are in rather smaller proportion compared to regions and cities, probably because they constitute a kind of niche hydrogen community, with relatively smaller markets for hydrogen deployment. European funding schemes may also, inadvertently, be more targeted towards or suited the other community types. Regions are somewhat more dominant than cities, accounting for almost half the potential hydrogen communities identified. Regions represent an important community type, since in many countries, such as Germany and Spain, they have a high level of autonomy and thus decision-making power with respect to the allocation of development funds, and thus for deployment of innovative technologies. This is important since the majority of hydrogen technologies/applications are not yet commercial and their deployment can be significantly facilitated in the early stages, if supported by investment from public authorities. This would apply equally to islands that are effectively at the same administrative level as regions (or countries).

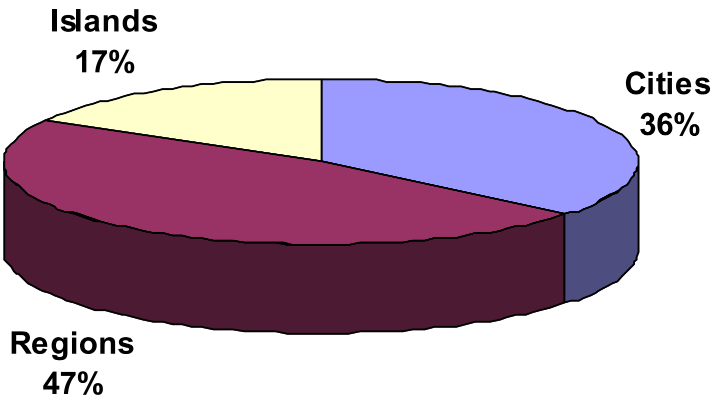


Figure 4: Classification of potential hydrogen communities according to various community types (determined by geographic and demographic characteristics)

3.4 Potential hydrogen communities' map

The map below (Figure 5) shows the geographical spread of the 36 potential hydrogen communities identified across Europe. The majority (as already described in section 3.1) are concentrated in the Scandinavian countries, Italy, Germany and the UK.

These communities are displayed according to the status of implementation of the initiative and the end-use sector targeted for H_2FC deployment. The communities' status are indicated according to colour: blue for "operational/established" sites, where all project(s) constituting the hydrogen community initiative is/are in place and operational; pink for sites in the "initiation" phase, where the initiative is in the process of being implemented meaning one or more projects are being set up or are in operation; green for sites in the "proposal" phase, where the proposed initiative(s) has/have yet to be approved by the relevant authorities. Two-thirds of the identified potential hydrogen communities are still being developed i.e. are either in the proposal or initiation phase. Only one third of potential hydrogen communities can be considered as being on the way to operational, i.e. where the vision, and one or several projects/initiatives, are already in place.

The targeted end-use sector is represented on the map according to the shape of the mark/pointer. Squares denote those communities that have targeted "multiple" sectors, i.e. a combination of transport and residential/service sectors (and/or other stationary applications); circles denote communities where the targeted end-use sector is transport only; triangles denote communities where the targeted end-use sector is residential/services only. The majority of communities deploy applications geared towards multiple end-use sectors.

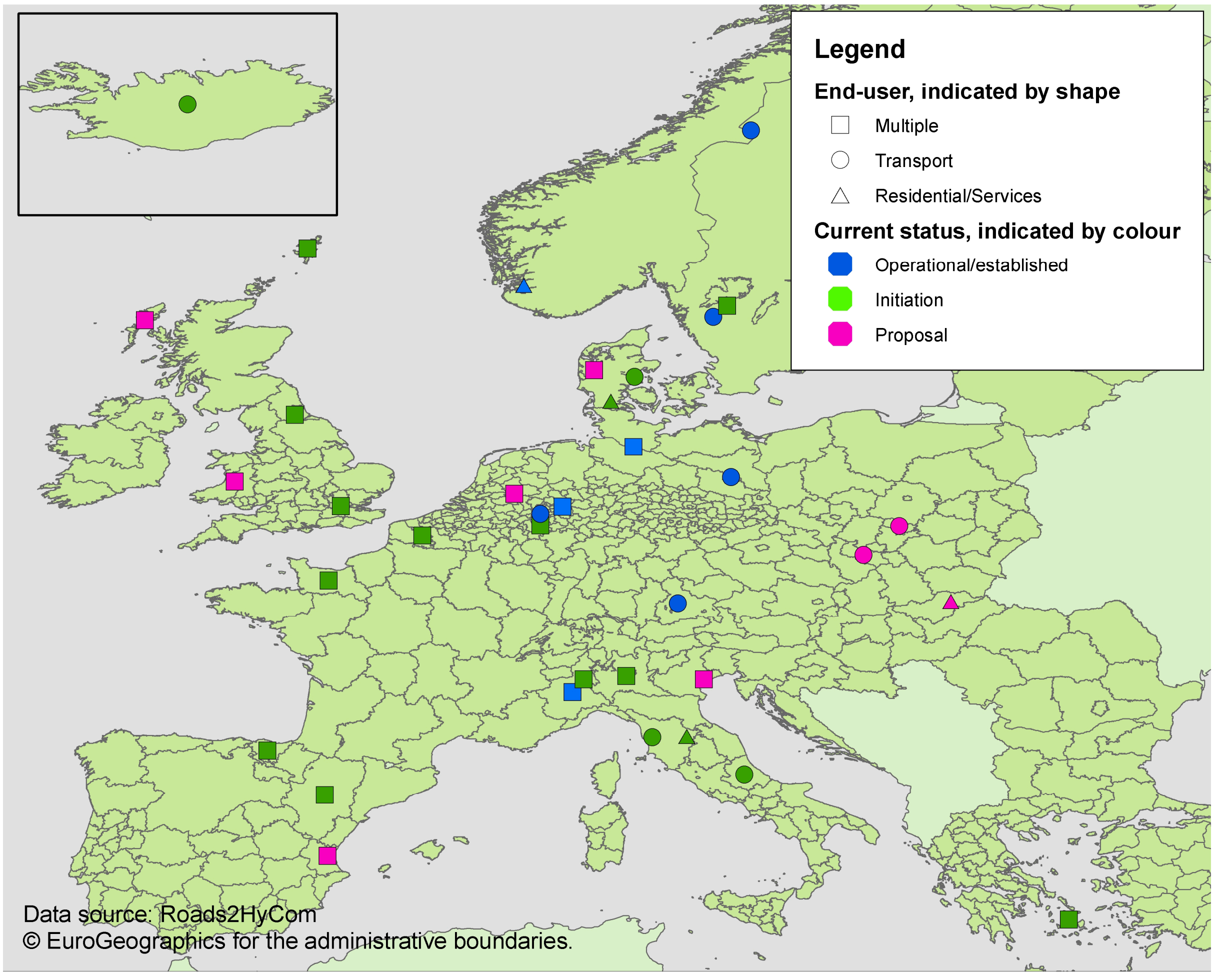


Figure 5: Map showing potential hydrogen communities identified in Europe

4. Assessment and profiling of communities

4.1 Approach

The aim of profiling is to be able to characterise, using a systematic framework, community sites according to their potential for successful integration of hydrogen-related energy technology, forming "hydrogen communities". The framework for assessing the potential for "hydrogen community" formation is based on investigation of two factors that are decisive in technology adoption – "driver" and "capacity" – defined as follows:

- **Driver:** The driving force or motivation of a community in exploring or implementing the adoption of hydrogen and/or fuel cell (H2 &/or FC) applications.
- **Capacity:** The inherent ability or capability of a community to accommodate and integrate disruptive energy technologies (e.g. H2-FC) within their energy system. This includes the ability to cope with all the technical and economic implications associated with its implementation.

The indicators of driver and capacity are taken from a set of metrics, developed as part of a general methodology for assessments in the Roads2HyCom project. The general methodology enables a consistent approach for the different types of activities assessed in the project, namely: RTD activities; hydrogen resources and infrastructure, and communities. The methodology consists of assessing using 11 common metrics, namely:

- Technology accessibility
- Global environmental impact
- Local environmental impact
- Efficiency
- Capacity and availability
- Cost
- Safety
- Public acceptance
- Political will
- Security and sustainability
- Potential for growth

The interpretation, relevance and measurement of these metrics are obviously different for each type of activity being assessed. For instance the metrics of efficiency and safety are considered technology-specific parameters that are not directly relevant for a community where the focus of hydrogen integration is socio-economic rather than technical. Indeed, the technical issues are constraints on the hydrogen and fuel cell industry, since the community, through regulations and standards, would by default assure that only safe technology is deployed. Similarly, the issue of efficiency can only be directly addressed by industry but at the same time will automatically be reflected in the socio-economic metrics considered relevant for communities. For example, low efficiency technologies will cost more and have a lower impact in terms of reducing emissions. These technologies would therefore be less attractive for the community concerned by energy that is cost-effective (metric “cost”) and less detrimental for the environment (metrics “local environmental impact” and “global environmental impact”). Thus, metrics efficiency and safety, from the community perspective, are already embedded and thus accounted for in other metrics counted as being of direct relevance to the community.

Table 2 shows the categorisation of each of the above 11 metrics as either “driver” or “capacity” in relation to a community. It also gives a general definition of each metric when assessing and profiling community sites. A more exhaustive definition of the metrics, and a list of suggested thresholds to evaluate them, is given in Annex 6.2.

Table 2: Grouping of metrics and their definitions

No.	METRIC	Driver (D) or Capacity (C)	Definition
1	**Technology Accessibility**	**C**	Presence of **manufacturers/suppliers of H2FC equipment** within the community, including non-locally based companies that have previously acted as suppliers to the area
2	**Global Environmental Impact**	**D**	A need to reduce **CO2-emissions** as evidenced by the setting out of community strategies/targets for climate change or CO2-emissions reduction
3	**Local Environmental Impact**	**D**	A need to improve local air quality based on long term exposure level of community, and the setting out of community strategies/targets for air pollution reduction **(particulates, SO2, NOX)**
4	**Efficiency**	N/A	Not relevant for communities: refer to section 4.1
5	**Capacity & Availability**	**D**	**Expected energy demand** or need for new energy supplies in community that could provide **opportunities for H2-related technology**
6	**Cost**	**D**	Expectations for **cost-competitiveness** of H2FC application vis-à-vis alternatives which can provide the same benefits as H2FC
7	**Safety**	N/A	Not relevant for communities: refer to section 4.1
8	**Public Acceptance**	**C**	Expected/demonstrated **level of acceptance of H2FC technology** within the community
9	**Political Will**	**C**	Backing of decision-makers for alternative energies (and H2FC in particular), as evidenced by **government-led mechanisms** (e.g. financial, technical, administrative assistance...)
10	**Security & Sustainability**	**D**	A need to **reduce dependence** of community on **external energy supplies**
11a	**Potential for Growth A: Project Continuity, Growth & Sustainability**	**D**	A need to boost **economic growth** through **creation of local industries/companies and jobs** as a result of the H2FC integration
11b	**Potential for Growth B: Cluster Development**	**C**	Ability to create or form part of a **self-sustaining network** of H2FC/energy-technology related activities and expertise that will assure a **long term enabling environment for H2FC** integration in the community and for transferring the technology outside to other communities

Note: metrics 11a and 11b refer to different types of “potential for growth” and are evaluated separately; however, collectively they represent the single metric 11, and as such are subsequently aggregated to obtain a single score. A more detailed definition of the different metrics and how to measure them is available in Annex 6.2

Each metric is assessed for a given community using a rating scheme of zero to four; corresponding to various levels of performance, as follows:

0 = not possible to assess or not relevant
1 = poor
2 = fair
3 = good
4 = excellent

The ratings for all "driver" metrics are aggregated into a single overall "driver" score. Similarly all "capacity" metric ratings are aggregated into a single overall "capacity" score. In aggregating the metric ratings, relative weightings are applied, according to the extent to which each metric is important for the particular community type in question. It can be expected for example that Metric 10 "Security and sustainability" will be a more important driver for islands/isolated areas, compared to cities or regions. The most relevant "drivers" and "capacities" for the various types of community have been determined [5]. Their relative importance, and corresponding relative weightings, are indicated in Table 3.

There are typically 1-2 dominant capacities per community type, with metric 9 "political will" being a recurrent dominant capacity across all community types. The differences across the community types are more pronounced with respect to drivers, islands and cities having few, very dominant drivers, and regions having a larger number of more evenly-weighted drivers. "Capacity and availability" is an important driving factor for all 3 community types, as it essentially dictates the scope for new/alternative energies of any type, and thus the maximum opportunities available for H_2FC integration.

Table 3: Relative importance of metrics and indicative relative weightings used in the assessment of "driver" and "capacity" for different community types.
"++" indicates a weighting of 30% or more, "+" indicates a weighting of 20%-30%, blank means a weighting of less than 20%

Metrics	**Capacity**			**Driver**		
	Cities	**Regions**	**Islands**	**Cities**	**Regions**	**Islands**
Technology Accessibility			+			
Global Environmental Impact					+	
Local Environmental Impact				++	+	
Capacity & Availability				++	+	++
Cost						
Public Acceptance	+	+	+			
Political Will	++	++	++			
Security & Sustainability						++
Potential for Growth A: Employment				+	+	++
Potential for Growth B: Cluster Development	++	++	+			

The assessment and profiling of sites as "hydrogen communities" is done in two stages. First, the site is evaluated on a "macro" level, that is, the overall socio-economic climate for uptake of hydrogen/fuel cell technologies is evaluated, bearing in mind the influence that community type can have, whether region, city, or island/isolated area. Secondly, the site is evaluated with respect to its favourability (or otherwise) for uptake of H_2FC for a given energy demand sector, whether stationary (industrial, residential/services etc.), or transport (public/private passenger, private fleets, niche). This second level is referred to as the "micro" level and serves to evaluate the suitability of a given H_2FC end-use application(s) in responding to the goals or drivers that are sought to be met through H_2FC adoption. It should be noted that for community systems in which multiple end-use sectors are addressed through hydrogen/fuel cell applications, the macro- and micro- level assessment is treated as a single assessment (only one overall score given), since no specific end-use sector is considered to be targeted or dominant over the others.

Table 1 (above) gives an overview of the various end-use sectors, or micro-level categories, which can be considered when profiling a site.

The overall aggregated score that a site gets for "driver" and "capacity" enables the characterisation of any given site according to one of four possible "generic profiles", as illustrated in the two-by-two matrix, in Figure 6 below.

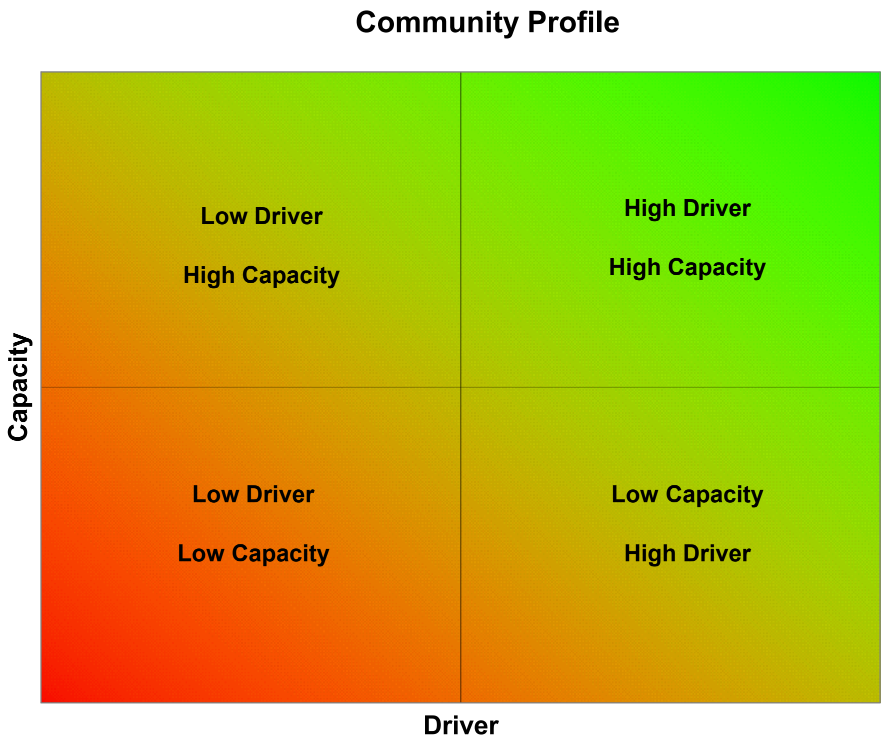


Figure 6: Profiling of communities according to driver and capacity

The profile gives an initial indication as to the potential for hydrogen uptake in a given community system so as to form a “hydrogen community”. A site with a high “hydrogen community” potential would have a high driver for deploying and taking advantage of hydrogen and fuel cell technologies, and a high capacity to actually adopt or integrate these applications in their energy system. Such a site would be located in the solid green quadrant in the diagram. A well-placed candidate for a hydrogen community would therefore have high aggregated scores for “driver” and “capacity” (a “high” score being one above 2.5 (midway between 1 and 4)). On the other hand, a site whose aggregated scores place it in the solid red quadrant – low driver and low capacity – is not in a good position to become a hydrogen community. A site placed in the mixed red/green quadrants scores low on only one factor and is potentially eligible as a hydrogen community, but has shortcomings. The identification of measures to address (if possible) these shortcomings will be the key to providing advice to similar borderline communities to enable them to improve their position for becoming hydrogen communities.

4.2 Benchmarking and advice

The benchmark position, or driver-capacity goal, for all sites is in the solid green quadrant of Figure 6. The actual profile of a given site, as plotted in the quadrants, will give at a glance an indication of which, if any, of the two factors – driver or capacity – must be addressed in order for the site to progress towards the solid green quadrant, i.e. to improve its hydrogen community potential.

The deficient factor indicates globally where the gaps lie, and further investigation can be used to identify the specific metrics contributing to this outcome. On this basis, advice for communities can be developed as to the types and extent of actions that can be taken in order to improve their standing.

There is, however, evidently a limit to which actions can be used to enhance the uptake potential of a site. For instance, it is easy to see how “capacity” factors can be made to change, since these are or can be determined/influenced through the decision-making framework of the community. The metrics “political will” and “public acceptance” are two examples where the community framework can be decisive in the outcome, although there may be some impact also from outside the community (e.g. national legislation or lobby groups).

On the other hand, “driver” factors can be significantly influenced by factors that are external to the community framework and thus not directly controllable by the community itself. For example: obligations related to “global/local environmental impact” can be expected to originate from a national regulatory framework; “costs” depend on the global H_2FC industry as a whole rather than any given single actor; and “capacity and availability” is significantly influenced by the inherent geographic and demographic features of the community, defined in this case through the community type (region, cities, island/isolated area). The “driver” factors will therefore determine the upper limit, and the benchmark, to which each site can aspire. At the same time, some driver factors may change according to changes in political priorities, which could have an impact on the benchmark.

4.3 Presentation of selected communities

Sixteen sites were selected for assessment. Each site was assessed for H_2FC integration in one or more specific end-use sectors. Twenty assessments were conducted by the WP partners, as shown in Table 4. The selection of assessments aims for diversity in geographic coverage and in the end-use sectors considered for H_2FC integration. Furthermore, in the selection, consideration was given to the WP partners' knowledge of experiences with H_2FC projects, and the possibility to access the relevant information.

Table 4: Geographic location of projects selected for community assessments
(The names of the specific communities are omitted to retain anonymity of the communities, and thus their performance from the assessment)

			Macro-level		
			Region	**City**	**Island/ Remote area**
Micro-level	**Transport**	**Public / private passenger vehicles**	Denmark	Germany Germany UK	
		Private fleets (private terrain)		Germany Germany	
		Niche applications			Greece
	Stationary	**Industry**			Spain
		Residential/ services	Denmark	France Germany Italy	Norway
	Multiple	**Multiple**	Germany Spain UK	Germany	Greece UK UK

4.4 Results of selected community assessments

This section presents the results of the assessments conducted on the selected sites, and their resulting profiles according to their potential to form a “hydrogen community”.

4.4.1 Islands

The general performance of islands (and isolated areas by extension) to the 11 metrics is depicted in Figure 7. Not surprisingly the results indicate that islands give high importance to security and sustainability (this indicator demonstrates the highest score), since islands/isolated areas generally rely on external energy supplies. As islands are far-removed from the main centres of energy production and often have limited routes for import/exchange, energy comes at a high cost and can be easily disrupted. Security and sustainability is in fact the most dominant driver (drivers are circled in green in the figure) for adoption of hydrogen and fuel cell technologies in islands, followed by potential for growth (A) or job creation. These will have a positive effect on other (capacity-related, circled in blue in the figure) factors, such as political will (a determinant capacity, as explained in Section 4.1), which in turn can influence public acceptance, both of which are also above-average. The relatively high visibility of hydrogen-related projects in isolated communities would also have a significant impact for public acceptance.

Finally, the potential for growth (B) for islands, namely with respect to project replication and cluster formation (not necessarily within the island itself but as a network with other communities), is also above average. This is due to the fact that as a group, islands represent a relatively homogenous setting for uptake of (autonomous) hydrogen applications, meaning that there is reasonable scope for replication in similar islands/isolated settings or even in other types of setting. Islands constitute an important niche market, with already existing flagship examples e.g. Utsira, and as such there is reasonable potential for exchange of experiences and formation of networks.

On analysis of the metrics with below-average performance, it can be seen that local, and to a lesser extent global, environmental impact is/are not significant as driver(s) for islands; even though preservation of air quality may be important for islands, in particular those dependent on tourism, other factors such as security of supply dominate island energy-related concerns. Technology accessibility is also relatively low, as may be expected for isolated areas. In terms of the cross-cutting determinant driver “capacity and availability” (see Section 4.1), islands demonstrate a slightly below-average level, not surprisingly, as islands, and isolated areas in general, tend to have a relatively low, slow growing population density, and thus relatively low energy intensity and growth. An important exception, however, are popular tourist islands, which will experience energy demand peaks at certain times of the year in accordance with their tourist season, or which may experience a higher than expected growth due to the settling of retirees or the setting up of second homes in the island.

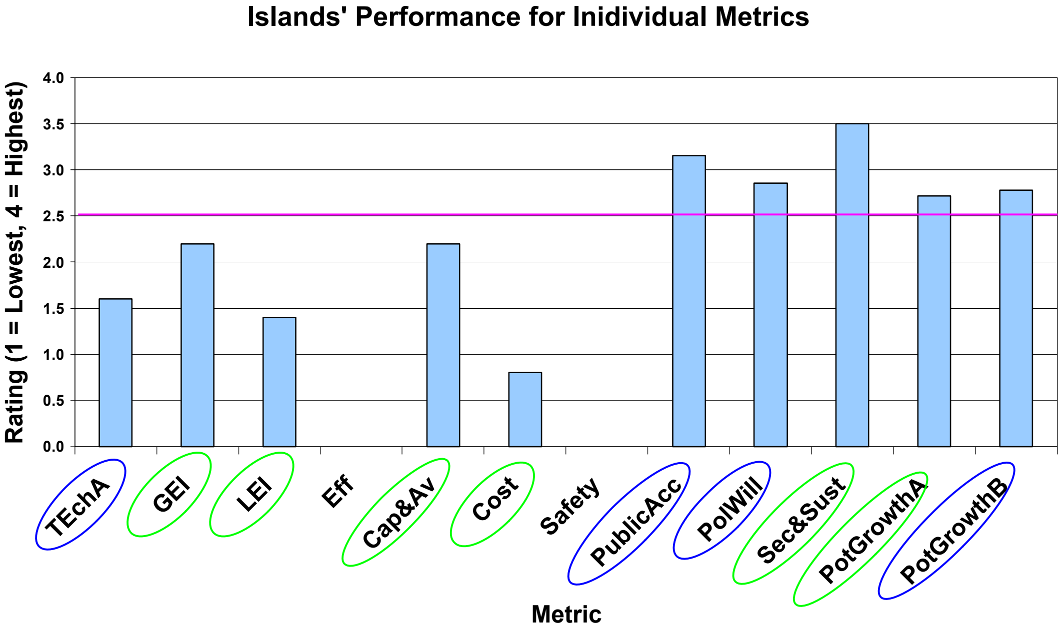


Figure 7: Metric ratings considered from the context of Island community systems (Note: The abbreviations on the x-axis represent the 11 metrics, whose definitions are given in Table 2 Metrics Efficiency (Eff) and Safety are not considered relevant with respect to hydrogen communities. Metric Cost is a technology-related parameter, specific to the application eventually adopted within the community, and is therefore not considered for the overall community point of view)

The specific profiles obtained at macro and micro levels for the island systems assessed (I1, I2, I3, I4, and I5), are shown in Figure 8. From a macro perspective the performance of the islands varies, with two (I1 and I4) of the five islands falling in the solid-green quadrant (favourable for hydrogen integration), the other three being in the mixed red/green quadrant. It is interesting to look at how the targeted end-use sector for hydrogen/fuel cell technology deployment impacts the potential of the site for technology uptake.

I1_a and I1_b: The overall framework of the island appears favourable (green quadrant) for integration of new, more sustainable technologies and hydrogen/fuel cells specifically. If the end-use sector targeted is niche transport applications (I1_a) the result is not favourable for “hydrogen community” potential (low driver, high capacity). The low driver means the niche transport sector does not provide sufficient opportunity to enable the community to respond to the goals that are the driving force for hydrogen adoption. This is mainly because of the relatively small impact that niche transport applications can make with respect to improving long-term local employment opportunities (driver metric “potential for growth (A)”), and meeting the growing energy demand (driver metric “capacity and availability”). On the other hand, if multiple end-use sectors are targeted this situation is overcome and the result is a high “hydrogen community” potential.

I2: The island demonstrates a high capacity for technology uptake overall (high “political will”, “public acceptance” and “potential for growth (B)” (or cluster formation)), and even more so for the specific case of the residential/services end-use sector. However, there is relatively little driving force for hydrogen uptake. This is because the island is well-connected to (relatively cheap) electricity supplies from the mainland (thus a low score for driver metric “security and sustainability”). Moreover, unemployment (driver “potential for growth (A)”) and expected energy demand (driver “capacity and availability”) do not appear to be significant for this community. With respect to the latter it is worth noting that of the four islands, this one is much less of a tourist destination, and thus has a relatively low average year-round energy demand

I3: At macro level, this island has a reasonable driver for hydrogen technology uptake, but does not have an overall favourable capacity. This is mainly due to public acceptance for hydrogen/fuel cell applications being dependent on whether or not renewable sources are used for the hydrogen production (there is opposition to the use of non-renewable sources such as natural gas). However, the capacity is seen to improve when considering the specific application (micro level), which is an integrated application comprising wind turbine, electrolyser, fuel cell and reverse osmosis plant for the production of hydrogen, electricity and fresh water. On the other hand, the driver at micro level is lower due to the limited potential for long term job creation (metric “potential for growth (A)”) within this sector, and the uncertainty for improving security of supply, since the necessary wind resources to enable renewable hydrogen production on a meaningful scale are yet to be exploited.

I4 and I5: These are both of borderline “hydrogen community” potential, which do not display exceptional driver or capacity. In terms of driver, although security of supply remains an important issue, there is no additional drive for H_2FC integration: energy demand (metric “capacity and availability”) is expected to remain relatively stable, with other alternatives favoured for meeting any expected increase; consequently opportunities for economic growth (metric “potential for growth (A)”) via H_2FC are limited. In terms of capacity, these islands lack the network (“potential for growth (B)”) that would enable them to assure the necessary expertise and cluster framework for sustained H_2FC integration.

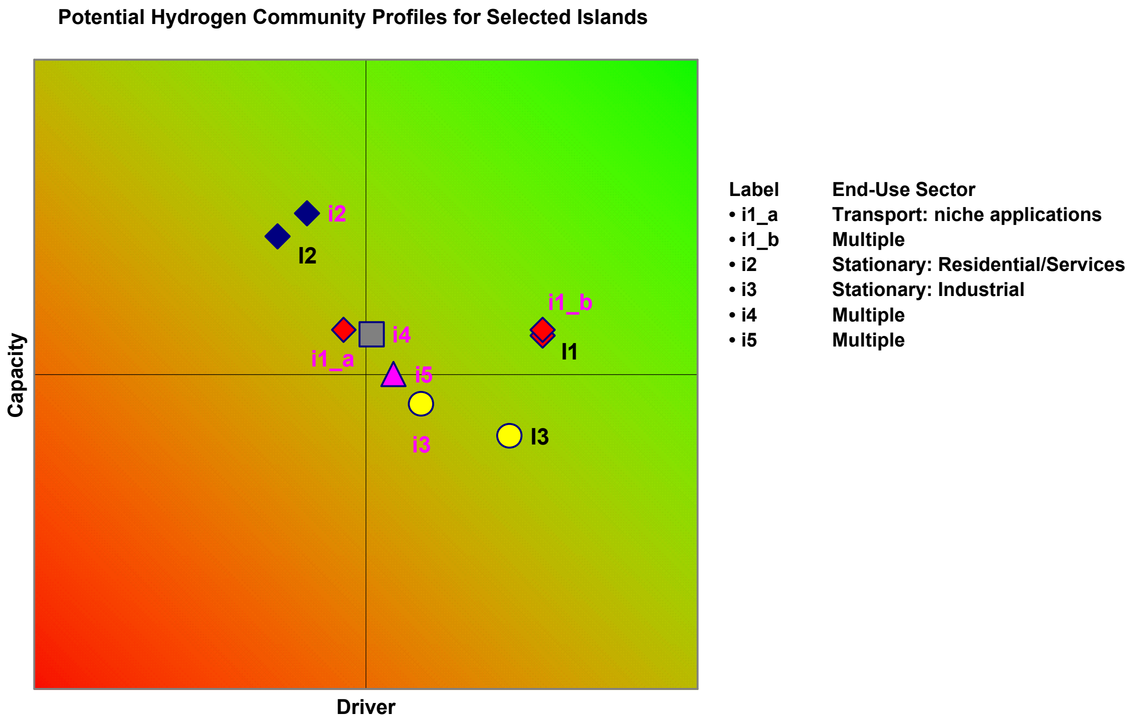


Figure 8: Potential hydrogen community profiles for selected islands
(Note: Labels indicated with uppercase letters (“I”) are macro level assessments and those in lowercase letters (“i”), micro level. The targeted end-use sectors considered at micro level are indicated in the chart legend. Each island is differentiated by its pointer colour and shape (which are common to macro and micro levels))

Clearly the choice of end-use sector in which to adopt hydrogen/fuel cell applications has a pivotal role in the potential (and eventual success) of islands as a hydrogen community type. The results indicate that the prospects are best for multiple applications, as this increases opportunities for hydrogen adoption to be able to respond to drivers of security of supply and job creation, in a setting which is typically characterised by relatively low energy demand (thus fewer opportunities for making an impact with hydrogen uptake).

4.4.2 Regions

As shown in Figure 9, all of the above-average metrics are capacity-related metrics (circled in blue), showing that regions generally have a favourable disposition for accommodating H_2FC technologies. The presence of equipment manufacturers (metric “technology accessibility”), companies, research institutions, and other organisations, across the region (metric “potential for growth (B)”) determine the region’s chances to successfully adopt H_2FC technologies. Their successful introduction also depends on a high support from local political authorities (metric “political will”), and a strong acceptance of the technologies by the general public (metric “public acceptance”).

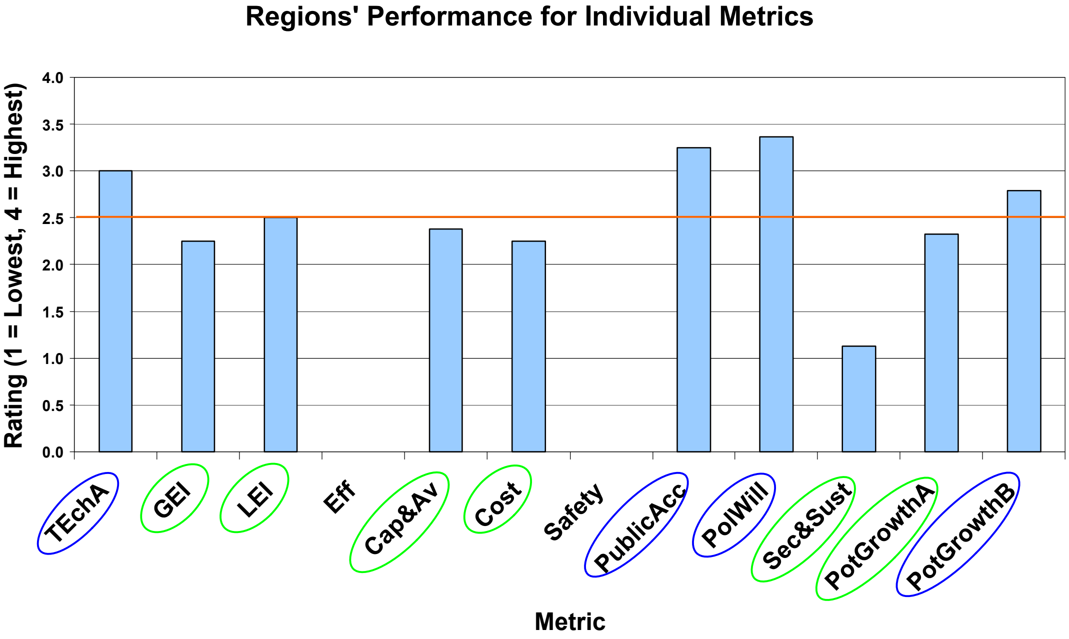


Figure 9: Metric ratings considered from the context of Region community systems (Note: The abbreviations on the x-axis represent the 11 metrics, whose definitions are given in **Table 2**. Metrics Efficiency (Eff) and Safety are not considered relevant with respect to hydrogen communities. Metric Cost is a technology-related parameter, specific to the application eventually adopted within the community, and is therefore not considered for the overall community point of view)

Driver-related metrics (circled in green) are generally slightly below-average results (only security and sustainability scores really poor). This can be explained by the fact that in several of the regions analysed, the main push for the H_2FC sector is coming from industry and private sector, and, in the cases where there is public interest it is mainly from the point of view of maintaining a competitive position in energy markets as exporters of innovative technologies. In addition, they are generally in good environment and socio-economic positions. As the metrics primarily reflect drivers from the point of view of integration of H_2FC in the community itself (as opposed to technology export) for meeting local needs, many of the regions score below average. Interestingly, the average ratings for all driver metrics (except for security and sustainability) are very similar, indicating that they are of similar importance for regions. This is expected since regions have a wider set of equally important goals compared to islands and cities, when exploring H_2FC adoption, and would thus have several equally-weighted priorities or drivers, as opposed to one or two dominant ones. Only metric “security & sustainability”, is of relatively little importance, as regions have limited power in ensuring security of energy supply, since this is general and issue dealt with at national level.

When analysing the regions’ performance according to the macro-level, which gives an indication of their overall readiness for successful H_2 uptake (see Figure 10): R3 and R4 present a favourable environment for hydrogen uptake in a regional context (they score high in the green-quadrant); while R1 and R2’s high capacity is not matched by a high driver for H_2FC introduction.

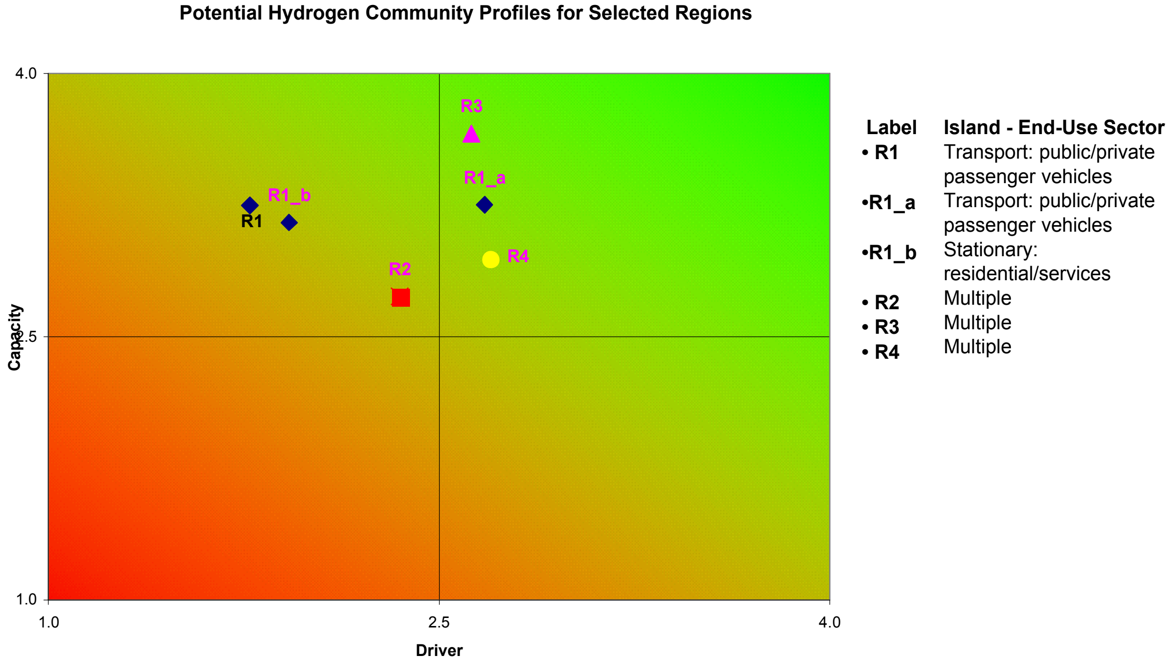


Figure 10: Potential hydrogen community profiles for selected regions (Note: The targeted end-use sectors considered at micro level are indicated in the chart legend. Each region is differentiated by its pointer colour and shape (which are common to macro and micro levels))

A combined analysis at macro and micro level (Figure 10) shows how, if at all, the targeting or “matching” of H_2FC for specific energy end-use sectors can influence the potential as a “hydrogen community”. R1 has been analysed for H_2FC integration in both transport and residential/services sector, while R2, R3 and R4 have been analysed for multiple end-use sectors:

- **R1**: This region has the necessary capacity for successful H_2FC integration, but little motivation to do so, especially in the short term, as other technological solutions are preferred. The chances of successful hydrogen integration increase when the public transport sector (R1_a) is targeted. The adoption of hydrogen-fuelled buses in the region responds well to the forecasted increase in energy demand in the transport sector (higher score in metric “capacity and availability”), and the consequent expectation of increased emissions of greenhouse gases (higher score in GEI) and air pollutants (higher score in LEI) if conventional fossil fuel alternatives were to be implemented to meet this demand. Moreover, the sector’s forecasted growth could be expected to create more employment opportunities (higher score in metric ”potential for growth (A)”), compensating to some extent for the progressive downsizing of the national oil and gas industry that is being experienced.

- **R2**: The capacity for H_2FC integration is above-average, however there appears to be little driving force for its implementation. The only driver above average for this region is the metric “capacity and availability”, since a high energy demand is expected in the next years to come from the residential and services (especially, tourism) sector. However, this is not enough to justify the need to deploy H_2FC technologies in the region, when cheaper alternatives are available in the short term. For instance, this region is investing in highly efficient natural gas turbines, which can be easily deployed in the region, at least in the short term.

- **R3**: Of the regions analysed, this region shows the most favourable profile for being a “hydrogen community”. It is characterised by a high concentration of equipment manufacturers (metric “technology and accessibility”), and related companies, end-users, research institutes (metric “potential for growth (B)”), which have gained in-depth experience in H_2FC by developing a number of demonstration projects, in both transport and stationary applications. These visible and successful demonstration projects have fostered public acceptance for H_2FC integration in the region. The deployment of H_2FC technologies can well respond to the region’s need to improve its environmental quality, while keeping a high employment in an innovative sector.

- **R4** also presents a favourable environment for H_2FC integration. This region is characterised by a strong need to develop the H_2FC sector, since its innovative potential can positively contribute to the economic restructuring of the region, in terms of high employment, and higher economic growth (high score in metric “potential for growth (A)”). This high driver has a positive effect on the metric “public acceptance”, since citizens consider the further deployment of these technologies as a good opportunity to increase their well-being. However, the region still needs to fully develop the necessary knowledge and skills, in terms of companies, research institutes and other organisations, and to develop further demonstration projects, in order to take fully advantage of the potential of H_2FC technologies deployment on the region’s development. A strong political support to attract business in this area is needed to enable a stable supportive environment, which can favour the growth of this sector

Successful H_2 integration is higher in those regions where there is a focus on economic growth and a need to restructure the existing energy industry (e.g. coal industry, oil and gas industry), to be in line with current energy policy focus on migrating from fossil fuel-based energy systems towards more sustainable ones. These regions are characterised by a deep knowledge of energy technologies, which can be transferred and applied to the H_2FC sector.

As a result of our analysis, H_2FC technologies seem to respond well to the region’s mix of priorities, in terms of economic growth and job creation, environmental quality, and, to a less extent, security of energy supply. The choice of the end-use sector where first to develop H_2FC demonstration projects has to be in line with the region’s expected needs. A thorough analysis of the region’s situation in terms of its needs, to be translated into the region’s vision, can help in targeting the most relevant end-use sector.

4.4.3 Cities

The overall performance of cities with regard to the 11 metrics is depicted in Figure 11. The results show that high importance is given to environmental protection, namely with respect to reduction of greenhouse gas emissions (GEI), and other air pollutants (LEI). As highly urbanised areas, cities generally suffer from increased air quality problems compared to more rural areas and therefore give greater importance to pollutant emission reduction (LEI) for quality of life. Moreover carbon-dioxide reduction obligations and mitigation measures (GEI) are very evident in cities, since they are an appropriate level to tackle major emissions sectors, such as urban transport, energy use in buildings that are targeted in national and regional climate change strategies. “Global environmental protection” (GEI) and “local environmental protection”” (LEI) are thus the most important drivers for adoption of hydrogen and fuel cell technologies in cities, followed by “capacity and availability”, or expected growth in energy demand, especially for the transport sector. These factors (drivers, circled in green in the Figure) have a positive effect on capacity-related (circled in blue in the Figure) factors, such as “political will” (commitment of local authorities) and “public acceptance” towards the adoption of alternative, less-polluting energy systems (e.g. H_2FC), as shown by above-average scores for these metrics in Figure 11.

Potential for growth (B) for cities, namely as regards cluster development in and around the city, is also above average. This is due to the typically high concentration, in cities and their vicinity, of academic, research and professional organisations, which are likely to possess or be able to develop the specific knowledge and expertise necessary for successful development and deployment of H_2FC technologies. Early adopters of the technology are also easily found in cities and their proximity.

On analysis of the metrics with below-average performance, energy security and sustainability does not emerge as a relevant driver for cities, since this is primarily an issue of national and, in some cases, regional strategy, and are not of direct concern at city level. Technology accessibility, although just below-average – since equipment manufacturers tend to be located in industrial outskirts away from cities – is not an issue for cities, since transport and communication infrastructures connecting cities to these areas are well-developed.

The specific profiles obtained at macro and micro levels for the seven city systems (C1, C2, C3, C4, C5, C6, C7), are shown in Figure 12. In the case of C6, three profiles have been conducted at the micro level to analyse the effect of implementing of H_2FC in various end-use sectors, given the same overall (macro) framework. Three of the seven cities are not located in the green (favourable hydrogen uptake) quadrant, and are spread across the other three “less favourable” quadrants.

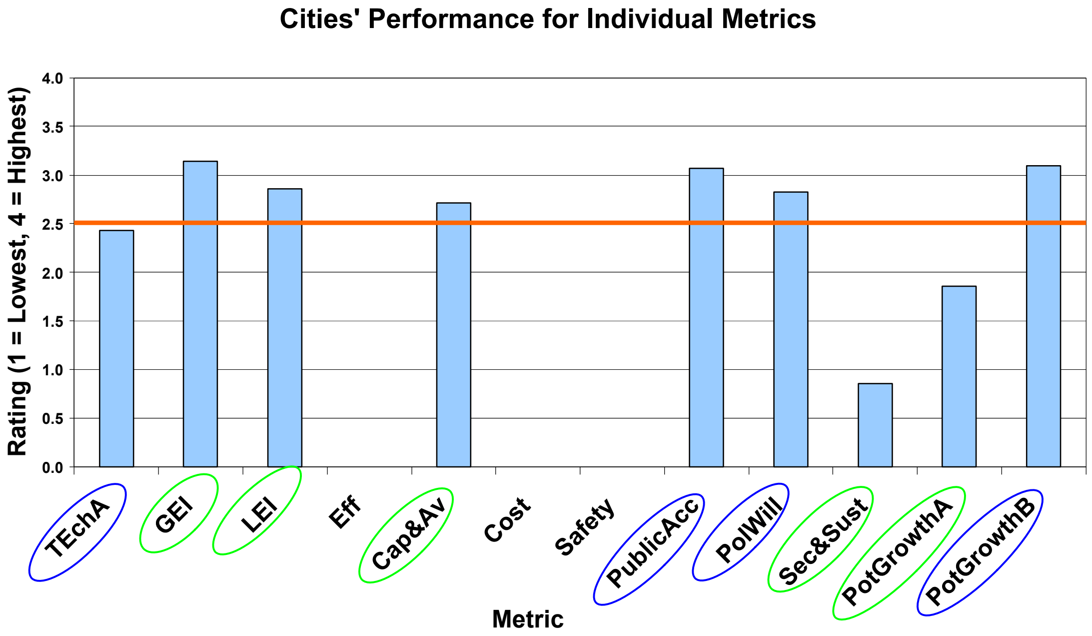
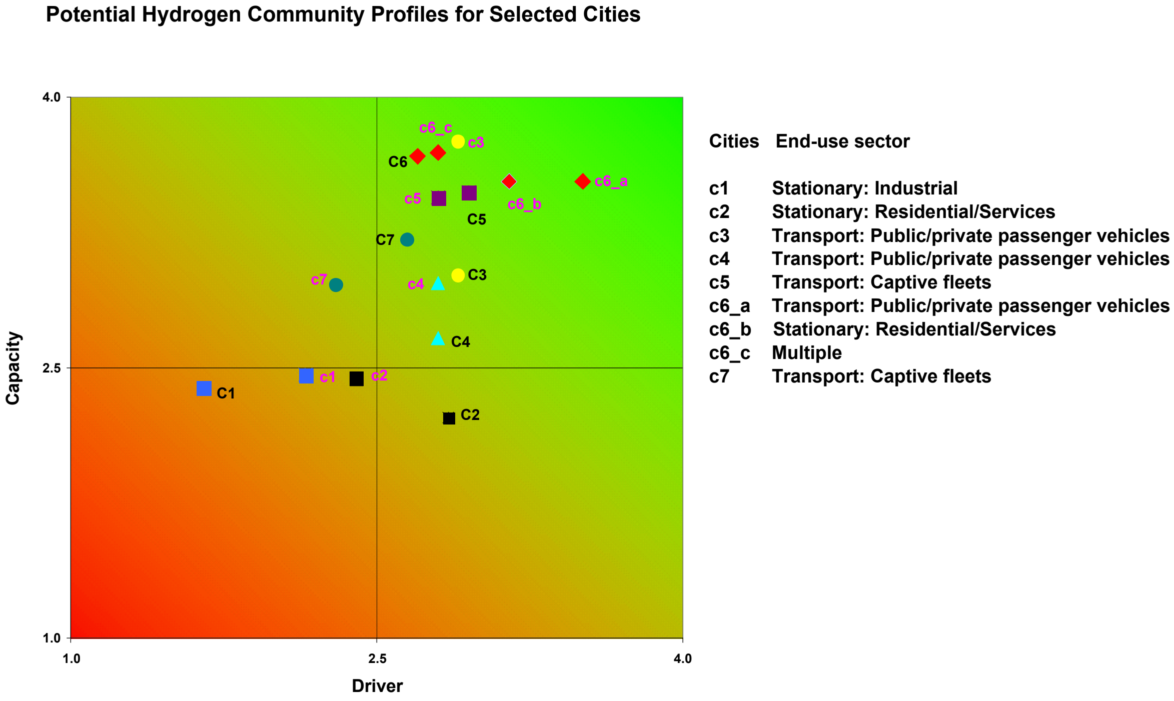


Figure 11: Metric ratings considered from the context of City community systems (Note: The abbreviations on the x-axis represent the 11 metrics, whose definitions are given in Table 2)



Cities	End-use sector
c1	Stationary: Industrial
c2	Stationary: Residential/Services
c3	Transport: Public/private passenger vehicles
c4	Transport: Public/private passenger vehicles
c5	Transport: Captive fleets
c6_a	Transport: Public/private passenger vehicles
c6_b	Stationary: Residential/Services
c6_c	Multiple
c7	Transport: Captive fleets

Figure 12: Potential hydrogen community profiles for selected cities (Note: Labels indicated with uppercase letters (“C”) are macro level assessments and those in lowercase letters (“c”), micro level. The targeted end-use sectors considered at micro level are indicated in the chart legend. Each city is differentiated by its pointer colour and shape (which are common to macro and micro levels))

From a macro perspective (Figure 13), the majority of cities (C3, C4, C5, C6, C7) present a favourable environment for the deployment of H_2FC technologies.

C1, which presents poor results both in terms of driver and capacity-related metrics, is atypical, as it is does not display the high level of urbanisation generally assumed for all city type communities. This has a significant impact for the driver score, since, as a result, it has a low driver for "local environmental impact", the metric given the greatest weighting when aggregating overall driver scores for cities. On the other hand, C1's main driver is "security and sustainability" of energy supply, which is not considered to be an important driver for cities in general. This highlights a weakness in the assessment method, since, in applying a common assessment framework to **all** communities of a selected type, communities that do not conform to the general characteristics assumed for the selected type are not readily accommodated.

The low capacity scores for C1 and C2 result primarily from a lack of "political will", and passive "public acceptance".

Communities, such as C5 and C6, with the highest potential for successful and sustained integration of H_2FC are characterised by a strong need to reduce local air pollution ("LEI"), and significant energy demand growth ("capacity and availability"), supported by local authority initiative ("political will") and the necessary technical expertise and networks ("potential for growth (B)"):

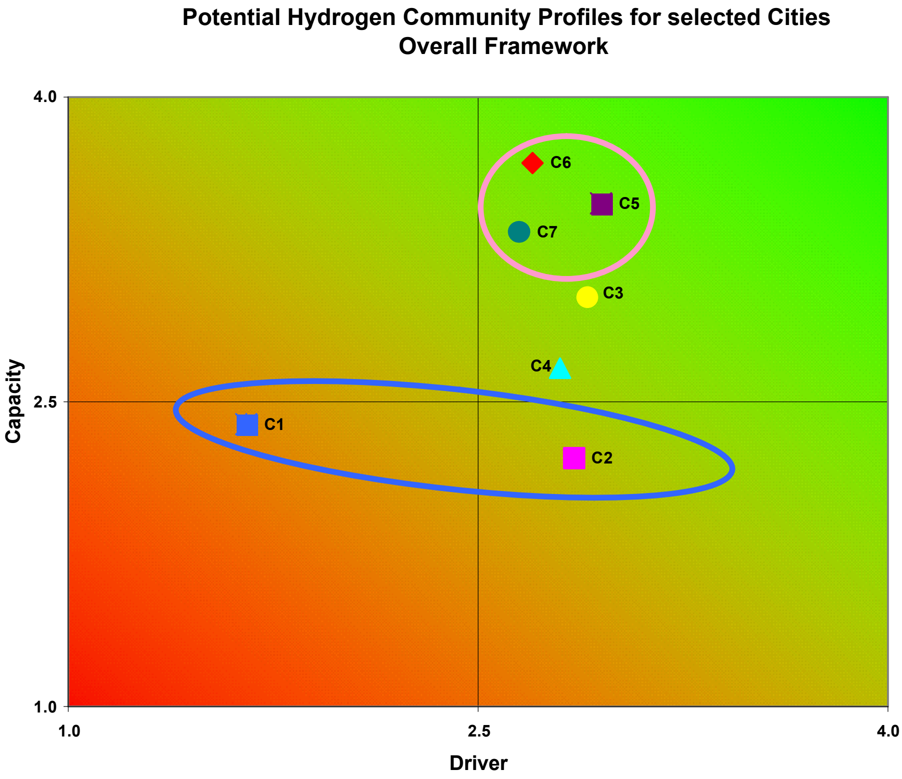


Figure 13: Potential Hydrogen Community Profiles for selected Cities Overall Framework

(Note: The seven cities, which are the object of the macro level assessment, are indicated by uppercase letters ("C") and a different number)

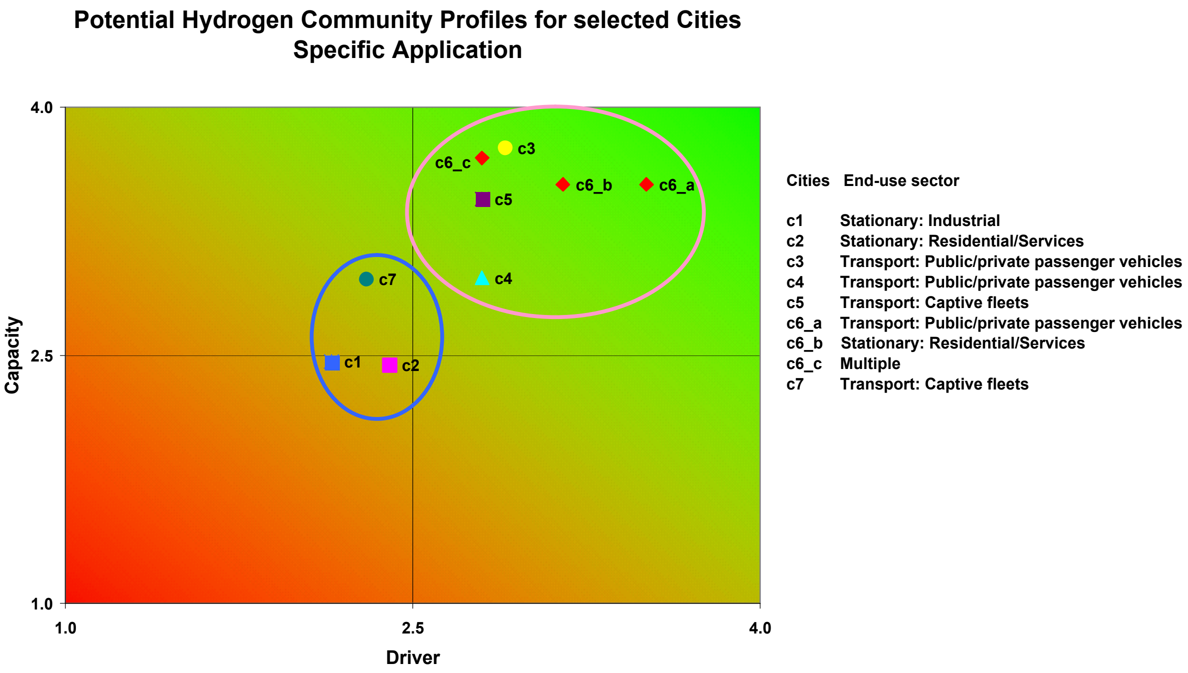


Figure 14: Potential Hydrogen Community Profiles for selected Cities- Specific Application

A combined analysis at macro and micro level (comparing Figure 13 and Figure 14) shows how, if at all, the targeting or “matching” of H_2FC for specific energy end-use sectors can influence the potential as a “hydrogen community”:

- **C1**: The macro level performance indicates that the overall framework is not favourable to adoption of H_2FC technologies. While the improved driver score at micro level is a positive indication for the adoption of H_2FC in the stationary sector, the overall capacity remains low, reinforcing that there is not much scope for H_2FC integration

- **C2**: This shows a marked difference (decrease) in driver score at the micro level compared to the macro level. This is because the chosen application (fuel cell for CHP in the residential sector) envisages the use of natural gas as a fuel, reducing the positive effect that the introduction of fuel cells can have for the community’s environmental quality (both LEI and GEI metrics have lower scores at micro level).

- **C7**: This has a favourable overall (macro) framework, but has low potential as a “hydrogen community” when considering the micro level, where the targeted end-use sector is niche transport: private fleets (for private terrain). Further investigation shows this to be a result of low potential of the niche transport sector for improving long-term local employment opportunities (driver “potential for growth (A)”), one of the main drivers of this city for exploring H_2FC integration. As a direct consequence, the local political authorities are less willing to implement incentive mechanisms targeting this sector (lower score for capacity metric “political will”).

- **C5** and **C6**: Both of these have a favourable enabling environment, and also have good results for the specific applications considered, indicating a high potential for H_2FC integration in the corresponding end-use sectors. Different types of applications/end-use sectors have been analysed for C6. The results indicate that H_2FC adoption, whether in stationary, transport or both sectors combined, represents a potentially good match for the community’s energy-related needs.

- **C3** and **C4** are characterised by a favourable overall framework (macro level) for the uptake of H_2FC technologies (they are both situated in the green quadrant). Looking at the targeted end-use sector (in both cases, public/private passenger transport), the capacity of both increases considerably. This indicated that this type of application is well tailored for a city-type community. In fact, the introduction of H_2FC technologies in the targeted (transport) sector has the strongest potential for reduction of greenhouse gas and air polluting emissions, and thus for responding to the main drivers (LEI and GEI), given that the bulk of energy demand increase (metric “capacity and availability”) is expected in this end-use sector. The introduction of this technology would, as a result, receive a strong support from political authorities (metric “political will”).

Transport applications, namely public/private passenger vehicles, seem to be well tailored to city-type communities. The transport sector is a major source of air quality degradation (both local and global) in cities, and few alternatives exist in this field for replacing fossil fuels. The high projected increase in energy demand in the transport sector also creates opportunities for the adoption of H_2FC technologies. Introduction of H_2FC technologies in the building sector seem to be less appealing in a city context, given that other initiatives (e.g. introduction of energy-efficiency measures, support to the development of solar panels and other renewable energy technologies) can contribute to the reduction of greenhouse gas and other polluting emissions in a more cost-efficient way, in a shorter term.

Transport applications are usually more visible and accessible to citizens than stationary ones. A strong political support to demonstration projects in this area can, therefore, have a stronger impact on public acceptance, and on the long term introduction of H_2FC technologies.

4.4.4 Cross-comparison of results for different community types

Islands/remote areas generally present a high driver for hydrogen uptake, but not always a high capacity – the majority of islands are situated to the right hand side (towards increasing driver) of the capacity-driver chart (see Figure 8). Compared to cities and regions, islands present the highest average score in terms of driver, but the lowest in terms of capacity. Islands and remote areas, in contrast to the other community types, are driven by a strong need to improve security of energy supply (highest score for metric “security and sustainability”), and enhance employment opportunities (highest score for metric ”potential for growth (A)”). Their overall lower capacity compared to regions and cities can be attributed to a lack of specialised energy industries within the area (lowest score for metric “technology accessibility”), since these isolated areas have difficulty in accessing technical expertise. More important however is the fact that the characteristic low energy intensity and low energy demand growth rate of islands/remote areas (metric “capacity and availability”) provide few opportunities for H_2FC introduction. This can jeopardise the sustained integration of hydrogen energy in the long term, but the risk is lowered if a wide-scope approach is adopted, considering hydrogen integration in multiple end-use sectors. At the same time, islands that are also popular destinations for tourism and second homes, or which attract retirees in large numbers, can demonstrate higher growth in energy demand and thus more opportunities for H_2FC introduction.

Cities appear to provide a favourable setting for successful hydrogen uptake, being generally characterised by an above-average driver and an above-average capacity – the majority of cities are situated on the top-right hand (green quadrant) of capacity-driver chart (see Figure 12). Cities, compared to regions and islands, are driven by a high need for environmental quality improvement (metrics “GEI” and “LEI”), and also have the best perspectives for sustained hydrogen energy deployment (metric “capacity and availability”). Cities also have, on average, the highest potential for cluster development (metric “potential for growth (B)”), given the high concentration in their vicinity of academic, research and private energy and transport related companies, which are likely to possess or be able to develop the knowledge and expertise necessary for successful development and deployment of H_2FC technologies. The limited presence of equipment manufacturers in the area does not have a strong impact on the chances for successful hydrogen uptake in cities, as their extended networks allow for access to the technology and, similar to regions, cities are major customer bases for hydrogen and fuel cells. The same factor can be a show-stopper in the case of islands and remote areas.

Regions are generally characterised by a high capacity for a successful hydrogen uptake – they are all positioned in the top half of the capacity-driver chart (see Figure 10), but this is not necessarily matched by a high driver. Compared to islands and cities, regions have the highest average capacity score, but low or borderline driver scores. This is largely due to the fact that many of the regions analysed do not have an internal “need” for H_2FC adoption, primarily because they have a relatively good socio-economic position. The main push for the H_2FC sector is coming from industry and private sector, and an interest in maintaining a competitive position in energy markets as exporters of innovative technologies. However, for the general case, the flexibility of H_2FC technologies and thus their potential to respond to the regions’ mix of needs should not be ignored. Regarding overall capacity for H_2FC integration, regions that have already invested and developed an innovative energy sector have the highest chances of success.

All three community types are characterised by strong support from local authorities (above-average score for the metric “political will”), high involvement from the citizens (above-average score for the metric “public acceptance”), and strong perspectives for cluster development (above-average score for the metric “potential for growth (B)”). Independent of the community type, the first two factors are crucial for successful hydrogen integration. A strong position for cluster development is also an important facilitating factor, given the presence of a local energy innovation industry, and related knowledge.

5. Conclusions and recommendations

This last chapter gives general guidelines on what measures could be taken in order to facilitate the development of a hydrogen community (positioned in the “green quadrant”).

5.1 General conclusions and recommendations

1) High capacity and low driver (case of R1, R2 and I2): driver-related metrics reflect an existing or imminent situation (need) of the community, as a result of past actions, and, by definition are not controlled by the community. Drivers constitute the reaction of the community to an existing or expected negative situation. For example, a driver for improvement in air quality is a situation which results from pollution accumulated over a (past) period of time. Improving driver performance is therefore not a meaningful goal. On the other hand, a prospective outlook can identify negative situations that may arise in the future (future drivers). From this point of view, drivers for H_2FC adoption may arise or increase in order to pre-empt the creation of a negative situation over the long term. For example the integration of H_2FC in the transport sector as a proactive measure for expected energy demand growth in that sector, and for tackling the resulting air quality degradation (as in the case of R1_a). In such cases, the engagement of local political authorities and mobilisation of the local energy industry would enable the migration of the community towards the green quadrant. These communities should therefore look closely at their long term strategy when considering the potential benefits from adopting H_2FC technologies, compared to alternative shorter term options. They should also take into account possible purchasing strategies

2) Low capacity and high driver (case of I3, C2): the low capacity of these sites is typically a result of lack of interest or backing from local public authorities. Although in the communities analysed there is strong interest from the local industry to develop H_2FC technologies, the lack of political support could jeopardise the industry’s commitment. Strong public-private partnership involving local industries, public authorities, and citizens are key in such cases, to mobilising and actively involving public authorities and citizens. Well-targeted, multi-stakeholder demonstration and deployment projects will create a sense of ownership amongst public authorities and citizens and thus be central if there is to be further development into a hydrogen community.

3) High capacity and high driver: the majority of analysed sites are positioned in the green-solid quadrant. They can therefore be said to have good potential as hydrogen communities. However, the extent to which such sites will result in successful hydrogen communities will depend on the approach taken in the start-up process, as these will be the foundations to determine further development, if any. The factors that must be taken into consideration are specific to each community type and are therefore considered in Section 5.2.

4) Low capacity and low driver (case of C1): as already discussed in Section 4.4.3, C1 is a particular case, since it does not display the high level of urbanisation generally assumed for all city type communities. As a result, we can consider that no communities, amongst those which have been

evaluated, display poor results in terms of *both* driver and capacity-related metrics.

This last point (4) raises an important conclusion of the study. This is that the methodology is not suited to evaluating all sites or communities, as it relies on being able to categorise a site/community according to region, city or island/remote area. Each of these categories embodies certain assumptions relating to geographic size, population density (implied energy intensity), and remoteness (in terms of connection to energy networks), which may not apply for certain sites/communities. In addition, the methodology may need to be slightly modified to analyse the situation for communities/sites where integration of alternative energy, such as hydrogen and renewable energy, are not yet recognised as important to the community.

The support of local public authorities is fundamental to enable the **quick start** of hydrogen energy integration**,** from the financing of visible and well-targeted demonstration H_2FC projects to the setting up of larger H_2FC initiatives, within a broader sustainable energy framework. Those communities, which have already developed a deep knowledge in this sector or which have a tradition of investments in high-tech energy sectors, would have a competitive advantage to successfully deploy and integrate H_2FC technologies in the medium term. These communities may even consider the development of H_2FC technologies as a business opportunity, namely via technology export.

The creation of **public-private partnerships** is an important step to enable successful hydrogen adoption. A successful public-private partnership should be based on balanced involvement from local public authorities (metric “political will”), and the local industry (metric “potential for growth (B)”), while keeping citizens informed and recognising their concerns (metric “public acceptance”). In order to ensure that the development of the H_2FC sector is in line with the community’s long term objectives, a **long term strategy**, to be agreed by the main public and industry stakeholders, should form the basis of the hydrogen energy initiative.

5.2 Conclusions and recommendations by community-type

5.2.1 Islands

In order to obtain a critical mass for integration of hydrogen energy, island-type communities should consider targeting multiple end-use sectors. Such an approach would enhance the impacts that H_2FC adoption can have with respect to the need to improve security of supply and create jobs. In addition, a particular characteristic of islands and remote areas is the possibility of an abundance of stranded renewable energy sources. A hydrogen sector that is able to capitalise on these energy sources would have greater chances of long term success.

The main risk, which could hinder the successful hydrogen uptake in an island-type community, is its difficulty in developing and keeping knowledge within the community. In the majority of islands, the limited localisation of companies and institutes means the necessary competence for the successful realisation of demonstration projects in the short term, and integration of hydrogen energy in the long term, would have to be imported. This type of community should therefore focus on developing knowledge and expertise through demonstration projects, and also on implementing mechanisms to retain the created knowledge. One option would be to include, in the tender process, a stipulation that the supplier not only deliver the product and the related technical knowledge for technology installation, but also train local persons for its long term operation and perhaps expansion. Transfer of knowledge and the development of local ownership are fundamental for the successful realisation of an island-type hydrogen community.

5.2.2 Regions

Regions are in a good position to benefit from H_2FC technologies, as the technology has the potential to respond to their mix of needs. The key for region-type hydrogen communities lies in their capability to successfully integrate the technology in a relatively large area, characterised by varying levels of urbanisation and energy intensity. Regions that already have invested and developed an innovative energy sector generally have the highest chances for success. Inexperienced regions interested in H_2FC adoption should therefore invest as early as possible to develop their hydrogen energy sector, starting demonstration projects based on a carefully devised long-term strategy, and to look at the potential for these types of projects to respond to energy demand needs, and thus be adopted on a wider scale.

From the point of view of a regional development strategy, the innovative nature of the H_2FC sector is of additional importance, as it presents opportunities for regional industries and private sector to gain a leading edge and eventually become exporters of these technologies.

Regions potentially also have an important role to play in the adoption of H_2FC in city and island type communities, particularly when these can become interconnected. Through central coordination of the range of city-level and/or island-level initiatives under their jurisdiction, the regional dimension can result in and exchange of experiences, expertise and realisation of economies of scale that may not otherwise be possible for disaggregated initiatives.

5.2.3 Cities

Cities are well-placed for successful long term integration of hydrogen energy. Development of the H_2FC sector in a city will be driven largely by expected growth in energy demand, and the environmental implications of such growth. Smart targeting of end-use sectors will therefore be critical in the early stages, for generating useful experience and confidence that H_2FC can have a meaningful contribution to meeting a city’s energy needs. The transport sector, namely in the area of public/private passenger vehicles, appears to present the highest opportunity for successful H_2FC integration in cities in the short term.

6. Annexes

6.1 Potential hydrogen communities' database

Country (NUTS 0)	Community name	Site Location	Planned end-result	Current Status	Application type	Project Description	Macro level
CZ	Polish-Czech-Slovak Hydrogen Community/Tesin	Tesin/ Cieszyn	fully fledged community	proposal	Transport	Joint initiative between Poland and the Czech Republic with the aim of setting up a series of hydrogen refuelling stations in the area around the Czech-Polish border to operate fuel cell buses, which will be part of the common public transportation system linking the Czech and Polish parts of the town. This is the Czech part of the Polish-Czech-Slovak Hydrogen Community (also depicted in Cieszyn, NUTS code PL224)	City
DE	HafenCity Hamburg	Hamburg	fully fledged community	operational/ established community	Multiple	A series of projects in Hamburg launched by the Hamburg local initiative for fuel cells and hydrogen technology, a network that brings together different stakeholders (companies, local authorities, hydrogen association) interested in developing and deploying hydrogen and fuel cell technologies in the city of Hamburg. The projects, started in a delimited area of the city of Hamburg (the so-called HafenCity), are now taking place in the whole city. The ongoing projects include: fuel cell buses (HyFleetCUTE), car sharing, forklifts, Combined Heat and Power fuel cell (powered by natural gas)	City
DE	Berlin transport	Berlin	isolated project	operational/ established project	Transport	Building of two hydrogen filling stations, the vehicle fleet (17 hydrogen powered Internal Combustion Engine and Fuel Cell cars to be tested), a hydrogen information centre and a service station for hydrogen cars; operation of 14 hydrogen-powered internal combustion engine buses	City
DE	Munich airport	Munich	isolated project	operational/ established project	Transport	Modern vehicles and systems (passenger cars, buses and fork lifts), fuelled by both liquid and gaseous hydrogen, in the area of the Munich airport. The hydrogen is produced both through natural gas reforming and water electrolysis	City
DE	HyCologne	Cologne	fully fledged community	initiation	Multiple	Aim to realise a hydrogen community in the Rhineland area. Two demonstration projects are going to be established, as a start: operation of a 1MW Fuel Cell Power Plant in Cologne area using the existing hydrogen pipeline infrastructure; hydrogen bus fleet	Region
DE	Messe Düsseldorf	Düsseldorf	isolated project	operational/ established project	Transport	Operation of two fuel cell midi buses by Messe Düsseldorf. More fuel cell technology applications (busses, fork lifts, stationary systems, etc) are to be deployed in the same area	City

Country (NUTS 0)	Community name	Site Location	Planned end-result	Current Status	Application type	Project Description	Macro level
DE	NRW H2 Roadmap	North Rhein Westphalia	fully fledged community	operational/ established community	Multiple	Series of projects and initiatives coordinated by the fuel cell and hydrogen network of NRW, with the objective to support the establishment of a sustainable hydrogen economy in the region. The Network is currently working to foster the introduction of fuel cells into early markets (fuel cell bicycles, fuel cells in residential applications)	Region
DK	Lolland	Nakskov	fully fledged community	initiation	Residential/Services	Three-phase project to establish Nakskov as European leader for the "Community Testing Facility" for the hydrogen economy. After the current preparatory phase, a micro Combined Heat and Power fuel cell unit (powered by hydrogen) will be installed in selected houses	City
DK	H2PIA- World's first hydrogen city	Herning	fully fledged community	proposal	Multiple	Intention to fully integrate hydrogen into a complete urban community with residential houses, businesses, shops, cars, and roads. The inhabitants will be ordinary citizens who can enjoy life in a clean and sustainable society.	City
DK	Scandinavian Hydrogen Partnership-Hydrogen Link	Denmark	isolated project	initiation	Transport	Pre-studies are ongoing in various locations, which have been identified as ***H2 HUB's***: pioneer cities for the implementation and use of hydrogen technology in transport applications. The demonstration projects to be implemented in the chosen H2 HUB's represent the Danish contribution to the Scandinavian Hydrogen Highway Partnership	Region
ES	Pais Vasco	Pais Vasco	fully fledged community	initiation	Multiple	Aim of realising the widespread use of hydrogen in the region. An ongoing demonstration project is based on the installation and evaluation of a generator based on a PEM-Fuel Cell running on hydrogen, at the Renewable Energies Centre at Usurbil Lanbide Eskola	Region
ES	Aragona	Huesca	fully fledged community	initiation	Multiple	Real scale test bench for electrolytic hydrogen production from photovoltaic arrays and wind turbines to be applied for use in the surrounding industrial area. More projects are being proposed and implemented	Region
ES	Valencia Hydrogen Community	Valencia	fully fledged community	proposal	Multiple	A strategic plan aimed at identifying business opportunities for the regional industry is currently being evaluated by the Regional government. Some demonstration projects are being identified: possibility for equipping a public building with fuel cells; use of fuel cells in car toys; plans for incorporating hydrogen in the city fleet (buses, police cars, and other civil service cars)	Region
FR	Basse Normandie	Coutances	fully fledged community	initiation	Multiple	Aim of creating a (small) hydrogen community in Basse Normandie. Currently, the community has a demonstration fuel cell working with methanol, and has proposed other projects based on utilisation of renewable hydrogen.	Region

Country (NUTS 0)	Community name	Site Location	Planned end-result	Current Status	Application type	Project Description	Macro level
FR	Nord Pas de Calais	Nord Pas de Calais	fully fledged community	initiation	Multiple	A number of projects are ongoing in the area with the objective of positioning the region at the forefront of the use of hydrogen in internal combustion engines. The projects are currently focusing on transport applications (buses and cars), but plans are to test internal combustion engines in different applications	Region
GR	Milos- H2 ellenic island	Cyclades islands	fully fledged community	initiation	Multiple	Aim of providing 10% of power demand, 5% of heat demand and 5% of transport energy on the island using hydrogen applications. Various projects in implementation: 1 hydrogen-fuel cell bus, Combined Heat and Power fuel cell system	Island/ remote area
HU	Village in Hungary	Bükkaranyos Pf.1	fully fledged community	proposal	Residential/Services	Aim to realise the first village in Eastern and Middle Europe, based on wind-hydrogen technology. The concerned village is independent from the central grids, and is composed of 25 households.	Island/ remote area
IS	Iceland	Reykjavík	fully fledged community	initiation	Transport	Aim of achieving widespread use of hydrogen in the transportation sector. Currently 10 hydrogen Toyota Prius vehicles and 1 fuel cell car are in operation in Reykjavik; other projects are ongoing to introduce private vehicles using hydrogen,	Island/ remote area
IT	San Zeno	Arezzo	fully fledged community	initiation	Residential/Services	Use of hydrogen (produced, in the first stage, via biogas reforming) as an energy vector to supply heat and electricity in the Arezzo goldsmith industry. Project up-scaling to include hydrogen use for combined heat and power in the close residential area	City
IT	Patto per l'idrogeno-Lombardia	Lombardia	fully fledged community	initiation	Multiple	Joint initiative between Lombardia and Piemonte with a view to creating a first European hydrogen community in Italy. An executive committee with representatives from the two regions will be created to organise and plan common activities	Region
IT	Porto Marghera	Venice	fully fledged community	proposal	Multiple	Aim at promoting and coordinating various hydrogen and fuel cell projects, which are to be implemented in the region: micro combined heat and power fuel cells to be used in small buildings; hydrogen vaporetto-boat; refuelling station for hydrogen vehicles	City
IT	Sistema Piemonte Idrogeno	Piemonte	fully fledged community	operational/ established community	Multiple	Aim to promote hydrogen as an energy carrier in the region, while supporting the development of regional hydrogen infrastructure. Various projects are ongoing in the region, covering both stationary and transport applications.	Region
IT	Abruzzo	Abruzzo	isolated project	initiation	Transport	Widespread use, on the regional territory, of cars fuelled by a methane-hydrogen mixture. This is coupled with the building of a service station for H_2-CNG mix fuel, open to the public.	Region

Country (NUTS 0)	Community name	Site Location	Planned end-result	Current Status	Application type	Project Description	Macro level
IT	Pisa	Pisa	fully fledged community	initiation	Transport	Starting in 2008 with the aim of introducing widespread use of hydrogen vehicles (from utility vehicles to buses) in the city of Pisa.	City
IT	Patto per l'idrogeno-Piemonte	Piemonte	fully fledged community	initiation	Multiple	Joint initiative between Lombardia and Piemonte with a view to creating a first European hydrogen community in Italy. An executive committee with representatives from the two regions is going to be created to organise and plan common activities	Region
NL	Arnhem	Arnhem	fully fledged community	proposal	Multiple	Four pre-study projects are currently ongoing in the area, covering: small fleets, hydrogen bus, clean hydrogen production and small stationary applications. These studies will help in identifying which hydrogen and fuel cell technologies and the corresponding application sectors are most promising for the area of Arnhem.	City
NO	Utsira	Utsira	fully fledged community	operational/ established community	Residential/Services	Provision of supplementary power via fuel cells using stored hydrogen, produced from surplus wind power. The supplementary power is generated when wind power is not sufficient to meet customer electricity needs. Currently 10 households are connected to the system, which is in stand-alone operation	Island/remote area
NO	Scandinavian Hydrogen Partnership-Hy Nor	Norway	isolated project	operational/ established project	Transport	Setting up and operation of hydrogen production facilities and fuelling stations at six different locations. At each location a number of hydrogen vehicles (cars and buses) with fuel cells are being tested. This represents the Norwegian contribution to the Scandinavian Hydrogen Highway Partnership	Region
PL	Polish-Czech-Slovak Hydrogen Community/Cieszyn	Cieszyn/Tesin	fully fledged community	proposal	Transport	Joint initiative between Poland and the Czech Republic with the aim of setting up a series of hydrogen refuelling stations in the area around the Czech-Polish border to operate fuel cell buses, which will be part of the common public transportation system linking the Czech and Polish parts of the town. This is the Polish part of the Polish-Czech-Slovak Hydrogen Community (also depicted in Tesin, NUTS code CZ080)	City
SE	Scandinavian Hydrogen Highway Partnership- Hydrogen Highway Swedish West Coast	West Sweden	isolated project	operational/ established project	Transport	Collaboration between three regions to build hydrogen refuelling stations and other hydrogen infrastructure along the West coast of Sweden. This infrastructure represents the Swedish contribution to the Scandinavian Hydrogen Highway Partnership	Region
SE	West Sweden	West Sweden	fully fledged community	initiation	Multiple	Aim of introducing hydrogen infrastructure and applications in West Sweden. A series of projects are ongoing in the region, such as: environmentally-friendly power production onboard ships, and stationary applications in a cultural centre	Region

Country (NUTS 0)	Community name	Site Location	Planned end-result	Current Status	Application type	Project Description	Macro level
UK	Shetland	Island of Unst	fully fledged community	initiation	Multiple	Aim to test different technologies of hydrogen production from renewable energies, and using the hydrogen in different applications. Various renewable energy projects are ongoing, including a 215 kW wind turbines, electrolyser, hydrogen storage facilities, and a 5 kW hydrogen fuel cell system in 5 industrial units at Hagdale industrial estate on the island of Unst in Shetland.	Island/remote area
UK	London Hydrogen Partnership	London	fully fledged community	initiation	Multiple	London Hydrogen Partnership, established in 2002, aims to contribute towards a hydrogen economy for London. Projects are being identified in various areas: stationary applications; transport applications; renewable hydrogen projects	City
UK	Outer Hebrides	Eilean Siar	isolated project	proposal	Multiple	Local production of hydrogen for use in council pool vehicles and other stationary applications. In the long-term the aim is to cover export markets. Hydrogen is to be produced from local energy resources: organic waste anaerobic digester and wind turbines.	Island/remote area
UK	Tees Hydrogen Community	Tees Valley	fully fledged community	initiation	Multiple	Planning, development and implementation of a series of projects in the region towards a strategy to realise a hydrogen community within the Teeside Valley & North East Region.	Region
UK	Wales Hydrogen Project	Wales	fully fledged community	proposal	Multiple	Establishment of a range of hydrogen and fuel cell activities in Wales aimed at the transition to hydrogen-based energy in Wales. Various projects are being examined for their implementation: hydrogen production station and vehicle refuelling facility; hydrogen boat demonstration; hydrogen-related demonstration in the National Botanical Garden	Region

6.2 Excel sheet for projects evaluation according to metrics methodology

METRIC	No.	Generic Sub Metric	Driver (D) / Capacity (C)
Technology Accessibility	**1a**	Presence of suppliers of H_2FC technology and expertise in region = Local suppliers of expertise/H_2FC hardware (WP1 data) **AND/OR** Level of demonstrated activity of local+external companies in the region (as measured by installed FC units in region)	C
Global Environmental Impact	**2a**	**Macro-level:** Degree to which targets/strategies for CO_2-reduction that are relevant for the potential community exist **Micro-level**: CO_2-reduction impact (per unit energy delivered) of specific project/application compared to status quo or alternative (Life cycle - must take into account source from which H_2 produced)	D
Local Environmental Impact	**3a**	Degree to which the potential hydrogen community suffers or can be expected to suffer from chronic environmental problems (particulate or non-CO_2 emissions (SO_2, NO_X etc)	D
	3b	**Macro-level**: Existence of targets/strategies for reductions (particulates, SO_2, NO_X) e.g. industrial or (transport) sector relevant for the potential community? **Micro-level**: Contribution of specific project/application to pollution-reduction at the point of use compared to status quo or alternative	D
Efficiency	**4**	Not relevant in WP3	N/A
Capacity & Availability	**5a**	Expected (commercial) demand or need for new/increased energy availability in region/community that may provide opportunities for H_2FC in general **(macro level)**, or public transport applications **(micro-level)**	D
	5b	**Macro-level**: Existence of *early* adopters/private users (e.g. niche markets) of H_2FC technologies **in general** within the community? **Micro-level**: Existence of *early* adopters/private users (e.g. niche markets) of **specific project/application** within the community?	D
Costs	**6a**	Potential for future cost reductions in the project / application proposed by the community. When is H_2FC technology /application expected to be competitive with alternatives that can fulfil the same role (utility) as H_2FC?	D
Safety	**7a**	Not relevant in WP3	N/A

METRIC	No.	Generic Sub Metric	Driver (D) / Capacity (C)
Public Acceptance	**8a**	**Macro-level:** Expected or Demonstrated degree of openness/ acceptance of H_2FC or alternative energy technologies from local communities **Micro-level**: Expected or Demonstrated degree of openness/ acceptance of specific application from local communities	C
	8b	Level of activity H_2FC associations, NGOs etc. in the region	C
Political Will	**9a**	Level of public financial support for H_2FC or alternative and/or more environmentally friendly technologies (As measured by financial incentives for R&D, demonstration, desktop studies)	C
	9b	Extent of subsidies available to offset capital costs (subsidy as % of estimated capital cost (where possible))	C
	9c	Availability of other (indirect) government-assisted financing instruments e.g. tax breaks, low interest loans, financing schemes)	C
	9d	Is pre-project assistance available from government bodies, other agencies, for the potential community? (E.g. assistance with business plans, pre-feasibility studies etc.)	C
	9e	"Documented" (theoretical) political support	C
	9f	"Demonstrated" (proven) political support (Community track record - other energy, transport or sustainability initiatives (including H_2FC projects)	C
Security & Sustainability	**10a**	Degree to which H_2-FC alternative offer significant increases in energy independence & security	D
	10b	Are there programmes/policies in place to promote energy independence?	D
Potential for Project Continuity, Project Growth & Sustainability	**11aa**	Current (un)employment situation compared to national average	D
	11ab	Potential for creation of new H_2FC industries/companies in the community as a result of the H_2FC project / application	D
	11ac	Potential long-term job creation for local people as a result of the H_2FC project / application (i.e. The skilled force is not imported with the project, local people are trained) (10-yr perspective)	D
Potential for Cluster Development	**11ba**	Concentration of LOCAL companies active in H_2 &/or FC or related areas in proximity of community **(refer also Metric 1a - WP1 mapping) AND/OR** Indication of private/corporate investment in H_2 &/or FC or related areas (related areas can refer to "energy" in general or to any part of the H_2FC chain: component manufacture, supply, or use)	C

METRIC	No.	Generic Sub Metric	Driver (D) / Capacity (C)
	11bb	Presence of specific knowledge & expertise (research community) in H_{2}-FC and/or new energy concepts in proximity of the potential community	C
	11bc	Degree to which professional demanding lead-users or early adopters of H_2FC technologies are available within the proximity of the community?	C
	11bd	Availability within the community of renewable resources (e.g. wind, biomass etc.) that can offer synergies for the hydrogen chain (e.g. its production/use)	C
	11be	Track record of potential community with respect to previous or other CO_2 reduction or environmental initiatives?	C
	11bf	Potential for replication of the demonstration project(s) elsewhere/in other communities?	C

7. References

[1] European Commission, Directorate General for Research, Directorate-General for Energy and Transport, *Hydrogen Energy and Fuel Cells: A Vision of our future*, Final report of the High Level Group (2003), EUR 20719 EN (European Communities, 2003)

[2] Intelligent Energy Europe, Sustainable Energy Communities- 8 innovative projects for an energy intelligent Europe

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[4] JRC-IE, Results from Call for Community Registration of Interest. Mapping Analysis of Potential Hydrogen Communities in Europe (Roads2HyCom)

[5] Project *Roads2HyCom*, deliverable D3.1b: ‘A study of Experience with Hydrogen Community Projects in Europe and Worldwide”, prepared by Risoe National Laboratory and European Commission Joint Research Centre Institute for Energy