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Indicators of European public research in hydrogen and fuel cells—An input–output analysis

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Abstract

A prerequisite of any coordinated research activity is a comparison of the current status of research in the countries in question and a means to monitor the progress in particular sectors. Analysis of indicators of research in different countries allows comparison of the research undertaken. This paper compares input and output indicators of public research in hydrogen and fuel cells (H&FC) both within Europe and between Europe and the US, Japan and China. Overall the combined public H&FC research budget for the EU25 countries, associated states and accession countries was €276M in 2005, slightly higher than in the US, but lower than in Japan. An analysis of research outputs indicates that European competitive advantage is being lost to China and the US. Greater and more effective research coordination as well as more targeted allocation of research funds are proposed as potential solutions.

Keywords: Research policy; Indicators; Hydrogen; Fuel cells; Europe

1. Introduction

1.1. Indicators of hydrogen and fuel cells (H&FC) research

It is recognised that the transition to a hydrogen energy system will require further technological advances in hydrogen production, conversion, storage, distribution and end use applications to achieve the desired levels of performance and cost [1]. Effective research and development (R&D) activities are essential for these advances to take place [2,3]. While there are numerous R&D activities being undertaken in the countries included in this study—the EU25 and its associated states of Norway, Switzerland, Iceland and the accession countries Romania and Bulgaria (or EU25+, as they are collectively referred to in this paper)—there is increasing acceptance that international coordination of research is more efficient and leads to faster technology development through pooling of resources, providing common answers to common issues and developing common approaches to exploit synergies [4].

A prerequisite of any coordinated research activity is a comparison of the current status of research in the countries in question and a means to monitor the progress in particular sectors. Indicators first emerged as a way of measuring economic progress in the 1930s and their use has grown subsequently to the point where they are almost ubiquitous in the assessment of all aspects of society [5]. They are particularly widely used to measure the status and effectiveness of research activities [6–8], although the choice of indicators is by no means straightforward [9], and there is little consensus about which indicators should be used or how to interpret them. An appraisal of theoretical approaches to the measurement of R&D is given in Section 1.2 below.

Indicators are particularly useful in that they allow comparisons to be made between different entities involved with the same issue. Thus, analysis of indicators of research in different countries allows comparison of the research undertaken, for example, in terms of effort, effectiveness or value for money. This paper uses indicators selected for the analysis of public

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research in H&FC to compare research inputs and outputs within Europe with the equivalents for the US, Japan and China.

1.2. Measuring R&D

The majority of literature published on measuring R&D performance refers to micro-level assessments of the performance of particular research units, which, while fulfilling different ultimate aims than country-level assessments, use analogous metrics. According to the extensive literature review performed by Werner and Souder [10], approaches to measuring R&D can be assigned to three broad groups: quantitative metrics, qualitative metrics and integrated metrics. The main advantages of quantitative metrics are their ease of use and interpretation and the ease with which they can be correlated with other measures. On the other hand, care must be taken to ensure their validity with respect to the issue of interest. The advantage of a qualitative approach is that it requires in-depth expert analysis, resulting in the production of metrics of high relevance. It is, however, more complex and time-consuming than a quantitative approach. The authors conclude that the most effective method is to integrate both quantitative and qualitative metrics, provided the process is transparent.

The oldest and most widely adopted methodology for measuring R&D at country level is that developed by the OECD in the 1960s, known as the Frascati manual [11]. The manual focuses exclusively on R&D input data, namely ‘human and financial resources devoted to research and experimental development (R&D)’. Thus, the indicators that the methodology includes are R&D personnel and R&D expenditures (corrected for differences in GDP), both of which could be classified as quantitative.

The success of this methodology can be related, according to Lepori [12], to three factors: completeness—coherent R&D statistics can be produced; the fact that R&D statistics are linked to a relevant policy question; and that the statistics are readily available and of a reasonably low complexity. However, he also notes shortcomings of the methodology which are to do with data quality and the lack of categorisation suitable for policy analysis. He proposes that a more successful approach would be *ad hoc* development of indicators best suited to answering specific policy questions, based on the real availability of data and the inputs of national experts in the countries included in the study, provided that the process is conducted in a transparent fashion. This could be seen as a type of integrated approach as recommended by Werner and Souder. Thus, it appears that while there is no commonly accepted methodology for measuring R&D at country level, the most successful approach is likely to be the one based on quantitative data with additional qualitative expert input.

2. Methodology

2.1. Choice of indicators

The approach adopted for this study can be considered semi-integrated. For practical reasons such as data availability the indicators chosen are predominantly quantitative in nature, but their compilation drew as far as possible on the expertise of individuals at the funding agencies in the countries studied. Indicators were chosen by selection from a long list of potential indicators with the aim of providing clearly understandable messages that are easy to update in the future—the longer the time period over which a set of indicators are gathered at regular intervals, the more useful they become as the wider trends become more apparent. Indeed, a common theme amongst the various definitions of indicators is that as well as demonstrating the strengths and weaknesses of a particular activity, indicators should follow the changing character of this activity, thus providing early warning of significant trends [5].

Although a large number of research themes necessitating a wide range of indicators were originally considered for the study, in view of the complexity of the different systems included under the overall heading ‘H&FC research’ it was deemed more useful to focus only on a comparison of research input with research output. The data used for the indicators should fulfil the following criteria:

- Accuracy—the data used should be measurable, representative, as unambiguous as possible and easily understood.
- Availability—the data should be readily available in all the countries studied.
- Comparability—data gathered in one country should be comparable to data gathered in another country.
- Updatability—the data used should be consistently available for future rounds of data gathering.
- Transparency—the methodology for gathering and compiling data should be clearly stated.

Research input data were gathered via a questionnaire sent to representatives of relevant organisations in the countries in question (government or research bodies). Output indicators were compiled through desk-based research. Results were not always available in all countries, but the data presented here represent the most complete picture possible.

2.2. Research input

R&D funding has historically been one of the most widely measured indicators of research activity and innovation [9]. A similar indicator was chosen for H&FC research effort: the H&FC research budget of the country in question. This was defined as the total public H&FC research budget, including not only H&FC programme budgets but all other H&FC spending. For the purposes of this project, the budget was assessed in absolute terms and also as a percentage of the national gross expenditure on research and development (GERD) and of GDP. The focus of the research spending—the research areas where the budget is spent—was also qualitatively assessed.

2.3. Research outputs

Measuring the output of a research activity is important as a method of evaluating the effectiveness of the research.

However, choosing a suitable indicator for the output of a particular technology research programme is at best problematic (see, for example, [13,14], and more recently, [15]). Data are rarely gathered on the outcomes of research programmes or projects, and the deployment step may take place separately, both temporally and geographically, from the R&D stages. Two of the most widely used indicators of research output are the number of patents related to the technology in question [15,16] and the number of publications [17–19].

2.3.1. Publications

The number of publications related to the topics in question was chosen as the first output indicator. Online citations databases were searched for information relating to publications on H&FC by country for the years 2000–2005. Databases included in the searches were:

- Science Citation Index Expanded (SCI-EXPANDED),
- Social Sciences Citation Index (SSCI),
- Arts and Humanities Citation Index (A&HCI).

The search was divided by technology area, with separate searches conducted for hydrogen production, hydrogen storage and end-use applications, thus minimising the need to develop a way of treating the double counting of publications relevant to more than one technology area. Key words used for the searches were 'fuel cell*', 'hydrogen production' and 'hydrogen storage'. These were selected by a process of elimination from a long list of key words covering the areas of both fuel cells and hydrogen. The long list was derived by comparison with those used by Wietschel [20] and other hydrogen literature [3,21]. The key words chosen were found to generate the largest number of relevant hits. The results generated from each of the searches were inspected to assess their relevance and to check for double counting of results. For simplicity, only the key words generating the largest number of relevant results were included in the final analysis. Although finding a key word relevant to hydrogen distribution was attempted, no key word generated enough results for it to be worthwhile including in the analysis.

Once the final key words had been selected, the number of publications, and their corresponding citations, was recorded per country per year between 2000 and 2005. The citations were treated to a further level of refinement by creating a ratio (hereafter referred to as the 'index') of the total citations per publication for a particular country with the world average of citations per publication for the same search. An index equal to one indicates that the paper received the world average number of citations. Values higher than one indicate above average numbers of citations and vice versa.

2.3.2. Patents

The number of patents and patent applications (for simplicity, referred to hereafter as just 'patents') filed in these technology areas per year was chosen as the second output indicator. These patents were obtained through searches using the European Patent Office online search tool (esp@cenet®) [22] worldwide database, selected because it allows both IPC/ECLA symbol[1] searches and title and abstract searches using key words. It also contains records on the entire timeframe (2000–2005) of this study, although the data sets for the last year are incomplete due to the length of time taken to process and publish a patent application.

Searches were conducted by technology area for hydrogen production, hydrogen storage and distribution and conversion and utilisation (end-use) using the relevant combinations of patent symbols and key words. Whenever possible both the ECLA and IPC symbols were used for the search, so as to generate as many results as possible. In all other cases the ECLA code was used in isolation. In order to avoid double counting of the same patent or patent application (many are filed in several different countries and therefore appear a number of times in the database), only the first filing of each patent was considered in the analysis.

The nationality of a given patent was assigned according to the nationality of the patent applicant (usually an institution or company), except when this was not available, in which case nationality was assigned according to the nationality of the inventor, or failing that, according to the country where the patent was first filed. Nationality of the patent applicant was considered the primary criterion as this determines the nationality of the ultimate patent-holder.

The timeframe of a given patent was assigned according to its application date. This is closest to the time when the research was conducted.

2.4. Critique

The practical application of this methodology presented certain challenges. Collection of budget data for the European countries was complicated by the large number of countries included in the study, and the large number of research themes that can be included under the overall heading of H&FC. In many cases data on research funding had never before been collected in this manner. Further, each country has it is own administrative system and research culture necessitating a high level of familiarity with the local situation in each case. The active collaboration of national experts was therefore essential—in some cases new accounting practices were put in place to facilitate the collection of such data in the future. Although reliance on national experts led to the unavailability of some data, it resulted in the most complete picture possible of H&FC public funding in Europe, and can therefore be considered successful.

With respect to the output indicators, a number of limitations are known to be associated with the use of publications and patents. Patents are intended primarily to protect the

[1] *Note*: ECLA—European classification; IPC—international patent classification; ECLA and IPC are classification systems, they assume the form of a systematic code (symbol). This code (combination of letters and numbers) gives details on the type of technology(s) and technical content of patent documents covered by the patent application.

investments of product developers, and secondarily to provide information for prospective product developers. Their use as an indicator therefore presents certain difficulties, of which the most immediately obvious is that not all inventions are patented and patents have a heterogeneous nature (some patents are more innovative than others or have a greater impact in the social, economic and environmental spheres). Further, the validity of a patent study comparing different technologies depends on the accuracy of the underlying patent classification system [16]. Similarly, the use of publications as an indicator does not necessarily capture research conducted outside academia, and in the case of citations, which are used as an indication of the quality of a paper, results can be seriously skewed by one paper receiving a very large number of citations. As King [18] points out, this can arise from the paper being discredited as easily as from it being lauded. Possibly the most important potential bias in bibliometric analysis arises due to the different languages in which papers are published—non-English publications are sometimes under-represented in the bibliographic databases [23]. However, it is widely recognised that English is now the *de facto* international language of science, and most papers are published in English. Further, the Thomson ISI database used for this study indexes more than 8000 journals in 36 languages [18] so any language bias should be minimal. Despite these limitations, patents and publications are widely accepted as useful output indicators [24] and have been applied successfully in a number of previous studies (see, for example, [25–27]).

3. Results

3.1. Research input

The total public H&FC research budgets including not only H&FC programme budgets but all other H&FC spending for the year 2005 are detailed in Fig. 1. There is a wide spread in magnitude of the budgets—the top three countries (Germany, Italy and France) account for more than 64% of the total (excluding the European Commission contribution) and there is a gap of €10M in research spending between France and the next biggest budget, the Netherlands. The majority of the countries studied have relatively small budgets of the order of €10M or less.

However, the combined spending power of the EU25+ countries on H&FC research is substantial. When the research spending of the European Commission (€75M) is added to the sum of the national research budgets, the grand total reaches €276M (see the box in Fig. 1). This compares favourably with the 2005 H&FC public research budget of €241M in the US ($310.3 million, of which $225 million are allocated via the Hydrogen Fuel Initiative, and $85.3 million allocated via the FreedomCAR and Vehicles Technologies Programme [28]). At first glance it compares favourably also with the 2005 budget in Japan of €235M (JPY 35.46 billion [29]), although it should be noted that this figure refers only to support for fuel cell technology. Japanese hydrogen research also receives funding under the budget related to new energy measures (JPY 167.36 billion [29], or €1.1 billion), and the overall budget is closer to €300M [30]. The Chinese H&FC research budget is considerably lower. Exact information for the 2005 budget was not available, but it can be estimated at €18.3M based on the sum of one-fifth of three five-year initiatives (30 million Yuan between 2000 and 2005 and 22 million Yuan between 2003 and 2008, both under the 973[2] programme; 880 million Yuan between 2000 and 2005 under the 863 programme [31]).

In relation to GDP, the EU25+ countries are spending a comparable amount to the US, and the EU15 countries plus associated states (EU15&) are spending slightly more than the US. Both the US and EU research budgets are dwarfed by research spending in Japan—per unit GDP, Japan spends more than three times as much on H&FC research. China appears to be spending considerably less than the other countries studied—about half the EU25+ expenditure, Fig. 2. However, China has expressed firm long-term commitment to developing H&FC technologies and research investment is likely to rise in the future.

In terms of evaluating research effort within Europe, it is more useful to derive indicators based on research spending as a proportion of their GDP as the countries vary greatly in size and in economic power. This changes the picture quite dramatically, with Iceland and Denmark now at the top of the list and a much smaller spread between the major players, Fig. 3. In relation to GDP, research spending on H&FC in France and the UK is comparatively lower, indicating a proportionally smaller research effort in these countries. This is not due to a lack of research funding in general, however. Both countries have among the highest GERD (the most commonly used metric for comparing R&D efforts of countries) per unit GDP of the countries studied, but make hydrogen less of a research priority than in other countries. In relation to overall research spending, the countries with the greatest focus on H&FC research are Lithuania and Romania, followed by Italy, Iceland and Norway.

The focus of this research effort is also important. Of the €201M budget for the EU25 countries plus associated states (EU25+ countries) (without the EC contribution), the allocation according to research areas is known for €167.5M (83% of the total). The majority of the budget is spent on research into transport and stationary applications, and to a lesser extent on hydrogen production, and storage and distribution, Fig. 4. Portable applications and socioeconomic issues receive less funding.

A comparison of these allocations with the recommendations of the Strategic Research Agenda (SRA), the strategy produced by the European Commission's H&FC Technology Platform to guide H&FC research [32], yields some interesting results. Spending on stationary applications appears to be overemphasised, with the actual budgets 13% higher than the recommendation. Conversely, spending on hydrogen storage and distribution research is 7% lower, spending on hydrogen production research is 4% lower and spending on portable applications research is 3% lower than recommended. This raises the

[2] The programmes are named after their starting years in the Chinese calendar i.e. 1997 and 1986.

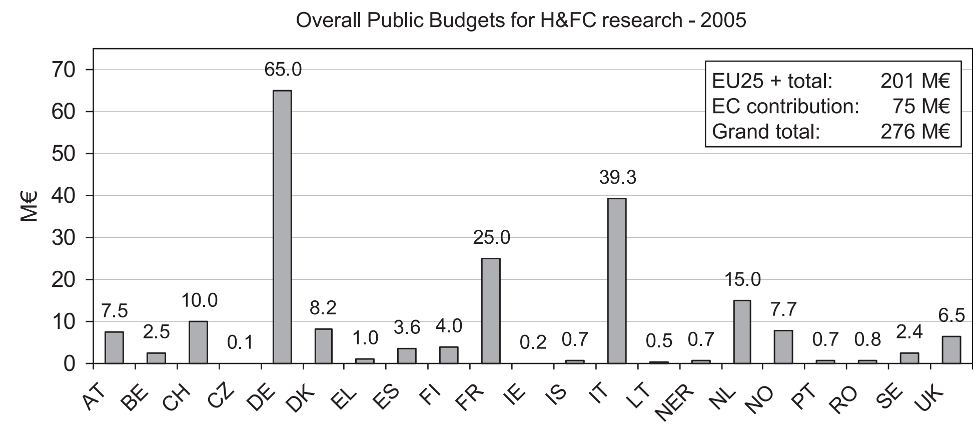

Fig. 1. Research input: EU25+ public budgets for H&FC research.

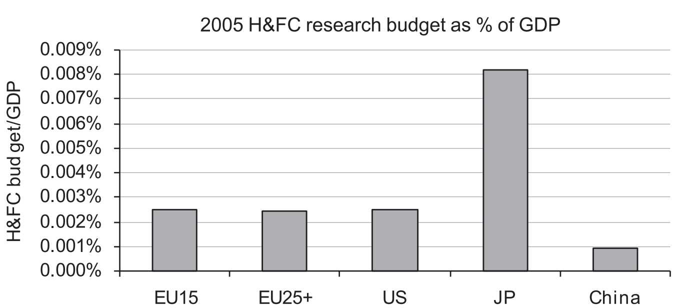

Fig. 2. Research input: 2005 H&FC research budgets as a percentage of GDP—EU, US, Japan and China.

question of whether research spending should be reallocated from stationary applications to the other areas to maximise the efficiency of research in the EU25+ as a whole, or whether the divergence from the recommendations of the SRA represents a reasonable bias towards exploitation of a niche area where the EU25+ countries are leaders.

Analysis of these results indicates that most countries prefer a particular research topic. Austria and France have a clear focus on transport applications, while in Germany, Finland and Romania the primary focus is on stationary applications. In countries with smaller overall budgets this effect is even more pronounced. Greece, Ireland, Portugal, Sweden and the Netherlands focus on hydrogen production, whereas Lithuania, NER and Switzerland are concerned primarily with storage and distribution. Both Spain and the UK split their main focus over two areas—in the UK they are transport and stationary applications, while in Spain they are stationary applications and hydrogen production. Iceland is unique in focusing on socio-economic issues.

3.2. Research outputs

3.2.1. Publications

The general trend seen in the number of publications per year in the EU25+ between 2000 and 2005 is for growth, Fig. 5. The growth is particularly marked in publications related to hydrogen storage, which increased from 39 in 2000 to 209 in 2005, a more than five-fold increase. In absolute terms, the research area with the most publications is clearly conversion and utilisation, with publications reaching almost 800 in 2005. It should be noted, however, that the overall number of publications relevant to H&FC research is likely to be much higher. Due to the multi-disciplinary nature of the research activities, there may be many more publications in areas such as materials science that cannot easily be captured by a simple key word search. The results here should therefore be taken as indicative, rather than absolute.

Within the EU25 and its associated states, there are marked differences in the number of papers published in different countries, with Germany, the UK and France consistently in the four top positions in all three areas, Fig. 6. Between them these countries publish between 60% and 70% of the total papers for the countries studied. This correlates with the magnitude of the combined H&FC research budget for these countries.

Germany stands out as a clear leader in all research areas except hydrogen storage, where it comes a close second after France. However, although the quality of the German papers is always close to the world average (as shown by an index close to one, indicating that the papers are cited approximately the same number of times as the average paper on that topic in that year), other countries, particularly France and Italy, record a greater number of citations which appears to indicate higher quality papers. This might be evidence of different research policies, where publication is only considered worthwhile for results of extremely high importance.

In addition to the overall increase in publications seen across the countries studied between 2000 and 2005, the number of countries publishing papers is also growing. In 2000, only 20 of the 30 countries studied published any papers, but by 2005 this had risen to 25 out of 30.

The results show a general correlation in trends between the number of H&FC publications in a given country and the size of the country's H&FC research budget. While it is difficult to draw any absolute conclusions from this data, as publishing practices vary between countries, there are perhaps lessons to be

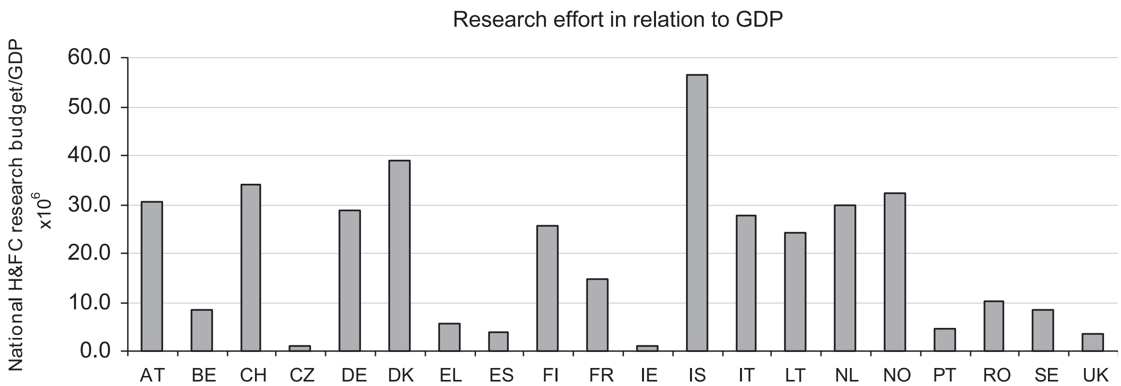

Fig. 3. Research input: EU25+ H&FC research budgets in relation to GDP.

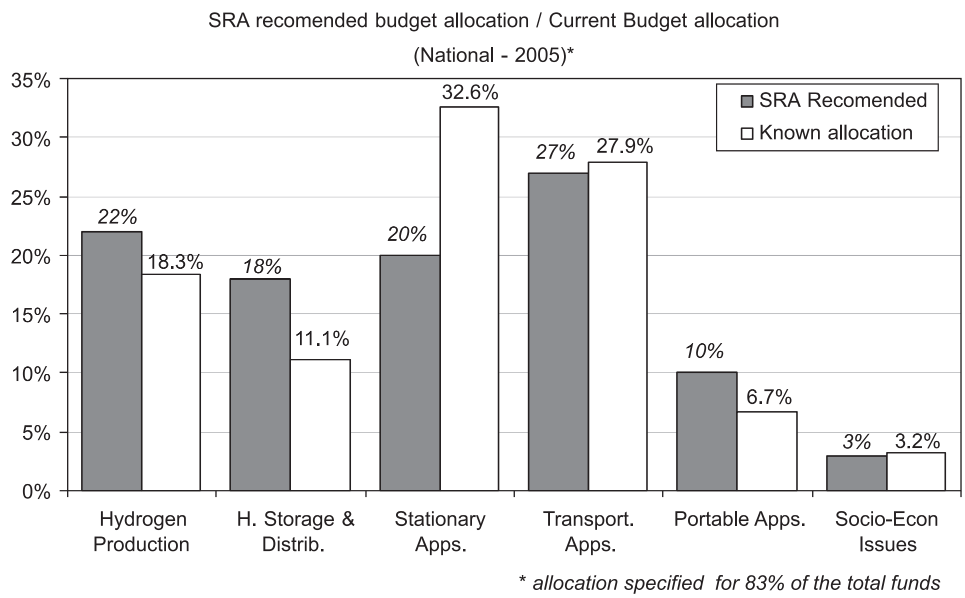

Fig. 4. Allocation of EU25+ research budgets in comparison with the SRA recommendations.

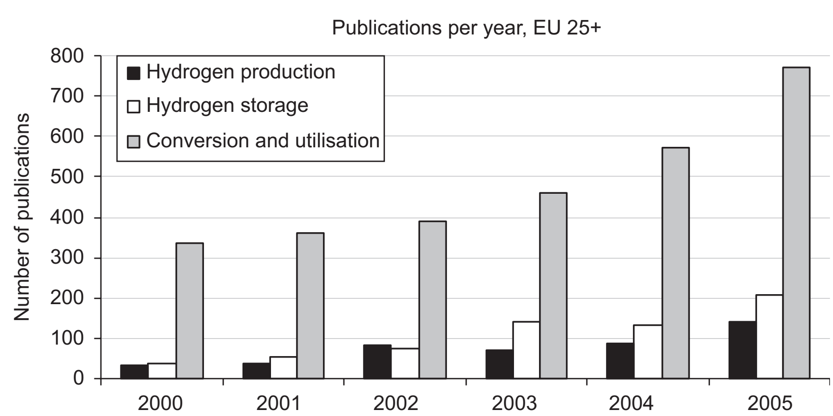

Fig. 5. EU25+ publications per year, by technology area.

learned from the countries which appear to have large numbers of publications compared to the size of the research budget, for example, the UK, Spain and Switzerland.

In terms of overall publications, the EU25 and associated countries are world leaders, generating the largest number of publications in almost all areas. This appears to indicate high

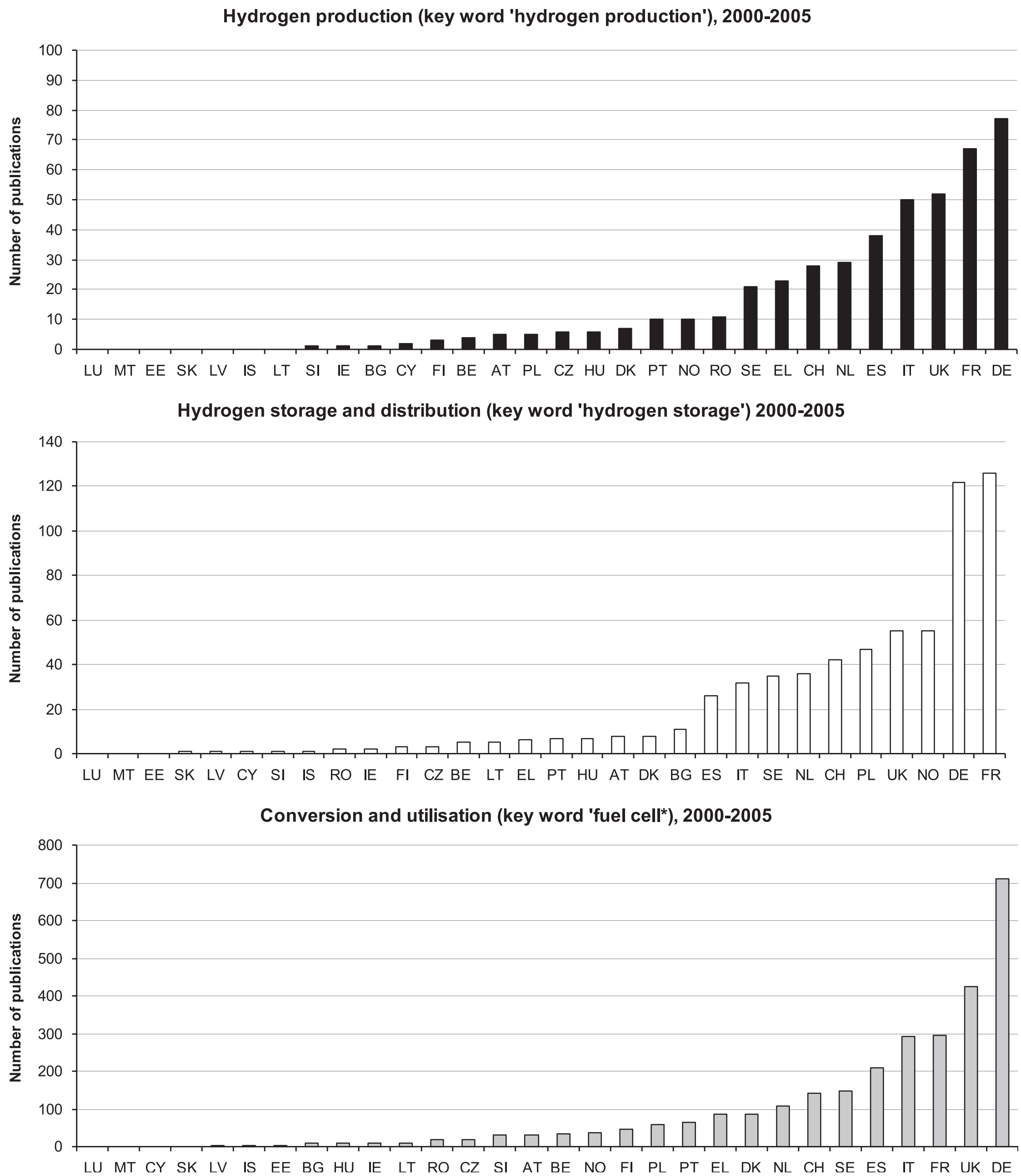

Fig. 6. EU25+ publications per country, 2000–2005.

efficiency in H&FC research in the EU25+—the research budget in these countries is comparable with that of the US, and significantly lower than that of Japan, but the outputs are significantly higher.

However, there are indications that the EU25+ is losing its position as leader. In the areas of both hydrogen storage and fuel cell applications, the two areas with the largest number of publications overall, by 2005 the gap between the EU25+ and its nearest competitor was very small. Moreover, in terms of end-use applications, by 2005 the EU25+ countries had been overtaken by the US, as shown in Fig. 7. China is also showing very strong growth in its overall publications in all three areas.

When the index is also considered, the quality of Chinese publications is consistently lower in the first years studied than EU25+ or US publications. In later years the Chinese index increases, indicating that not only is the volume of publications increasing, but also the quality. The US has a consistently higher index, possibly at least partly due to a language bias caused by the comparatively larger readership of English-language publications [23].

The charts in Fig. 7 clearly demonstrate that the other regions of the world, and the US and China particularly, are beginning to catch up with the EU25+ countries in terms of H&FC research. The rate of increase in publications is higher in these countries

Publications related to end use applications (Key word "fuel cell*")

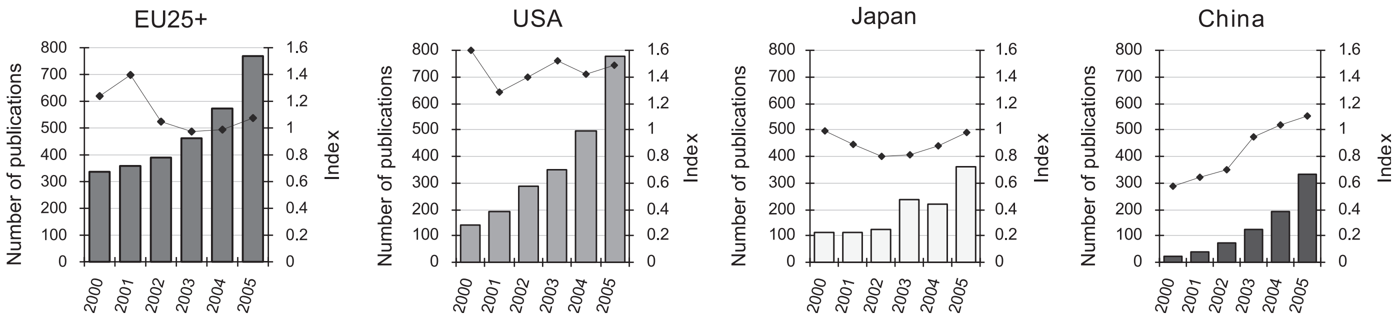

Fig. 7. End use applications: publications per year, EU25+, USA, Japan and China, 2000–2005.

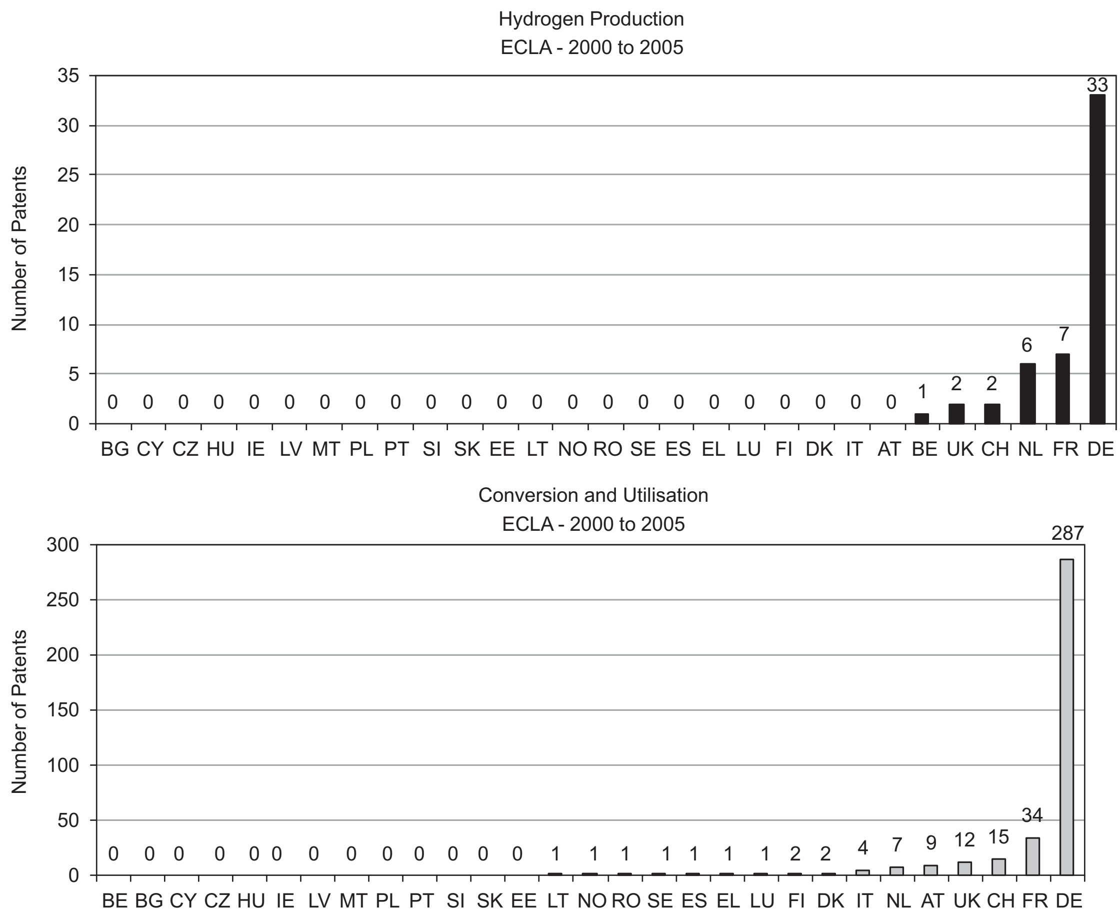

Fig. 8. EU25+ patents per country, 2000–2005.

than in the EU25+. A similar trend is observed in the results from the other two research areas, hydrogen production and hydrogen storage.

3.2.2. Patents

In terms of patents, Germany is a clear leader in both the research areas that generated significant numbers of hits—conversion and utilisation and hydrogen production, Fig. 8. Only one patent was found in the storage and distribution category for the EU25+ between 2000 and 2005, so this area has been discarded from the analysis. As with the results obtained for the publications, the other leader countries include France and the UK. The Netherlands and Switzerland are also noteworthy with significant numbers of patents.

When the EU25+ countries are considered as a whole, the patents analysis does not show a large increase in number of patents between 2000 and 2005, as was the case with the publications. While this may be due in part to the length of time it takes for a patent application to be published in the database (at least 18 months, often more), which causes a tailing off in

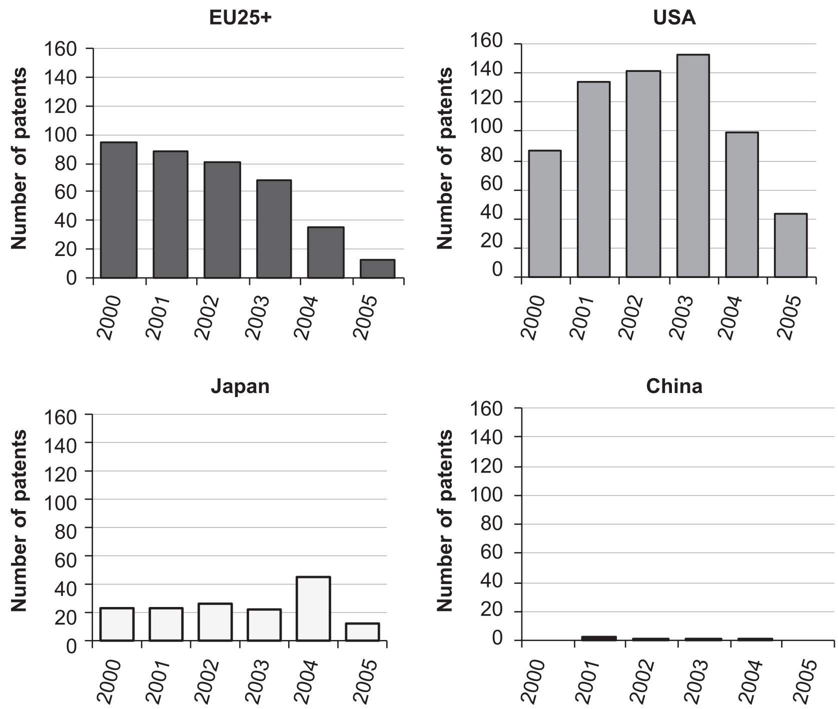

Fig. 9. Patents per country, hydrogen production and hydrogen conversion and utilisation, EU25+, US, Japan and China.

all the countries' patents in the last two years of the study, it nevertheless appears that commercialisation of H&FC research is not growing rapidly in the EU25+ countries.

The patents study further reinforces the impression that the EU25+ countries are losing ground compared with the US and Japan. Analysis of the patents by ECLA shows that although in 2000 the EU25+ countries enjoyed a position as a world leader in conversion and utilisation patents, by 2001 this had already been lost to the US, Fig. 9. A similar situation is seen in the case of hydrogen production, with the US increasing its lead over the EU25+ countries between 2000 and 2001. The number of Japanese patents also appears to be increasing relative to those of the EU25+, and indeed may be much larger than the ECLA search results indicate. Performing the same analysis using the IPC symbol instead shows that there are many more Japanese patents for H&FC technologies than European or even American ones. This difference is likely to be due to the length of time taken to process patent documents in Japanese, attribute an ECLA and include them in the database.

4. Discussion

H&FC research in the EU25+ countries is a complex, multi-dimensional issue. Owing to the large number of countries involved, the complexity of R&D in general and above all the sheer breadth of topics included under H&FC research, it is difficult to draw obvious conclusions from these results. Gathering the data presented in this paper was challenging. In many of the countries studied this information had never been compiled before, and this was often a complicated process for the organisations involved. Nevertheless, future rounds of data gathering should be easier as systems have now been put in place in some countries to enable these data to be compiled—this was found to be useful for national initiatives in the countries in question in any case.

There is a wide range of H&FC research conducted in the EU25+ with different countries specialising in different areas. This is particularly marked for countries with small overall budgets—Lithuania, for example, spends its entire budget (€0.5M) in one area: hydrogen storage and distribution. This is probably the most efficient use of a small quantity of money in terms of generating useful results, but it risks research in the EU25+ as a whole lacking in strategy and focus. This is perhaps demonstrated in the comparison of the overall EU25+ budget allocation with the recommendations of the SRA. Overall, it appears that the EU25+ is spending a disproportionately large amount on research into stationary applications, and not enough on research into hydrogen production, storage and distribution and portable applications. On the other hand, this may be a valuable exploitation of a niche market in which these countries have a competitive advantage. Nevertheless, cooperation between small research programmes in different countries can deliver benefits to the EU25+ as a whole by efficiently allocating resources according to which areas require further research.

In terms of the amount of money spent on H&FC research in the EU25+, the budget appears reasonable—it is comparable with that of the US and that of Japan. Per unit of GDP spending is slightly lower than in the US, but if only the original EU15 countries plus Norway, Iceland and Switzerland are considered, this picture is reversed. It is therefore arguable that the 10 new member states should increase their research spending in this area so as to even out overall H&FC research contribution per unit GDP. In comparison with the H&FC research budget of Japan per unit GDP the EU25+ lags behind considerably. H&FC research spending also remains a very small percentage of overall research budgets, typically around 0.1%.

Arguably this proportion should be increased. As can be seen from the analysis of publications, the EU25+ has enjoyed a leading position in H&FC technology in the past. This appears to be confirmed by the leading global position the EU25+ had in 2000 in patents related to conversion and utilisation. However, the patent study also reveals an apparent loss of ground in the EU25+, particularly to the US. In the case of publications it is above all in relation to China that the EU25+'s position is slipping—China has seen extremely rapid growth in the number of publications over the past six years, and this is likely to be followed in coming years by increasing numbers of patents. There is consequently a real danger of losing the competitive advantage that the EU25+ currently has.

5. Conclusions

This paper has shown that there is growing interest in H&FC research in the EU25 countries and associated states. In terms of research effort as evidenced by public research budgets, the EU25+ countries are ahead of the US, although still somewhat behind Japan.

Within the EU25+ countries, the clear leaders in terms of absolute magnitude of H&FC research spending are Germany, Italy and France. Research budget in terms of GDP shows a very different picture and it is the smaller players such as Iceland and Switzerland that are making the largest proportional effort. Similarly, in terms of the proportion of GERD allocated to H&FC technologies, countries with smaller overall budgets often have a greater focus on H&FC research compared to other research areas.

This emphasises the importance of coordinated research, especially amongst the smaller players—owing to budget constraints these countries generally focus on one or two topics, which does not necessarily represent the most efficient use of money in terms of the overall European strategy. Comparison of the budget allocations with the recommendations of the SRA shows that research funding is not optimally distributed: stationary applications receive more funding than recommended, whereas hydrogen storage and distribution technologies receive less. Greater coordination between smaller research programmes could lead to greater overall benefits to the EU25+ countries in terms of more effective research.

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